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The Development of Commercial Local Area Resource and Emissions Modelling – navigating towards new perspectives and applications

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Abstract

Meeting near future UK greenhouse gas (GHG) emissions targets will require all parts of the UK economy to contribute, and in particular significant changes in business practices are required at the local level. From review it was found that there is a lack of detailed business accounting and reporting of GHG emissions at the local level, especially concerning supply chain impacts and small and medium sized enterprises. This paper presents a framework model to generate detailed benchmark estimates of GHGs (both on site and supply chain related) for individual businesses and all businesses of a sector within an area. The model makes use of available economic and environmental data, and, with similar datasets existing in other parts of the world, such models may be used elsewhere. The framework model is applied to an empirical case study. Estimates from such a framework can be used in a step-by-step approach to move businesses and local areas towards improved accounting, reporting and sustainability (including procurement). The model makes use of two different accounting perspectives: the production perspective (on site GHGs) and the provision perspective (supply chain GHGs attributable to purchased inputs of a business or

sectors production). The new provision perspective and its consequences are explored and explained.

Keywords: Environmental accounting; input-output; provision perspective; CSR; EMA.

1 Introduction and background

If the UK is to meet its challenging environmental targets, which include, for example, a reduction of greenhouse gas emissions (CO₂e) of at least 80% on 1990 levels by 2050 (CCC 2008), it is vital that all parts of the UK economy contribute. Forum for the Future (2009) state that an understanding of the contribution that a company (and its sector) is making towards achieving GHG reduction/stabilization targets (both local, national and global) is essential for leadership on climate change.

The progress made by large organizations in estimating and reporting emissions is demonstrated by reports from the Carbon Disclosure Project (CDP) that over 3,000 organizations in some 60 countries around the world now measure and disclose their GHG emissions, water management and climate change strategies, a rise from just 235 organizations in 2003 (CDP 2011). Another example of progress is the groundbreaking Environmental Profit and Loss Report produced by Puma in 2011 which valued the company's environmental impact for the key areas of GHG emissions, water use, land use, air pollution and waste, generated through the operations and supply chain, at € 145 million in 2010 (PUMA 2011).

In the UK, 47% of turnover and 48% of jobs are due to small and medium companies¹ (SMEs) however, and progress in these types of companies is less good. This is due to many factors, such as lack of in-house expertise, lack of financial resources to pay consultants and lack of awareness of environmental problems (Defra 2010, Carbon Neutral 2006 as seen in Oakdene Hollins 2011 and Institute of Directors 2006). And yet without information on the emissions and other environmental impacts of SMEs, it is hard for UK-wide progress in achieving reductions to be made and assessed.

¹ Employment less than 250, based on SME statistics from UK Department for Business Innovation and Skills (BIS) 2009.

Overall, it is clear that currently, businesses are still not reporting in a clear, consistent, comparable and transparent manner “*en mass*” in the UK and some other countries², as was reported in early studies (Gerbens-Leenes et al 2003 and OECD 2001).

From the literature, there are gaps in both environmental reporting and environmental accounting. Viere et al (2011) find that most studies dealing with implementation of environmental management accounting (EMA³) apply environmental cost accounting applications. The latter authors identify that employing just environmental cost accounting is unsatisfactory from a supply chain perspective and that life cycle assessment (LCA) and environmental life costing have become very important EMA tools. LCA can however, be very time consuming and expensive.

A range of top down GHG estimation models exist and can provide information on company GHGs. A study by King and Tsagatakis (2006) models carbon dioxide emissions directly produced by SMEs to geographic location (local authority level and 1km grids), but the method used means that aggregation is relatively high, the study does not attempt to estimate indirect⁴ GHGs or GHGs of individual businesses. Bradley and Jackson (2007) develop a model to estimate direct commercial and industrial waste that uses methods similar to those of King and Tsagatakis (2006).

In terms of indirect GHGs, the early work of Mathews and Lave (2003) shows benefits of a sector level environmental input-output (EIO) GHG tool for screening applications and benchmarking corporations, but business specific estimates are not provided. With regards to business estimation and ‘state of the art’ the methods of Lenzen et al (2006) are believed to be some of the most accurate in terms of ‘top down’ models, as the model allows companies to choose their own sector and incorporate financial accounts of businesses and other organisations into the national I-O tables (used in the model) as an additional sector before estimation. This model however, and the other most applicable and useful methodologies

² From a review in 2009, the Environment Agency found that 62% of FTSE listed companies report climate change related disclosures in some form (Environment Agency 2010), but from inspection however, often quantitative reporting (if provided) is not in a consistent, comparable and transparent form.. Similar rescent findings for other countries are [seen in](#) Clément Roca and Searcy (2012), Skouloudis et al (2010), Downie and Stubbs (2011, page 7) and Collinsa et al (2007).

³ “EMA is broadly defined to be the identification, collection, analysis and use of two types of information for internal decision making:

- physical information on the use, flows and destinies of energy, water and materials (including wastes) and
- monetary information on environmental-related costs, earnings and savings.” (IFAC 2005)

⁴ In this study direct emissions are the emissions that occur from processes owned, operated or controlled by a business of concern. Indirect emissions are defined as those emissions associated with processes that occur in the life cycle of a product prior to the processes owned, operated or controlled by the business of concern. The indirect definition corresponds with the upstream GHG emissions definition by British Standards Institution, Publicly Available Specification 2050 (BSI 2008).

found (Foran et al 2005 and Trucost 2008) for estimating indirect GHG emissions of business are, unable to estimate emissions for a large number of businesses of a local area, without excessive and unrealistic amounts of time or a reliance on companies coming forward with data. The same is true for a range of online tools available and government datasets, which generally do not provide the accounts required (see Bradley et al 2010). This is a key gap that the current paper attempts to address.

