Northumbria University
NEWCASTLE

Article title: Co-managing carbon and air quality: pros and cons of local sustainability initiatives

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ABSTRACT

This paper reports the pros and cons of co-management (i.e. concerted actions towards climate change and air quality management) through local sustainability initiatives using three case studies, each encompassing the planning and management issues at local government levels. Case study I is policy-based and reports outcome of a consultation exercise while case studies II and III have greater scientific bearing. These case studies pave the way for development of a more integrated Climate Change Strategy Action Plan at local scales, specifically regarding policies on emissions sources from transportation and decentralised energy. They highlight the merits and the trade-offs of implementing local scale co-management practices, using a more integrated planning framework than what is currently under offer.

We recognise that delivery of such ambitious, cross-cutting agenda may be impeded, primarily owing to limited expertise in assessing the synergies and the expected outcomes from cross-fertility between these two arenas. This calls for a step-change through more cohesive, cross-disciplinary policy frameworks, going beyond the local administrative spheres to maximise the co-management potentials while mitigating the wider environmental impacts.

Keywords: *carbon emissions; co-management; air quality; green infrastructure; integrated assessment; local authorities*

1. Introduction

Emergence of ‘co-management’ i.e. concerted, inter-sectoral local actions towards achieving cost effective air quality improvements while managing carbon dioxide (CO_2) reduction targets has gained grounds in times of austerity (Chae 2010, Thambiran and Diab 2011). Globally, there is growing emphasis on generic sub-national and national policies for maximising the returns of climate change adaptation strategies with regard to human health via improved air, water and food quality (Haines *et al.* 2007, Salon *et al.* 2010, Quevauviller 2011, Larsen *et al.* 2012, Takeshita 2012). The majority of ‘conventional’ air pollution as well as CO_2 emissions at a local level originate from anthropogenic sources, and measures to reduce one problem are likely to have some impact (either positive or negative) on the other (Hayes *et al.* 2007). National and federal governments have been increasingly empowering local authorities (LAs) to take action through localised management solutions given their wide range of responsibilities and greater understanding of underlying activities (Salon *et al.* 2010, DECC, 2012, Naiker *et al.* 2012). Owing to the lack of a formal policy ‘home’ for climate change within LAs in the UK, there has been a particularly strong set of arguments for integrating climate change strategies into aspects of well-established local air quality management (LAQM) remits. These initiatives have been broadly referred to as ‘co-management’ (Baldwin *et al.* 2009).

There have been significant calls for integrated policies, linking disparate air pollution and climate change management initiatives (van Amstel 2009, Defra 2011, EPUK 2011, UNEP 2011). Concurrently, the concept of climate change localisation and management has also been gaining centre stage (Wright *et al.* 2011). These calls are based on a range of logics. Economically, air quality co-benefits of greenhouse gas (GHG) reduction policies could potentially offset a large fraction of the cost of the mitigation actions, particularly in the developing countries (Stern *et al.* 2007, Nemet *et al.* 2010). Planned actions to reduce certain air pollutants (so called ‘Short Lived Climate Forcers’) may be advantageous in slowing the rate of warming (Ravishankara *et al.* 2012), particularly in the situation where significant GHG reduction is not expected to occur in the near future.

Integrated air quality management and GHG reduction measures have been reported to offer greater benefits than those obtained from implementation of isolated measures (Chae and Park 2011). Hence, greater emphasis placed on 'holistic' LAQM plans and strategies, incorporating climate change considerations, or vice versa, for example see London Borough of Brent (2012). However, despite the high-level calls for joined up action on air quality and climate change, the notion of 'co-management' has received little in-depth exploration at local scales. This is also marred by recent reports from several European countries, indicating 'uneven adoption' of Local Agenda 21 framework, suggesting feeble (or at least very uneven) support for the local sustainable development strategies at local governance levels across Europe (Fidélis and Pires 2009, Barrutia and Echebarria 2012). The key question remains whether significant carbon management might be better achieved utilising the same framework as applied by the LAs in the context of air quality. Theoretically, LAQM can be used to support climate change mitigation in the short-to-medium term (Thambiran and Diab 2011, Defra 2011), however, the limited skill-base in LAs (developed and developing countries alike) in delivering this novel, cross-cutting agenda, augmented by the complexities in integrating local and scientific knowledge (Raymond *et al.* 2010), is likely to impede the expected outcome from improved integration of these two issues.

This paper sets out to highlight potential benefits and inherent barriers of localised co-management initiatives. It considers a number of opportunities for linking these two policy spheres – combining the management of GHG and air quality – by capturing multiple developments in the policy environment towards a single reference point of co-management. The first part of this paper presents an overview of the current practice and the issues in LAQM and carbon management approaches, highlighting their benefits and barriers within the UK context. The three case studies presented in the following section are UK specific - incorporating the varying elements of co-management, the challenges of consolidated actions and the possibilities (and the opportunities) for converging the carbon and the air quality agendas at a strategic level rather than just in terms of individual interventions. Based on these case studies the implications for an integrated strategy for co-management in the urban environment (specifically regarding policies on emissions sources from transportation and decentralised energy) and the pertinent hurdles to be overcome are discussed in subsequent parts of the paper.