This paper describes the methodology of a novel framework designed for estimating the GHG emissions for an individual business of a specific sector, or all businesses within a defined geographical area: the framework is specifically designed to provide support to SMEs. Importantly, the framework does not require informational input from the company(ies) in question and hence overcomes the problem caused by lack of resources within SMEs as well as issues with current estimation models described above. The approach leads to GHG estimation with lower data collection requirements from business, whilst at the same time enabling full coverage of all businesses. This can lead to improved accounting, strategy and prioritisation at the local level. The approach uses one framework and consistent data across businesses, to ensure consistency and the framework bridges the gap between ‘micro’ and ‘macro’ level top down models by allowing estimation of the carbon(e) added⁵ at the level of a city, local area and individual businesses by postcode in a consistent and comparable way. This is in line with the principle of multi-scale reporting by Foran et al (2005). The case study for the paper is GHGs (CO₂e) for the Hospitality sector in Southampton. The framework can, however also be applied to other emissions, such as waste, or resource use such as water, and for any part of the UK and possibly other countries (if similar datasets exist). In this paper we refer to such work at certain points.

The framework developed is called the Commercial Local Area Resource and Emissions Model (CLARE). It builds on and is informed by a number of previous studies such as: Matthews and Lave (2003), Foran et al (2005), Lenzen et al (2006), Jackson et al (2007), Bradley and Jackson (2007), Druckman et al (2008), Bradley et al (2009), Albino et al (2002), Gerbens-Leenes et al (2003), Kytzia et al (2004), Sinclair et al (2005), Xue et al (2007) Kagawa et al (2007), Trucost (2008), and King and Tsagatakis (2006) amongst others.

Some uses of CLARE estimates are provided below in Figures 1 and 2.

⁵ Carbon(e) added = CO₂(equivalent) added,. Term

Figure 1: Use of GHG estimates for individual organisations

Figure 2: Use of GHG estimates for groups of organisations

It is the intention that local government and NGOs will be able to access estimates from CLARE to inform and help businesses, and to prompt businesses into action to recognise their obligation to act to reduce emissions and water use to help achieve national targets. Producing detailed CO₂e estimates for individual business and groups of businesses will help enable local government, NGOs and businesses lead action towards GHG reduction. All

implementation is local, and in practice, localities can become leaders as they can be less constrained in leadership than central government.

The paper is structured as follows. The methodology of CLARE is described in Section 2. Section 3 discusses the use of CLARE in a step-by-step approach and presents application of the theoretical framework. Discussions and conclusions are conducted in Section 4.

2 Methodology

The model CLARE is composed of two sub frameworks: CLARE-direct for direct emissions and CLARE-indirect for indirect emissions. The development of CLARE-indirect requires an Environmental Input-Output (EIO) model as part of the framework. An outline of CLARE is provided in Figure 3.

Figure 3: Outline of CLARE

For CLARE-direct, modelling makes use of sector (macro) and individual business (micro) data but final outputs are produced for businesses (micro level). EIO analysis modelling is done at the sector level (macro). For CLARE-indirect, modelling makes use of sector (macro) and business (micro) data but final outputs are produced for businesses (micro level). For simplicity, the term emissions will be used to describe GHG emissions for the remainder of the Section 2. In this particular paper, we illustrate an application of CLARE for the Hospitality sector in Southampton, the UK.

2.1 CLARE-direct

The key equation that CLARE-direct uses is quite simple as seen in equation 1. This example is for a single company in sector j.

$$e_o = t_o \bar{u}_j \quad (1)$$

Where:

e_o is the direct emissions occurring from business o (CO₂e for this paper);

t_o is the estimated turnover for the business o; and

$\bar{u}_j$ is the average emissions per unit turnover for the relevant sector (sector j), corresponding with the business;

Before equation 1 can be applied, both t_o and $\bar{u}_j$ have to be estimated for a business. A range of steps are required to produce t_o and $\bar{u}_j$ using various datasets and equations. The first step is to select the specific sector (i) for which one needs to estimate emissions of businesses within a geographic area.

The remaining steps, 2, 3 and 4 are outlined in Figure 4 (equation 1 is conducted lastly at the bottom of the figure). Steps 2 and 3 are applied to estimate t_o . Step 4 is applied to estimate $\bar{u}_j$.

Figure 4: System diagram of CLARE-direct

Once the sector is identified from step 1, the Business Structure Database (BSD) can be searched for all businesses within the sector, within a defined area. Once businesses are found from the BSD it is possible to identify the full 5 digit (most disaggregated level) Standard Industrial Code (SIC) that each business belongs to, the number of employees⁶ and the post code. For each business in the group, the following steps are conducted.

The average annual turnover for the relevant business now needs to be estimated (step two). The Annual Respondents Database (ARD) is used for this. Unlike the BSD, this dataset does not include businesses representing 99% of all UK output, but is a large dataset and has good representation for different business sectors (ONS 2008). For the businesses that are within the database however, the number of variables and the ‘richness’ of the data is much higher than in the BSD. The ARD is searched to find all businesses within the same size band and SIC sector (5 digit) as the relevant business found in the BSD. Businesses found are termed as matching businesses. The key details used to match businesses are the SIC code and number of employees. Once matched businesses are found, the calculation of the average turnover per employee for these businesses occurs in step 2 as follows:

$$\bar{f}_j = \frac{1}{n} \sum_i^n \left[\frac{t_i}{m_i} \right] \quad i = 1 \text{ to } n \text{ where } n \text{ is the number of businesses in the sample} \quad (2)$$

⁶ The term employees is used in the current paper to describe the number of people that work in a business, this is equivalent to how employment is defined by Office for National Statistics. The term employees is an easier word to work with linguistically.

Where:

$\bar{f}_j$ is the average turnover per employee for a given size band and SIC code j;

t_i is the turnover for the matching businesses i found in the ARD; and

m_i is the number of employees in business i within the matching sample.

This enables turnover estimation for business (o) isolated from the BSD dataset as shown in equation 3 (step 3):

$$t_o = \bar{f}_j m_o \quad (3)$$

Where:

t_o is the estimated business turnover for the business o; and

m_o is the number of employees of the business o.

Step four uses various databases to obtain the annual emissions data for a sector (and size band if possible) and turnover. Emissions per unit turnover is estimated in equation 4:

$$\bar{u}_j = \frac{e_j}{t_j} \quad (4)$$

Where:

$\bar{u}_j$ is the emissions coefficient for sector j (i.e. emissions per unit of turnover);

e_j are the emissions of sector j⁷; and

t_j is the turnover of sector j.

$\bar{u}_j$ from equation 4 and t_o from equation 3 are used in equation 1 to estimate direct emissions;

⁷ In application of CLARE in Bradley et al (2010) environmental data used for the above equations for carbon dioxide, was generated from BERR Energy Consumption in the United Kingdom: Service Sector Data Tables (BERR 2008), along with knowledge of the carbon dioxide intensity per unit of fuel burnt from Defra (2005). When later modelling indirect emissions, GHG data were previously used from ONS (2010). Input-output data and accounts previously used for EIO modelling were from Wiedmann et al (2008).

2.2 Environmental input-output model for UK

In this section we briefly introduce EIO analysis. Sub section 2.2.1 provides a brief introduction to EIO and introduces the perspective applied in modelling. The full EIO method applied by the current paper is described in Appendix A.

2.2.1 Environmental input–output analysis

Leontief first developed input–output analysis and the frameworks that enable this analysis (Millar and Blair 1985). The basic Leontief input-output model can be extended into an EIO model capable of estimating emissions attributable to consumption in a given region, resulting from final demand expenditure (in sectors). The framework referred to by Miller and Blair (1985) as the limited Leontief EIO system is used to develop the basic EIO framework for this study. See equation 5:

$$\mathbf{e} = \mathbf{u}'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \quad (5)$$

Where:

$\mathbf{e}$ is a vector of the emissions attributable to final consumption;

$\mathbf{u}$ is a vector of emissions coefficients for a region (with each coefficient being the result of a sector's generated GHG emissions divided by its output⁸);

$\mathbf{u}'$ is the transpose of $\mathbf{u}$;

$\mathbf{I}$ is an identity matrix;

$\mathbf{A}$ is the technical coefficient matrix⁹; and

$\mathbf{y}$ is a vector of final demands.

In order to account for trade, this basic framework is extended to a two region model following Proops et al (1993) and Jackson et al (2007). The two region model was deemed to be the clearest and best way to ensure transparency and tractability through the framework and estimates produced. Transparency and tractability of any framework that attempts to produce detailed estimates for business are important as business may want to compare their emissions estimates with those of CLARE. To do so would require knowledge of the assumptions and datasets applied. Use of large numbers of datasets for many countries as would occur if a multi-regional EIO model was used, would reduce the tractability and

⁸ See Jackson et al (2007) for deriving CO₂ emissions coefficients.

⁹ A technical coefficient (a_{ij}) of the A matrix characterises the inputs from industry i that are required as a result of an increase in one unit of industry j. Such a coefficient is generated by dividing inter-industry sales from sector i to sector j (over e.g. a year) by the output of industry j for the same time frame.

transparency of estimates. The two region model also enables the study to keep a relatively high level of disaggregation throughout the modelling.

EIO models are often used to account for the emissions attributable to household final demand: this is termed accounting from the consumption perspective. Applying this perspective, all emissions that arise in the production of goods and services are attributed to final consumers such as the households (household final demand) that consume the goods and services. The consumption perspective takes a life cycle perspective but assumes responsibility lies with those that consume goods and services. Yet when it comes to businesses the consumption perspective is not particularly appropriate as most inputs to a business are not ‘consumed’ by a business itself but are made/transformed into products for consumption (final demand) or use by other producers (intermediate demand).

A standard alternative perspective is the production perspective. Using the production perspective emissions arising and added directly from direct activity in different sectors are accounted for (industry and commerce, the public sector, investment and households). The production perspective is the perspective used in the CLARE-direct model (CO₂e emissions directly attributable to production) and it identifies the carbon(e) added directly by a business or sector. This perspective does not however allow one to understand upstream indirect emissions attributable to a business. For this reason the current project introduces a new perspective termed the “provision perspective”.

Using the provision perspective this study estimates the emissions occurring upstream of a business as a result of purchased inputs in order to provide the goods and services that a business produces; therefore indirect emissions attributable to production. This perspective provides businesses, policy makers and academics with an understanding of the amount of upstream indirect CO₂e added (by purchased input) that a sector or business potentially has influence over via sustainable procurement. To attain estimates for such a perspective, the ‘New firm in an existing industry’ method from Miller and Blair (1985) is applied to allow all upstream emissions to be attributed to sector purchases (see Appendix A for full details).

The provision perspective applies a similar system boundary to that of the cradle to gate system boundary in Life Cycle Analysis (LCA). CLARE-indirect applies the provision perspective to businesses following the methods of section 2.3. Combining the production and provision perspective carbon(e) added shows the total CO₂e emissions added that a business potentially has influence over, whether through changes in process or technology (on site or supply chain) or through changes towards sustainable procurement.

2.3 CLARE-indirect

When modelling individual businesses, indirect emissions are scaled to individual businesses based on their turnover. Scaling by turnover rather than gross value added (GVA) was chosen as this fits well with the provision perspective and avoids idiosyncrasies in GVA data at the business level (e.g. a business can have a GVA of zero, but still have substantial emissions, see Bradley et al 2010 for further information). A detailed system diagram of CLARE-indirect, identifying where turnover is applied, is provided in Figure 5.