2. Current issues in local scale air quality and carbon management

Over the last fifteen years, LAs in the UK have been involved in rigorous assessments and declarations of Air Quality Management Areas (AQMAs) under the Local Air Quality Management (LAQM) policy framework. To date, over 230 of LAs (around 60%) have declared one or more AQMAs for different pollutants (predominantly nitrogen dioxide, NO_2 and particulate matter, PM_{10}). Transportation, being a major urban activity, has been identified as the main source of pollution in the majority of the AQMAs (around 92%; Faulkner and Russell 2010), as well as being responsible for roughly 20% of UK GHG emissions (DfT 2010). This linkage has already garnered attention from academics and policy-makers with regard to their co-management potential. However, while there may be overlapping management needs, in terms of addressing the reduction in emissions at source, typically from transportation, the inherent nature of how the two entities influence the local and the wider environment would significantly affect the potential for co-management. Despite anthropogenic combustion activities being the prime source of both GHGs and air pollutants in urban settings, there is a key contextual distinction between the methodological approaches for their effective management. Air quality has a strong spatial association with residential population (expressed in legislation and guidance as exceedences of the objectives at 'relevant locations') and requires a management-at-source approach to avoid adverse impacts. On the other hand, GHG reduction is not reliant on location-based interventions to achieve its targets (e.g. action to reduce carbon emissions in LAs are often focussed on energy saving initiatives in relation to power plant CO_2 emissions that occur well outside their boundary). However, this discrepancy may be about to change if the new $PM_{2.5}$ exposure reduction responsibilities (EC 2008) get passed down to LAs in any way, as this will result in LAs needing to make reductions in the overall background pollution concentrations rather than just focussing on the hotspots. Further, there is also the consideration that whilst there are various end-of-pipe or combustion control technologies for many air pollutants (NO_x, PM, etc.), this is not the case for CO_2 till date, barring the proposed carbon-capture and storage technologies piloted for large coal-fired power stations.

Devising the best approaches to achieve 'win-wins' (i.e. those likely to result in the reduction of pollutants of importance to air quality and climate change) from such co-management initiatives is an evolving phenomenon. The links between air quality and carbon management lie, not only in the overlaps between the sources of interest, but also in the skills and policy understandings needed for their effective management (Baldwin *et al.* 2009). Currently (2012), the policy of managing climate change through local environmental initiatives is gaining ground, and increasing amounts of mitigation and adaptation methods for climate change are being implemented at local scales (AQMRC 2010). However, to facilitate this, policymakers require an understanding of the air quality ramifications of climate mitigation decisions (or at least clearly presented and plausible evidence). Whilst win-win policies are obviously most desirable, it is envisaged some actions will result in a 'trade-off', i.e. benefitting one aspect at the cost of the other. Over recent years some expertise involved in air quality management has been diverted towards finding a common path for providing guidance and support to LAs on the issues and the problems associated with this approach. The main area for combining carbon management with LAQM is around transportation emissions. This is due to the legacy of effective air pollution control after the 1965 Clean Air Act in the UK, which has meant that in the urban centres the vast majority of LAQM practice (at the moment) is based on transportation with very little considerations from industrial or domestic emissions. Though this may be changing due to the recent 'dash to biomass' with regard to 'sustainable' heating systems for buildings (see Case Study III below), which brings additional sources in urban/peri-urban context.

Robust policies to co-manage climate and air quality have the potential to create significant reductions in exposure to air pollution (Ravishankara *et al.* 2012). Through the following case studies numerous opportunities, barriers and compromises are identified in order to effectively and resourcefully co-manage and mitigate CO_2 and LAQM pollutants while ultimately accruing cost-effective environmental benefits at LA levels.

3. Case studies

These case studies present practical and policy interactions in co-managing climate change and air quality through local initiatives, creating opportunities for positive gains for both the issues (i.e. co-benefits) as well as the inherent challenges in assessing what is beneficial for one could be deleterious for the other (i.e. trade-offs).

3.1. Case Study I – Strengthening integrated policies: Reading Borough Council Air Quality and Climate Change Consultation and Action Plans

In 2007/8 Reading Borough Council (RBC), UK conducted a public and stakeholder consultation exercise to support the coordinated development of its Air Quality Action Plan and a Climate Change Strategy for the Borough (RBC 2008). The two-phase consultation was designed to look at the interlinked issues of climate change and air quality so that areas with potential synergies and conflicts could be identified and adequately addressed (RBC 2009 [p20]). The first phase consisted of awareness raising activities - including outreach events in the local libraries, community centres, leisure centres and community group talks. The second phase was conducted in partnership with the Air Quality Management Research Centre (AQMRC) at the University of West England, UK. This consisted of a questionnaire survey and two participatory workshops. The questionnaire surveys were distributed in various ways including a stand in a local supermarket, a double-page spread in the local newspaper, through libraries and leisure centres and by post to people who had requested further contact through the postcard consultation. In total 155 questionnaires were returned and 24 people attended the workshops. Overall, local interest in environmental issues was found to be somewhat split, with local councillors more interested in engaging in a problem of global importance such as climate change, whilst citizens wanting to see more action from the local authority on the problems that are immediately at their doorstep. In response to query on the most important environmental issue 53 people identified road traffic, 39 air quality and 16 the need to mitigate climate change (Chatterton *et al.* 2008). A co-management approach offered an opportunity for the LA to develop strategies and policies that meet the expectations of both their elected members and their citizens.

Following this consultation, RBC have developed a Climate Change Strategy Action Plan, joining the two separate policy streams of air quality and climate change, specifically regarding policies on emissions sources (,mainly transportation and decentralised energy) (RBC 2008). It includes 40 sets of cross-thematic objectives and actions with their estimated benefits in monetary terms. **Table 1** provides a shortlist of those objectives that cover potentials for co-management within the scope of this paper. In addition, in the council's Air Quality Action Plan, 14 out of the 26 proposed measures have potential climate change benefits associated with them. This means that when it comes to assessing the cost-effectiveness of these measures (as required by government guidance LAQM.PG(09)) the council would be able to recognise and evaluate these additional (non-AQ) benefits. By visibly and publically making a link between the two issues, the council has helped ensure that political weight (stemming from either a desire to improve air quality or to mitigate climate change) can be put behind win-win measures through integrated policies, further increasing the likelihood of their implementation.