Figure 5: System diagram of CLARE-indirect (for Hospitality businesses)

The first three steps apply exactly the same procedure as occurs up until step 3 (equation 3), where turnover is estimated for businesses in CLARE-direct. Step four requires that an estimate of the embodied indirect emissions intensities be produced for the sector. Intensities here are based on the amount of indirect emissions per unit of turnover for the sector¹⁰. This is calculated by dividing total indirect emissions attributable to the output of the sector by the turnover of the sector, as seen in equation 10:

$$\bar{u}_j = \frac{e_j}{t_j} \quad (10)$$

Where:

$\bar{u}_j$ is the embodied indirect emissions intensity for sector j;

t_j is the turnover of sector j; and

¹⁰ It can be more disaggregated as total indirect GHGs are given by (purchased) product type per unit of turnover.

e_j are the indirect emissions attributable to sector j (taken from the EIO model).

Finally step five requires estimation of the indirect emissions (e_o) attributable to the business of concern, as shown in equation 11:

$$e_o = t_o \bar{u}_j \quad (11)$$

2.4 Limitations and assumptions of the modelling approach

CLARE assumes that turnover can be estimated for the business of concern based on knowing a business's employment, and the average turnover per employee for a detailed business employee size band and subsector. CLARE-direct also assumes that the average direct emissions per unit turnover (for a detailed sector and sometimes employee size band) can be used in conjunction with the estimated turnover of a business to produce the emissions or water use for a business. A similar assumption is made (but with regards to indirect emissions) for CLARE-indirect. Additionally the assumptions inherent in EIO analysis also apply to the indirect estimates of CLARE-indirect, as identified in Appendix B, Also see Miller and Blair (1985). .

A limitation of individual business estimates generated by CLARE is that they must be viewed in a secure environment within the Office for National Statistics (ONS) by authorised individuals. The security is to protect the confidentiality of data provided by individual firms. If government and researchers are vetted, it is however possible to conduct analysis and view actual individual emissions and water use estimates for any business in a given area, as long as no disclosive data are taken outside the secure environment. If a business wanted to view its own emissions, this would only be possible through agreement with the business (its self) and ONS. Therefore future application of CLARE for single business applications will require agreement and involvement of government, but the potential is there. If in future this potential proves difficult, alternative databases such as those of Dunn and Bradstreet and the Financial Analysis Made Easy (FAME) could be employed which do not have such restrictions.

3 CLARE estimation: Use in a step-by-step approach and policy strategy planning and intervention

While CLARE is a complete framework, estimates for CLARE are of particular use in a step-by-step approach which has some similarities to an approach proposed by Suh and Huppes (2005) for hybrid analysis. In such an approach, estimations precede measurement, and rough

measurement again precedes a more and more refined measurement. This type of approach can lead to improved business accounting and reporting, and to local area planning and strategy.

3.1 Use of CLARE-direct production perspective carbon(e) added estimates

The first stage in the step-by-step approach is to identifying business specific impacts (in confidence)¹¹. The main role of CLARE-direct is in preliminary CO₂e emissions estimation and identification (stage 1): this can precede actual detailed measurement by businesses themselves. Such impact estimation and identification can be of use in sensitising individuals to their direct carbon(e) added and role in CO₂e reduction. By providing business specific benchmark information CLARE can help business understand and foresee their likely impact on GHGs as well as potential savings, without requiring time and effort by the business. In this way CLARE can also help reduce bounded rationality and increase awareness.

In future, once ensuring a way of allowing businesses to access their own GHG estimates in confidence has been navigated (either by government or through use of alternative databases as described above), development of CLARE-direct benchmarks could also provide financial information associated with CO₂e such as the cost of energy. Monetising CO₂e and energy can help a business understand its potential future liabilities if they were to be covered by an extension of CO₂ emissions trading schemes or carbon taxes, and potential savings from energy reduction in future. Defra (2006) demonstrate potential for such monetised estimation in Table 1 (using annual estimates).

Organisation Size	Micro (<10)	Small (<50)	Medium (<250)
Total Category Emissions (KtC)	5,578	4,198	1,188
Emissions (tC/organisation)	5	40	250
Energy costs (£/organisation)	£600	£4,800	£30,000
Energy savings at 15% (£/organisation)	£90	£720	£4,500
Equivalent person-days / organisation	0.2	1.4	9

Table 1: Annual indicative ‘private benefit’ calculation by organisation size (Defra 2006 and used in Oakdene Hollins 2011)

The above are very ‘broad brush’ aggregated estimates, but CLARE estimation is business specific and physical estimates could easily be converted into financial.

¹¹ A limitation of individual business estimates generated by CLARE is that they must be viewed in a secure environment within ONS by authorised individuals, including vetted researchers. If a business wanted to view its own emissions and water use estimate, this would need agreement with Office for national statistics and the business itself, therefore future application of CLARE for single business applications will require agreement and involvement of government, but the potential is clearly there.

3.2 Use of CLARE-indirect provision perspective carbon(e) added estimates

Provision perspective business estimates from CLARE-indirect can be used in a step-by-step approach where estimation of the likely impact on CO₂e emissions by a business in confidence (stage 1), firstly helps them understand and acknowledge their wider indirect carbon(e) added, and secondly estimates can be used in a stage (2) that identifies likely key products for sustainable procurement or products for application of detailed but more expensive LCA. Piloting for indirect water use and waste was also presented in Bradley et al (2010).

Tools such as CLARE could be particularly useful for helping new and existing businesses in a position of low or no information with identifying indirect CO₂e (or other emissions) attributable to production and the purchases result in most carbon(e) added. The latter information could be particularly important for both EMA and sustainability. An example application to generate absolute estimates from CLARE of total (direct and indirect) emissions of a scenario business is provided in Appendix C (actual businesses cannot be presented in publication due to disclosure issues). The example includes identification of key products for sustainable procurement. Issues faced in bringing about sustainable procurement are underlined by guidelines such as the Greenhouse Gas Protocol Corporate Standard in which estimating direct GHG emissions and emissions from purchased electricity is required, but less focus is put on supply chain emissions, accounting and reporting of which is optional (WRI 2011). So such reporting overlooks opportunities and progress on sustainable procurement. Matthews et al (2008) show that these protocols will in general lead to footprint estimates by organisations that are a relatively small part of their total life-cycle impacts. Using CLARE one can show both indirect impacts as well as direct and can provide a company specific picture of the incompleteness of their GHG footprints when only reporting primary energy and electricity use.

3.3 Use of CLARE and the production and provision perspectives for estimating businesses carbon(e) added in local areas

In this section we present an actual application of the model using a case study, in which use of CLARE is piloted for use in detailed area organisational CO₂e emissions accounting for hospitality businesses in Southampton (see Bradley et al 2010 for more detail). Southampton Unitary authority is identified in Figure 6.

Figure 6: Postcode districts of Southampton Unitary Authority and the surrounding areas¹²

The CLARE model allows a postcode reference to be associated with every production and provision perspective estimate. As a result of this accounts were piloted for postcode districts as shown below in Figure 7.

Figure 7: Hospitality business production perspective (direct) and provision perspective (indirect) CO₂e emissions in Southampton Unitary Authority in 2004

The production and provision perspective estimates allow one to understand potential for onsite reductions in GHGs as well as opportunities to reduce economy wide GHGs within and outside an area. The very high and varying amount of provision perspective carbon(e) added by businesses in the various postcode districts highlight the potential for purchasing by hospitality businesses in key local areas such as SO14 to drive change in upstream supply

¹² Supplied by Dr Christine Thomas.

chains via (lower CO₂) procurement. In this area indirect GHGs mainly relate (40%) to the following product chains: Alcoholic beverages (15%), Agriculture products and related services (13%), Production, processing and preserving of meat products (9%). The early pilot work in Bradley et al (2010) counted CO₂e emissions from generation of electricity for Hospitality in the production perspective estimate due to the significant control that the electricity user has in controlling the carbon intensity of electricity services. If counted as indirect (provision perspective) as WRI (2011) guidelines suggest, electricity production and distribution accounts for roughly 15%. Given the provision perspective carbon(e) added by the businesses, policy makers and businesses would be advised to focus their sustainable procurement (etc) in this area on electricity use, alcoholic beverages, and meat products. Such analysis could lead towards prioritisation of businesses sustainable procurement actions in local areas and development of targets. To draw on an old saying: 'what gets measured gets done'.

In Bradley et al (2010) the capability for further 'drilling down' to analyse CO₂e emissions and food waste for postcode sectors of postcode districts (SO14) was demonstrated as well as the ability to use CLARE with map information to map emissions tonnage information by location and business (within the secure environment). This approach is the starting point for the development of a 'material flow mapping system' including CO₂ estimation and a range of extremely useful applications to aid business sustainability in local areas as described in Appendix D.

4. Discussions and Conclusions

In this paper two key contributions are made: the development of a new model and the introduction of a new modelling perspective for EIO modelling (the provision perspective).

4.1 The development of a new model

The Commercial Local Area Resource and Emissions (CLARE) model reduces gaps in the literature as the model enables efficient estimation of very detailed (down to individual businesses) direct and indirect emissions estimates, with coverage of all relevant businesses in an area. Such estimates could be used for a step by step approach (as described in section 3) to identify business CO₂e impacts, and identification and prioritisation of actions to reduce CO₂e. Estimates can also encourage reporting and when conducted on aggregate can provide detailed organisational accounting information for local areas which can be mapped for a range of local area applications described in Appendix D. Importantly, CLARE produces emissions estimates across businesses (in the same sector) on a comparable basis using

consistent data, methods and system boundary. This fills gaps identified in the literature on environmental accounting and reporting GHGs. It should be noted however, that estimates from CLARE are a first step and do not substitute the preferred option of exact measurement and reporting by businesses themselves. It is envisioned that the new source of business level environmental benchmark and accounting information that CLARE provides can however, guide and encourage businesses to account, report and acknowledge impacts in a consistent, comparable and transparent manner. Area estimation from CLARE can also help policy makers prioritise businesses and target areas and products that have the highest production and provision carbon(e) added. Figure 7 demonstrated that provision perspective carbon(e) can be very high and that it can relate to specific product types such as Alcoholic beverages and Agriculture products such as meat.

The closest existing framework to CLARE is that developed by King and Tsagatakis (2006), which estimates direct CO₂ for aggregated 1km grids. In contrast CLARE estimates GHGs (CO₂e) for individual businesses as opposed to just CO₂ for aggregated sectors and areas, additionally CLARE undertakes indirect emissions estimation. . CLARE can also however, produce direct and indirect estimates for water use and waste categories for relevant businesses as seen in Bradley et al (2010), not conducted by King and Tsagatakis (2006). In future developments, however, estimates from CLARE-direct could benefit (mainly for GHGs) from King and Tsagatakis's use of point source data for large businesses that comes from data collected from regulations such as Integrated Pollution Prevention and Control (IPPC). Also the methodology that King and Tsagatakis (2006) use to apply actual aggregated energy use estimates (for detailed locations) to adjust their more detailed preliminary estimates, may be worth considering.

With regards to the closest existing indirect emissions estimation frameworks, these are the frameworks of Lenzen et al (2006) and Trucost (2008). CLARE makes developments in methodology of these studies by showing a way of incorporating the use of both the Business Structure Database and the Annual Respondents Database to enable individual business estimation and avoid the need for relevant companies to come forward with data. To use the two databases outlined required new methods being combined with existing methods. Incorporation of these data and the methodology means that indirect estimates can be achieved in detail and comprehensively for relevant businesses within a given area. This has not been achieved in the past as far as the authors are aware. Additionally, the use of geographic reference data within CLARE, means that the framework can lead to high resolution spatial mapping of emissions and water use in cities, which has some very useful applications as discussed in Appendix D.