<place Table 1 here>

Currently (2012) there is no prescriptive legislative requirement for LAs to act on climate change mitigation; there has been a tendency for strategies to be developed at a higher, corporate level (or at least in part of the structure with a more cross-cutting remit than environmental health). The RBC joint consultation process helped to firmly link the issues in the eyes of the local managers, ensuring that whilst there are still separate Climate Change Strategy and Air Quality Action Plans, these now clearly pay reference to each other and have policies which fall across both, facilitating an overarching level of co-management.

3.2. Case Study II – Boosting win-wins: The All London Green Grid initiative

Inclusion of green infrastructure (GI) in the design, planning and management of landscape resources to conserve ecosystem functions and to provide a range of economic co-benefits to the people across Europe has seen revived trends recently (Hamdouch and Depret 2010, Llausàs and Roe, 2012). In the UK all LAs are required to have a Planning Policy Guidance (PPG17) open space strategy and accompanying dataset, though GI planning is still feeble in most cases, primarily owing to their difficulty in devising successful strategies (Defra 2012). For example, even though all the London Boroughs work within the same policy context and guidance (ODPM 2001), there is no standard protocol for classification and mapping of individual spaces. The East London Green Grid (ELGG), promoted by the Greater London Authority (GLA) as a network of multi-purpose open spaces criss-crossing the Thames basin, has accrued (or anticipated) benefits (including carbon reduction) to the tune of £4.93 to every £1 of London Development Agency investment (LDA 2011). This initiative has now been extended across London in the form of All London Green Grid (ALGG), which aims to secure a network of high quality, well designed and multifunctional green and open spaces (**Figure 1**). It has earmarked co-management opportunities in terms of 'ALGG functions', including adaptation to climate change, improvement of air quality and soundscapes, conservation and enhancement of biodiversity, promotion of healthy living, improve quality and access to urban fringes (GLA 2012).

<place Fig 1 here>

This case study presents the potential benefits and limitations to co-management opportunities from local scale GI planning and design strategies. It covers a section of the ALGG in the Lower Lea Valley, around the area of the City Airport and its flight paths across East London (shown with a dotted square in **Figure 1**). The estimates of CO_2 and PM_{10} in the assessment have been generated using activity and emissions data from the London Atmospheric Emissions Inventory (LAEI) (GLA 2010), primarily from transportation and domestic sources (**Figure 2**). The spatial configuration of the green grid network and the flight path of the City Airport are shown in greater details in the inset of this figure, with the airport runway depicted as solid black rectangle. Adequate design and vegetation composition would offer co-management potentials for CO_2 emissions as well as wind and air quality amelioration (mainly particulate pollution) across the region, but has inherent land use challenges - for example restrictions to planting tall trees very close to the runway. From air quality perspective mixed tree cover, comprising of 75% grassland, 20% sycamore maple (*Acer pseudoplatanus L.*) and 5% Douglas fir (*Pseudotsugamenziesii*) has been shown to achieve PM_{10} reductions in London of up to 0.17 tonne ha^{-1} yr^{-1}(Tiwary *et al.* 2009). For CO_2 management on the other hand, there are different priorities in species selection; establishments of new woodlands have been shown to contribute to much higher yearly potential carbon sequestration (up to 3.63 tonne C ha^{-1} yr^{-1}), compared to bioenergy crops, short rotation coppice (SRC) and Miscanthus cultivation (up to 0.41 tonne C ha^{-1} yr^{-1}) (Cantarello *et al.* 2011).

<place Fig 2 here>

Emissions of CO_2 and PM_{10} at 1 sq-km resolution for 2011, based on the LAEI are plotted along with the design of the ALGG network in the study domain (**Figures 3a and 4a respectively**). Potential co-benefits have been estimated on the basis of reported carbon sequestration (Cantarello *et al.* 2011) and PM_{10} fluxes (Tiwary *et al.* 2009) for a mixed vegetation canopy, comprising of 75% grassland, 20% sycamore maple (*Acer pseudoplatanus L.*) and 5% Douglas fir (*Pseudotsugamenziesii*) for the 10,000 ha plot. The choice of the species mix and the PM_{10} reduction calculations applied to this assessment build on the methodology already reported in a previous study (see Tiwary *et al.* (2009) for numerical formulation and parameterisation details).

<place Fig 3 here>

The potentials for CO_2 sequestration is estimated in terms of annual flux to the vegetation (tonnes km^{-2} yr^{-1}, **Figure 3b**) whereas the air quality co-benefit is estimated as reduction in PM_{10} concentration downwind to the plantation (at 1.5 m height about ground) (µg m^{-3}, **Figure 4b**). The outputs support co-management potentials of the ALGG near the City Airport for both CO_2 and PM_{10} reductions through efficient design and choice of species, facilitating both enhanced dry deposition of pollutants on their foliage and localised carbon sinks for aircraft emissions in the region.

<place Fig 4 here>

While the pedagogical evidence generated through this case study is promising towards supporting multi-functional urban greening policies, it is still limited in scope in overcoming the inherent challenges in realising these functions, mainly utilising the skills available in LAs. This would be essentially at two stages of greening projects: i) appropriate design and implementation, ii) adequate appraisal of their co-management potentials.