CLARE does not incorporate financial data supplied by individual businesses of concern into the input-output table and resulting A matrix as Lenzen et al (2006) do. Some may perceive that to not involve businesses in the emissions estimation process to be a weakness of the CLARE approach: this may be so but it is also a strength, as to rely on each businesses coming forward with data would require significant business involvement and render the prospect of getting full business coverage on a consistent and comparable basis for a sector in an area impossible - or at the very least extremely expensive and time consuming. Without the detailed estimates and without such coverage, one cannot efficiently and effectively conduct the area, business and product prioritisation, and detailed planning activities, as discussed in the main paper and Appendix D. Without detail and coverage it is more difficult to effectively engage recognition, action and prioritisation of all or most businesses in an area: Yet in motivating behavioural change it is important that businesses are aware of their environmental impacts (and the affects they cause) and also that they see others around them matching their efforts, acting in a similar way (Defra 2007a).

In future CLARE could incorporate the ability for structural path analysis. Lenzen and Murray (2010) provide a good description of such analysis. They state that (p.261-270):

“Structural path analysis (SPA) is an input-output technique that is used to trace and scan an entire supply and sales chain web in order to extract and rank those chains that are most important in terms of environmental impact that they enable”.

4.2 The provision perspective and management consequences

In the development and presentation of CLARE-indirect in Section 2, a new modelling perspective was introduced: the provision perspective. The provision perspective allows businesses, policy makers and academics an understanding of the amount of upstream (indirect) emissions embodied in purchases (of inputs) by a business or sector; the indirect carbon(e) added when summed up. The perspective therefore provides a picture of the indirect CO₂e embodied in purchases that a businesses (or sector) of an area potentially has influence over. It is a complementary perspective to the production and consumption perspectives, and provides new insights and understanding of upstream abatement opportunities associated with a business's or area's purchased inputs. This can inform actions such as sustainable procurement for businesses as well as policy makers in a local areas. The perspective is particularly important given the increasing evidence of the importance of public and private sectors procurement emissions and sustainable procurement (see Larsen and Hertwich 2011, Ozawa-Meida et al 2011, Vörösmarty et al 2011, Matthews et al 2008 amongst others).

For individual businesses the total CO₂e footprint from CLARE is the sum of the production perspective (direct) and provision perspective (indirect) carbon(e) added and this equates to total emissions attributable to production. These two perspectives together account for emissions attributable to a businesses's sales to final consumers and to other companies i.e. business-to-consumer and business-to-business sales.

In order to account for indirect emissions that result from final and intermediate deliveries by local businesses or sectors (provision perspective estimates), the sector level EIO modelling of CLARE applied the 'new firm in an existing industry' methodology (Miller and Blair 1985) that applies a 'total flow' (TF) like concept (Szyrmer 1992)¹³. The early authors who investigated the use of the total flow concept include those such as Jeong (1984). Szyrmer (1992, p.921) states that:

"TF analysis can be viewed as an alternative to the classical Leontief analysis. Although based on the standard Leontief-type algebra, it is used to address different questions (and provide different results)."

With regards to classical Leontief analysis and TF analysis Szyrmer (1992, page 928) say:

"As is well known, in the standard Leontief model, each unit of final demand has its own 'support network', that is, its own direct and indirect inputs that are perfectly separable from other inputs required by other final demand units. Thus, the whole production system becomes a collection of mutually exclusive and collectively exhaustive production inputs required by a given FD mix. In the TF model the mutual exclusiveness of inputs is not present. The same quantity of input i may be required at the same time by gross output of two (or more) different sectors, say j and k. "

Due to this characteristic that the 'new firm in an existing industry' methodology entails, if provision perspective estimates are applied or analysed for two different business sectors at the same time (and added) double counting can result¹⁴. If looking at provision perspective estimates for one business or one sector at a time on its own there is no issue of double counting.

¹³ The 'new firm in an existing industry' methodology is a somewhat different (but similar) method to that used in Szyrmer (1992) when looking at total flow. From testing using the two methods estimates achieved from the 'new firm in an existing industry' method estimated at 0.3% above the method described in Szyrmer (1992).

¹⁴ Lenzen et al (2007) identify risks of double counting when adding ecological footprints.

Additionally, although for individual businesses one can add production (direct) and provision perspective (indirect) emissions with no risk of double counting, when looking at multiple businesses of a sector in an area, or a whole sector of a country, there is a risk of double counting a small (Roughly 0.1% in the case of Hospitality) part of the provision perspective emissions. Therefore, strictly speaking, one should not add total area production perspective and provision perspective estimates together, when looking at more than one business of a sector in an area: they should be reported and seen as estimates from two different perspectives. Such a need for separation is not uncommon with other perspectives: for example, adding the production and consumption perspectives estimates for an area leads to double counting.

A note should be made with regards to responsibility and the provision perspective. The provision perspective on its own does not attempt to directly allocate responsibility but is a perspective that can be applied to better understand potential upstream emissions that may be influenced via businesses' or sectors' sustainable procurement and supply chain management. A method of allocating responsibility across businesses from different sectors of a supply chain that avoids double counting is described by Lenzen et al (2007). These authors develop and cite earlier work that provide methods to allocate responsibility for ecological footprints along a supply chain between different actors. This is done using the shared responsibility perspective, such as described by Gallego and Lenzen (2005)¹⁵.