3.3 Case Study III – Managing the trade-offs: Decentralised Energy from Renewable Biofuels

Development of a reliable and clean energy infrastructure has been at the forefront of local planning framework in recent years, with earmarked potential co-benefits for public health improvements and for climate change mitigation (Haines *et al.* 2007). Biomass from both organised plantations (including energy crops) and solid wastes has been considered an integral component of the green energy mix in the UK towards development of smaller, decentralised heat and electricity applications in a multiplicity of locations (Barker and Evans 2009, Bauen *et al.* 2010). However, co-management opportunities from these initiatives have not proven to be effective at a systems level, and there is a significant risk identified for deleterious impacts on air quality at the expense of lower carbon energy and heat generation (Gallagher *et al.* 2008). In the UK new sets of guidance have been developed exclusively for LAs to address adverse air quality issues from biomass boilers and Combined Heat and Power (CHP) installations. These provide recommendations and spreadsheet-based screening tools to local managers for assessing and managing the potential air quality impacts, specifically for nitrogen dioxide (NO_2) and particulates (PM_{10} and $PM_{2.5}$) (EPUK 2009, 2012). It is acknowledged that the potential risk of a breach of air quality standards is increased if the CHP system is in or near an AQMA, attributed to the compounded impacts from associated activities at urban and regional scales. However, in the absence of any clear guidance, LAs are left to decide on the level of impact the installation would have directly within their bounds.

<place Fig 5 here>

This case study develops a hypothetical scenario for a decentralised bioenergy system spanning across two neighbouring LAs (LA1 and LA2 in **Figure 5a**, to illustrate the need for overlapping responsibilities) and evaluates the CO_2 and air quality issues for utilising a range of renewable fuels scenarios from the literature. This is pertinent to local planning in the near future, with a growing number of microgeneration schemes and smaller scale community boilers operating in peri-urban locations as part of GHG reduction strategy - their environmental responsibilities ought to be shared across the adjoining LA boundaries. However, LAs would not have direct responsibilities over imposing emissions control for the whole bioenergy system (for example, harvesting and non-road transportation and processing of biofuel would not be accounted within the LAQM framework). **Figure 5(b)** shows a spectrum of air quality burdens arising from different biofuel CHP systems from the harvest, transportation and power plant (here A=Miscanthus, B= Short rotation coppiced (SRC) wood, C=Residual waste wood, D=80% Miscanthus + 20% Residual waste wood, E=80% SRC + 20% Residual waste wood) estimated from emissions reported in the literature (Tiwary and Colls 2010). As can be noted, all the CHP systems studied have lower CO_2 burdens from the power plant (and hence promoted as green technologies), albeit at the cost of enhanced NO_x, N_2O (nitrous oxide; another potent GHG constituent), SO_2 (sulphur dioxide) and HCl (hydrogen chloride) emissions. This would potentially trigger interaction of criteria pollutants, exacerbating health risks from both primary and secondary pollutants, photochemical smog formation (ozone) and eutrophication (through nutrient enrichment) in the local environment, as well as impacting on the regional climate from secondary aerosol formation (Tiwary *et al.* 2012).

In policy terms this case study highlights the need for strengthening systems scale capabilities to assess and to effectively mitigate the impacts of such complex and spatially distributed concomitant emissions, spanning across a range of activities involved in fuel harvesting, pre-processing and consumption. Evidently, such initiatives would ask for a more integrated co-management framework, with greater cross-territorial interactions between the LAs than currently pursued (i.e. beyond the basic LAQM approach).

4. Discussion

The above case studies offer pathways to the manner air quality and climate change can be (and arguably ought to be) linked within LAs: to ensure the full benefit is obtained from complex win-win scenarios; to avoid (or at least minimise) the risk and extent of trade-offs where climate related policies might impact negatively on air quality; to ensure that co-ordinated agendas are taken forward at strategic levels in order to buy-in support from as many councillors and members of the public as possible; to be certain that positive impacts across the domains are fully accounted for in cost-effectiveness calculations for proposed measures. In the short-to-medium term the priority in co-management practices would be to implement air quality interventions that do not impact negatively on GHG emissions (Thambiran and Diab 2011) and vice-versa. However, as clearly recognised in RBC's Air Quality Action Plan (**Table 1**), the sources can differ considerably between the two management spheres, leading to a need to keep the two separate to some extent. On the other hand, the overlap between the sources and the interplay between the impacts of both technical and behavioural remedies for each highlights the opportunity for significant synergies that can be achieved.

Although, at least in principle, co-management initiatives are expected to be able to attain co-benefits in terms of both climate change mitigation and air pollution abatement (Baldwin *et al.* 2009), the majority of existing air quality related legislation has a limited ability to enforce interventions with such cross-cutting implications and bring about effective improvements. Some commonalities in the required skill base between air quality and carbon management for LAs have been identified, including - (a) existing networks of contacts; (b) understanding of gaseous and other emissions; (c) construction of emissions inventories; (d) understanding of role, behaviour and regulation of a range of sources; (e) identification of priority polluters. However, currently LAQM is predominantly considered as a health-based framework and thus focussed mainly on the exceedences in areas where receptors are likely to be exposed to the offending pollutant(s). This provides scope for the sources of emissions to be isolated and separated from the receptor without the need to reduce overall emissions. Conversely, carbon mitigation is concerned with reduction in the total load of emissions. Further, whilst the focus of LAQM is on emissions from sources, much of the work at a local level in terms of carbon management is in relation to end-use energy demand. For example, in the UK approximately 40% of CO_2 emissions within the scope of influence of LAs arise from electricity usage, rather than direct emissions (DECC 2011). This means that a significant amount of the focus of any local carbon management activities would, in any case, fall completely outside the remit of LAQM.