Although the shared responsibility perspective and approach is very useful and sensible when attempting to allocate responsibility for emissions along a supply chain (including consumers), like the consumption and production perspectives it does not provide an understanding of the indirect emissions embodied in purchases that a businesses or sector of an area potentially has influence over. This is where the provision perspective can 'add value' in EIO modelling. Additionally a major criticism of the production perspective is that it leads to countries with clean production (within their own country) but high import dependency for GHG intensive products. The provision perspective averts this by including embodied GHGs of imported inputs in estimation and allocating them to the provision of producers in a sector, in the same way as cradle to gate analysis is done in Life Cycle Assessment. Thus the provision perspective as applied in CLARE, provides a way to start understanding the upstream emissions embodied in purchases by a sector (and its businesses) within a local area under a given jurisdiction. The next step is to extend the model to

¹⁵ Lenzen et al (2007), put forward a method of allocating responsibility based on using value added as a measure of allocating responsibility shares.

understand the amount of these upstream embodied emissions actually emitted within the reference jurisdiction. Information from such a model could be extremely useful to policy makers and business that want to move towards contributing their share of UK GHG (and other emissions) reduction targets in local economies. Additionally when such models are applied for water use in conjunction with local water availability data, information potential resource ‘bottlenecks’ for local production could be provided.

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Appendix A

Methodology for estimating the indirect emissions of the Hospitality sector.

Hospitality sector businesses are chosen to demonstrate the CLARE methodology and the production and provision perspectives, due to the high population and contribution of SMEs in the UK Hospitality sector and quite significant energy use of service sectors.

The EIO method for modelling the Hospitality sector makes use of the first method under the sub-section ‘A new firm in an existing industry’, from Miller and Blair (1985). Using this method the first step is to estimate the set of initial intermediate demands (Hospitality sector purchases) that result in economic sectors of the economy, that are required to produce the output of a specific firm or a sector. The demand estimates are derived based on knowing the output (x) of the firm or sector (sector 1 for the hospitality example here) and the technical coefficients (a_{ij}). A three sector economy is used for illustrative purposes. The set of demands generated by equation 6 will later be placed in the position of the final demand vector in the standard EIO model. For this reason these demands are identified as y as seen in equation 6.

$$\mathbf{y} = \begin{bmatrix} a_{11}x_1 \\ a_{21}x_1 \\ a_{31}x_1 \end{bmatrix} \quad (6)$$

Where:

$a_{11}x_1$ are intermediate demands that result in sector 1 from the output of sector 1;

$a_{21}x_1$ are intermediate demands that result in sector 2 from the output of sector 1; and

$a_{31}x_1$ are intermediate demands that result in sector 3 from the output of sector 1.

The impacts from all three sectors of the economy are estimated in the following way as identified in equation 7.

$$\mathbf{e}_1 = \mathbf{u}'(\mathbf{I} - \mathbf{A})^{-1} \begin{bmatrix} a_{11}x_1 \\ a_{21}x_1 \\ a_{31}x_1 \end{bmatrix} \quad (7)$$

Where:

$\mathbf{e}_1$ is a vector of indirect emissions attributable to output of the Hospitality sector (sector 1);

x_1 is the output of the Hospitality sector.

This equation achieves the estimation of indirect emissions that result in the economy from a given level of output of the Hospitality sector. Essentially, the estimates achieved are the emissions attributable to Hospitality sector purchases; one could easily extend the model to also estimate economic (e.g. indirect gross value added) and some social (e.g. employment) impacts associated with the same purchases and this may help in benchmarking sustainability in a supply chain in a more interlinking manner as suggested by Lozano and Huisingh (2011). In the case of CO₂e emissions (different from other emissions) a final step is conducted. The CO₂e emissions occurring directly from the Electricity production and distribution sector as a result of supplying the Hospitality sector are subtracted from the results of equation 7, as domestic CO₂e emissions occurring from direct electricity use by Hospitality businesses are more accurately calculated in CLARE-direct. If classifying electricity as indirect as GRI standards advocate, once the electricity emissions are calculated they can be added to the remaining indirect CO₂e emissions estimates via EIO.

At this stage, there is now a need to estimate the foreign emissions attributable to Hospitality sector output. Using the two region model of Proops et al (1993) and later Jackson et al (2007) this is conducted as seen in equation 8 and 9. For more detail on the two region model and the equations leading up to equation 8, see Proops et al (1993) and Jackson et al (2007). Note that the final demand vectors here are obviously different to those of the previous papers.

$$\mathbf{e}_{\beta} = \mathbf{u}'(\mathbf{I} - \mathbf{A})^{-1} \mathbf{B}_{\beta\alpha} (\mathbf{I} - \mathbf{A})^{-1} \begin{bmatrix} a_{11}x_1 \\ a_{21}x_1 \\ a_{31}x_1 \end{bmatrix} \quad (8)$$

Where:

$\mathbf{e}_{\beta}$ is a vector of foreign emissions attributable to UK Hospitality sector purchases in domestic sectors;

$\mathbf{B}_{\beta\alpha}$ is the imports use coefficients matrix for imports from region β to region α ;

Emissions embodied in direct imports from foreign sectors by the Hospitality sector are described in equation 9:

$$\mathbf{e}_{\beta d} = \mathbf{u}'(\mathbf{I} - \mathbf{A})^{-1} \begin{bmatrix} b_{11}x_1 \\ b_{21}x_1 \\ b_{31}x_1 \end{bmatrix} \quad (9)$$

Where:

$\mathbf{e}_{\beta d}$ is a vector of foreign emissions attributable to UK Hospitality sector purchases direct from foreign sector; and

$b_{ij,s}$ are relevant elements of imports use coefficients matrix for imports from region β to α .

These equations and procedures enable the estimation of embodied indirect emissions attributable to output of the Hospitality sector.