London City Airport has recently set up a Sustainability Strategy and Airport Sustainability Action Plan covering 2012-2014 (LCY 2012) where managing both carbon and local air emissions have been prioritised. The options considered include enhancing natural environment, i.e. vegetation cover; however, this initiative is severely limited due to space, operational and safety constraints. Based on the Greenhouse Gas Protocol the emissions from the airport operations have been divided into the following two categories: (a) Emissions on site, from combustion of fossil fuels; and (b) Emissions from electricity imported from the grid (or from third party supplier in the form of heat or electricity). The reported annual CO_2 emissions from the London Atmospheric Emissions Inventory (LAEI) for 2011 in the area close to the airport are considerable (Fig 3a), ranging between 1.62×10^5 and 2.76×10^6 tCO_2 km^{-2}. On the other hand, the maximum annual CO_2 sequestration potential for the vegetation species evaluated in the region range between 350-830 tCO_2 km^{-2} (Fig 3b). Based on our assessment, assuming optimal vegetation performance, the fraction of local emissions off-set through this initiative would fall between 0.25 - 15% respectively, depending on whether the aircraft emissions are included or excluded from the local inventory. This suggests that the greening is more effective in off-setting ground level CO_2 emissions (mainly from the combustion of fossil fuels, i.e. gas, LPG locally) and less so in offering a blanket carbon neutrality for the entire airport operations.

Whilst technological and policy-based strategies have been shown to be effective in simultaneously reducing air pollution and GHG emissions from the transportation sector (Thambiran and Diab 2011) there is considerable evidence of LAQM and climate change initiatives still working in silos (Chatterton *et al*. 2007, Longhurst *et al*. 2009, Faulkner and Russell 2010, Olowoporoku *et al.* 2012). On the other hand, owing to the inherent distinction between the manner in which the two sources affect the human and the natural environments this does not necessarily imply that carbon management can be best achieved at a local scale by following similar policy frameworks and guidance to those currently used for air quality. This stems from the fact that the co-management approaches devised to date still have a spatial contrast, carbon management being considered as more cross-cutting and overarching whereas air quality management manifested into more local, issue-based initiatives driven by local authorities. Further, as demonstrated through the case studies, the benefits realised from co-management may not be readily apparent (and precisely quantifiable). Therefore, while such initiatives appear to be fostering the next generation of local sustainability measures, they still seem to be lacking the drive, specifically in terms of monetary markets for carbon mitigation.

The above three case studies explore the opportunities for linking the two policy spheres through a single reference point of co-management towards development of a more integrated Climate Change Strategy Action Plan at local scales, specifically regarding policies on emissions sources from transportation and decentralised energy. This is proving to be an eye-opener for the majority of actors involved in overcoming the complexities in integrating local and scientific knowledge. The UK government policy has long been criticised for not being ‘joined-up’ and it appears that the need to tackle the cross-cutting and overarching nature of the climate change problem is bringing additional urgency for this to be resolved. Whilst LAQM has to date had a strong spatial focus, this may partly relate to its lack of success (e.g. as indicated by widespread failure to achieve EU air quality limit values). Particularly within the context of an ‘age of austerity’ there will be an increasing need to argue the benefits of any proposed measure, making a co-management approach one that is more likely to pass this hurdle when undertaken well. It may also be the case that the resource pressures facing LAs will result in more streamlined, but possibly more co-ordinated structures that may avoid the large, disjointed departmental structures that reinforce siloed working patterns. These factors all strongly suggest the need for LAs to develop not just co-management thinking, but also organisational processes that clearly reveal the logic and benefits of such a strategy. This has for some time been suggested through using a budgeting approach to sustainable development involving a 'triple bottom line' (financial, environmental and social), but through the case studies presented we have highlighted that this may not be sufficient and that even the environmental issues will need to be unpacked (into carbon and air quality at the very least).

5. Synthesis and Future works

To date LAs in the UK have been set targets for air quality but they have not yet (i.e. in 2012) been set specific carbon reduction targets as such. Current initiatives, being pursued under the broader 'sustainability' umbrella at LA level, have climate mitigation agenda *per se* with either co-benefits or adverse impacts to air quality. A well-defined co-management framework, integrating carbon and air quality management on a single platform, is long overdue. Ideally this needs to facilitate the practitioners in a two-stage process - first, to develop a common metrics for the LAs, assisting them in ascertaining whether co-management would be more effective compared to working on air quality or carbon management in isolation in their respective areas; second, to prescribe them a customised local/regional implementation plan, linking with the broader strategic objectives at national level. In essence this would ascertain the impact of co-managing initiatives, albeit inadvertently or by design, which can manifest into either win-win (e.g. ensuring both lower emissions and freer flowing transportation) or win-lose/trade-offs (e.g. traffic calming measures adapted for reduced congestion but increased travel distance circumventing the city routes).

Whilst a 'co-benefits' approach (to a wide-range of other environmental and social factors) has always been a feature of local planning framework in the UK, there is a spectrum of potential for 'co-management' in the rapidly urbanising economies world-wide, which runs simply from the assessment of co-benefits, through to complete alignment of policy and management techniques. This paper, however, highlights that in the short–term at least, the delivery of this novel, cross-cutting agenda may be impeded owing to limited expertise of local managers (developed and developing world alike) in assessing the synergies and the expected outcome from improved integration of these two issues. It is expected that a step-change through a more integrated, trans-boundary policy framework, going beyond the local administrative spheres, would maximise the co-management potentials while mitigating the wider environment impacts. Whilst a full integration of air quality and climate change responsibilities in LAs may not (in all cases) be desirable, there is a strong need for a significant degree of integration to be recommended through adequate policy framework and best practice. Without this to direct the LAs, there is a huge risk that opportunities to co-management will be overlooked, ignored, or simply not receive the necessary local political priority.

6. Acknowledgments

We would like to acknowledge the EPSRC grant EP⁄F007604⁄1 to the 4M (Measurement, Modelling, Mapping and Management: an Evidence Based Methodology for Understanding and Shrinking the Urban Carbon Footprint) consortium. Acknowledgements are also due to the Greater London Authority for providing the emissions inventory for London and to Reading Borough Council with respect to the Air Quality and Climate Change consultation work.

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Tables and Figures Captions

Table 1. Policies addressing co-management issues in the Reading Borough Council Climate Change Action Plan (source: RBC 2008)

Figure 1. Spatial mapping of the proposed All London Green Grid and the case study area, Lower Lea Valley green space (shown in dotted square).[© Crown Copyright and database right 2011. Ordnance Survey 100032216] (source: GLA 2012).

Figure 2. The model domain showing the road and rail traffic (lines), 1 sq-km emission grids, London City airport (rectangle), flight paths (trajectories) and the square box showing the configuration of the green grid. Further details of the spatial layout relative to the street plan and the airport runway locations are provided in the inset. [© Crown Copyright and database right 2011].

Figure 3 (a) CO_2 hotspot map for London for 2011. (b) Estimated annual CO_2 flux potentials for the case study site (at 1 sq-km grid resolution).

Figure 4 (a) PM_{10} hotspot map for London for 2011. (b) Contour map of PM_{10} reduction potentials for the case study site (as concentration reduced downwind to the vegetation at 1.5 m height above ground level).

Figure 5 (a) Schematic of the conceptualised management boundary of a decentralised bio energy system shared between two local authorities [note: all the activities except biomass production would be accounted within the LAQM, the concomitant interactions of criteria pollution requires a more regional management framework, T = Transportation]. (b) Bar plot of emissions from biofuel-based CHP at systems scale, including biofuel harvest/sourcing, transportation, processing/drying and combustion [A=Miscanthus, B= Short rotation coppiced wood, C=Residual waste wood, D=80% Miscanthus + 20% Waste wood, E= 80% SRC + 20% Waste wood].

Figures

Fig 1

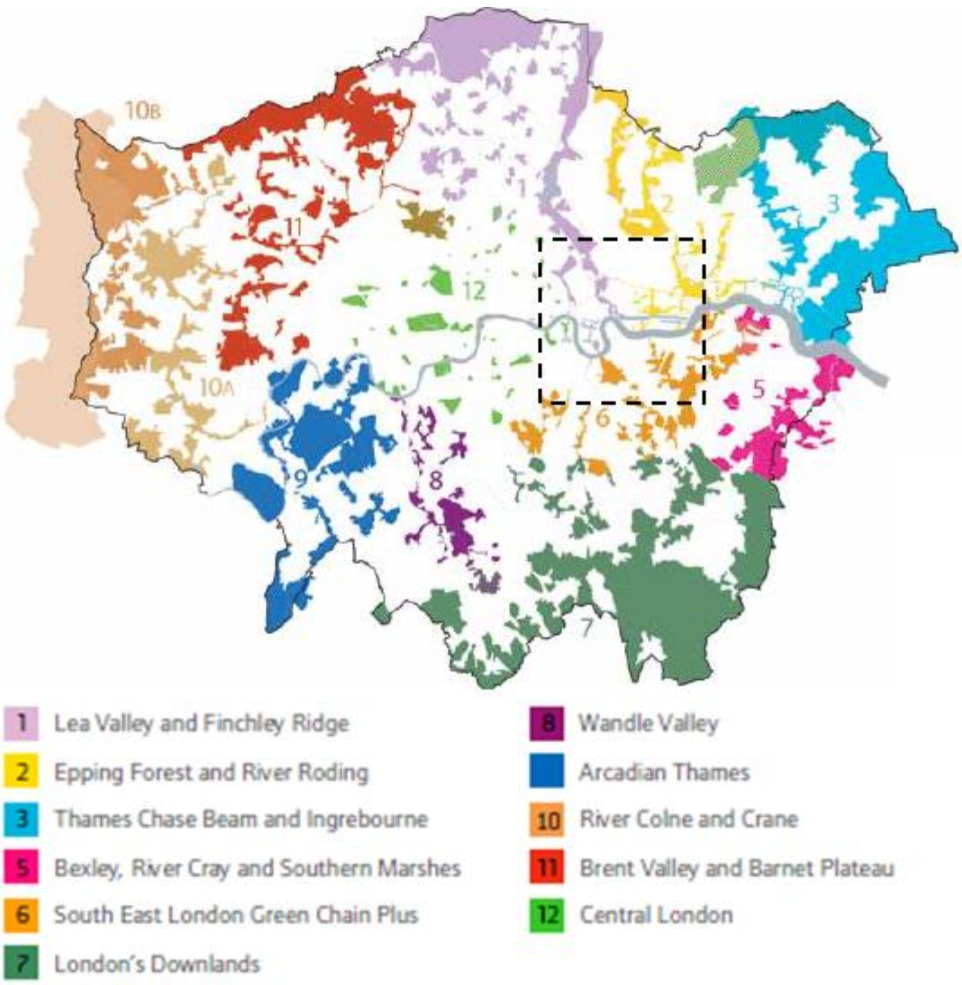


Fig 2.