Appendix B

Limitations and assumptions of the modelling approach

The CLARE model has a number of assumptions and limitations that should be made clear. CLARE-direct assumes that turnover can be estimated for the business of concern based on knowing a business's employment, and the average turnover per employee for a detailed business employee size band and subsector. In future this assumption can be avoided for some businesses, as the Business Structure Database has enterprise data where actual turnover is recorded and it is thought to be quite accurate to use this in some situations. Monte Carlo simulations carried out as part of the study, show that for many businesses of an area, the application of average turnover per employee is a reasonable way of estimating turnover and the emissions or water use of a business. More detailed assessment of the assumption is however required.

CLARE-direct also assumes that the average direct emissions or water use per unit turnover (for a detailed sector and sometimes employee size band) can be used in conjunction with the estimated turnover of a business to produce the emissions or water use for a business. The extent of inaccuracy caused by this assumption was found to rely very heavily on the extent to which sector and sometimes employee size band emissions data is aggregated, particularly for earlier work on waste. In general it was found that this assumption when making use of heavily aggregated sector data has the most potential to cause inaccuracies in CLARE-direct.

CLARE-indirect makes the same assumption when estimating turnover for businesses as used when estimating for CLARE-direct. It also assumes that average indirect emissions or water use per unit of turnover at a sector level can be used in conjunction with the turnover of a business to produce a correct estimate of the indirect emissions or water use for a business. Again, it was found that detailed environmental data particularly for waste has a strong influence on improved estimation. Disaggregation of economic datasets can also be important, but was not found to be as critical.

The assumptions inherent in EIO analysis also apply to the indirect estimates developed in the current study. For more detail on these assumptions and limitations with regards to GHGs see Jackson et al (2007). See Miller and Blair (1985) for more detail and references on the assumptions of both input-output and EIO.

A limitation of individual business estimates generated by CLARE is that they must be viewed in a secure environment¹⁶ within ONS by authorised individuals, including vetted researchers. If a business wanted to view its own emissions and water use estimate, this would need agreement with ONS and the business itself, therefore future application of CLARE for single business applications will require agreement and involvement of government, but the potential is clearly there.

CLARE makes use of SIC codes, in some situations a business may be classed under two different SIC codes and some may find that SIC codes do not sufficiently describe their activities. Also, the current study makes use of a UK relevant two regional model when conducting sector modelling, with BSD and ARD information providing localisation. A sector level model specific to Southampton could be employed in future and this would allow one to locate the amount of indirect impacts that occur locally.

¹⁶ The secure environment is a lab within ONS, where only authorised and trained researchers are able to access detailed data. Data going into the lab and outside of the lab is checked and assessed for disclosure by ONS staff. Any data or estimates taken out of the lab must be derived from at least 10 observations otherwise data cannot be taken outside of the lab. The security is to protect the confidentiality of data provided by individual firms. If government and researchers are vetted, it is however possible to conduct analysis and view actual individual emissions and water use estimates for any Hospitality business in a given area, as long as no disclosive data are taken outside the secure environment.

Appendix C

Within the ONS secure environment the use of the model is not limited by disclosure. Food waste (GHGs and water use) could be looked at for individual businesses. To demonstrate the detail achievable in a secure environment, a scenario business is presented below. In the scenario it is envisioned that the business of concern is a restaurant business with 25 employees. For this case, the following absolute estimate of food waste is produced for the hypothetical business.

Figure C1: A restaurant's direct and indirect food waste (25 employees)

For the example in Figure B1, the five key purchased products for which most indirect food waste were most attributable were: the production and processing of meat products, alcoholic beverages, bread rusks and biscuits, production of mineral waters and soft drinks, processing and preserving of fish and fish products.

Individual business estimates produced in this way could be used by businesses, government or NGOs to help benchmark and characterise a business's likely production and provision perspective impacts. The estimates could also help guide businesses on the format and form of quantitative reporting required.

Appendix D:

There is potentially significant value in using CLARE in planning and prioritising applications for waste and GHG infrastructure. Such applications of CLARE are now discussed and illustrated. The ability to map businesses is seen in Figure C1.

Figure D1: Restaurant business located in postcode district SO14

Business location by street map information used in conjunction with CLARE-direct could be particularly useful to businesses, government and NGOs in organising collective planning and management and decisions for waste management problems such as planning anaerobic digestion of food waste (which can reduce GHGs emitted from waste degradation). For example distances and tonnages could be estimated using CLARE in conjunction with map information and with use of other data such as miles per gallon information (to map the most efficient route to attain a given tonnage of waste), fuel costs and changing technology performance information, to assess the technical and economic feasibility (as Defra 2007b suggest is conducted) of a proposed waste management scheme at various scales. Within the ONS secure environment GHGs, food waste (and other variables) could be mapped for individual businesses. The ability to produce such detailed benchmark estimates for mapping is clearly an advantage in planning, but also in strategy applications, including the matching and pairing of most suitable businesses within close geographic proximity

for industrial symbiosis. Such uses of CLARE could be a starting point for the development of a 'material flow mapping system' including associated CO₂ impacts for government and NGOs as called for by Peter Jones of the London Waste and Recycling Board (Westminster Energy, Environment and Transport Forum 2009). Such a tool could be very useful in efficient matching of companies for industrial symbiosis.

Beyond planning waste infrastructure, such material flow mapping systems have potential to be used by government to provide tailored information (via a 'one to many' approach as called for by AEA and SRDN 2009 with tools such as CLARE) for priority businesses to help them overcome barriers to resource efficiency by quickly and efficiently¹⁷.

¹⁷ It is clear that businesses face barriers in resource efficiency even if profitable as seen in a report by Oakdene Hollins for Defra in (2011). The latter report calculated that for the UK in the year 2009 businesses could save 23bn a year at very little cost. It is said that the savings of this magnitude are feasible via business investments in reducing material, energy and water use with a payback of less than a year (ENDS 2011).