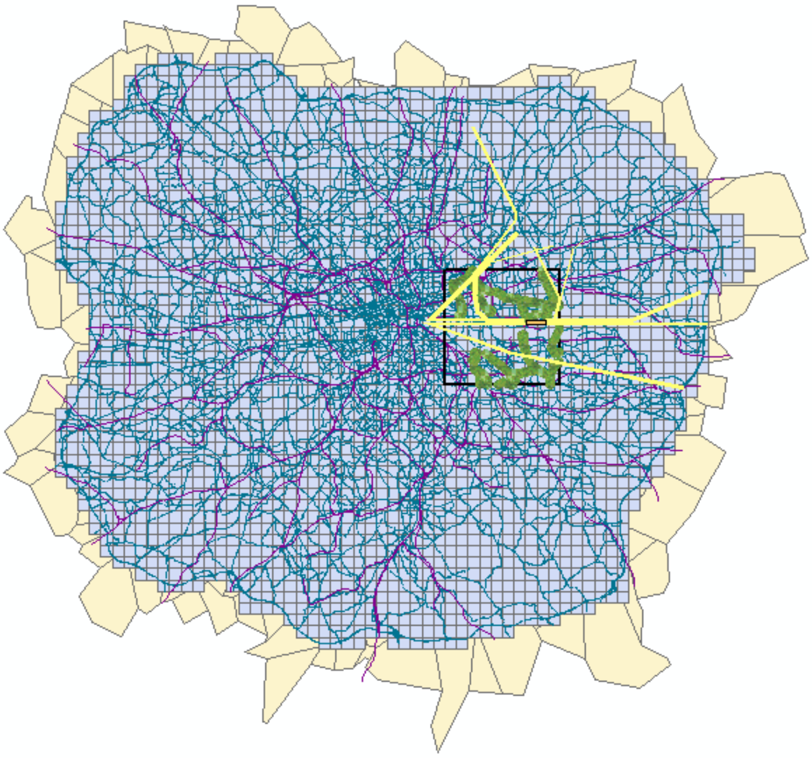


Fig 2 (inset)

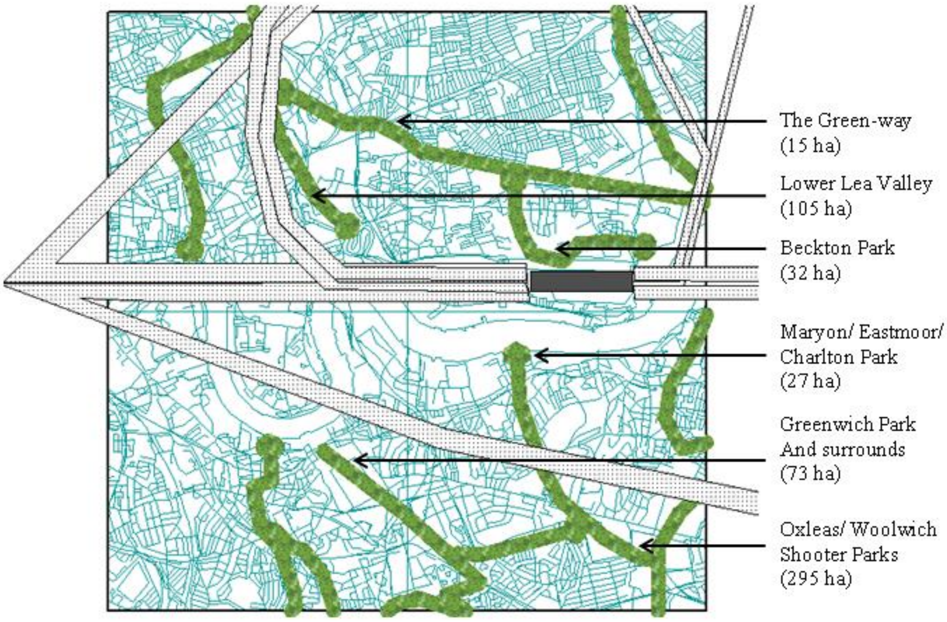


Fig 3(a)

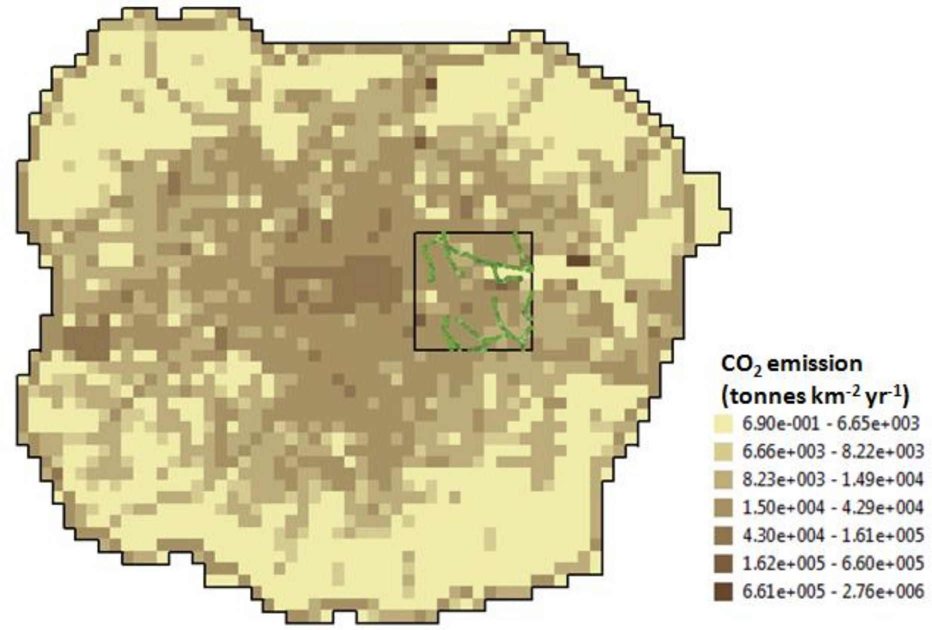

CO2 emission
(tonnes km-2 yr-1)
6.90e-001 - 6.65e+003
6.66e+003 - 8.22e+003
8.23e+003 - 1.49e+004
1.50e+004 - 4.29e+004
4.30e+004 - 1.61e+005
1.62e+005 - 6.60e+005
6.61e+005 - 2.76e+006

Fig 3(b)

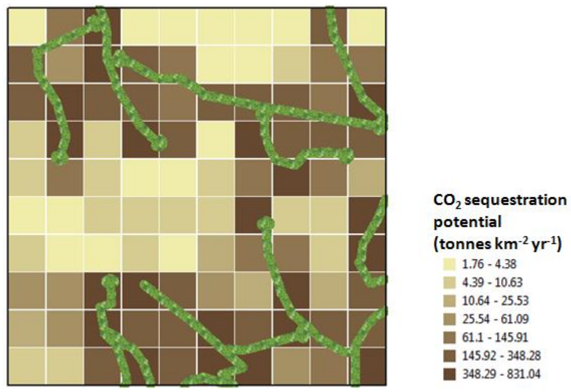

CO2 sequestration
potential
(tonnes km-2 yr-1)
1.76 - 4.38
4.39 - 10.63
10.64 - 25.53
25.54 - 61.09
61.1 - 145.91
145.92 - 348.28
348.29 - 831.04

Fig 4(a)

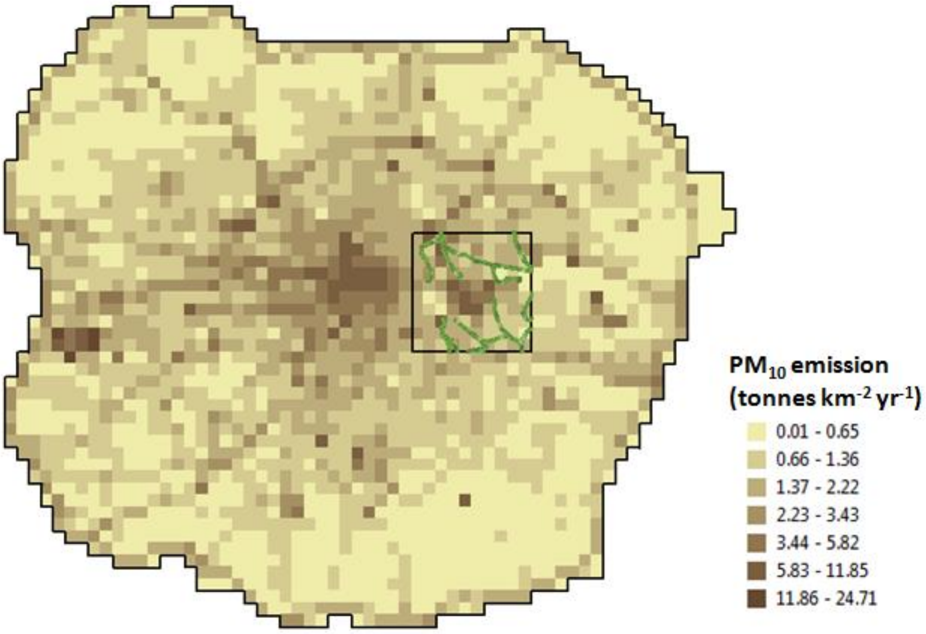

PM10 emission
(tonnes km-2 yr-1)
0.01 - 0.65
0.66 - 1.36
1.37 - 2.22
2.23 - 3.43
3.44 - 5.82
5.83 - 11.85
11.86 - 24.71

Fig 4(b)

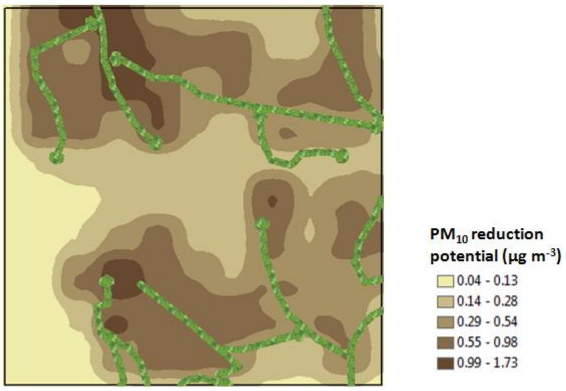

PM10 reduction
potential (µg m-3)
0.04 - 0.13
0.14 - 0.28
0.29 - 0.54
0.55 - 0.98
0.99 - 1.73

Fig 5(a)

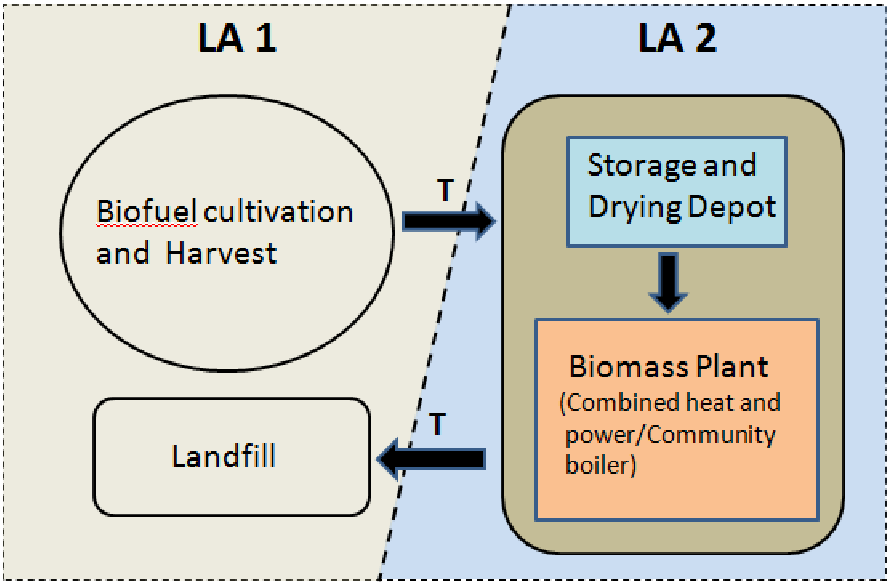
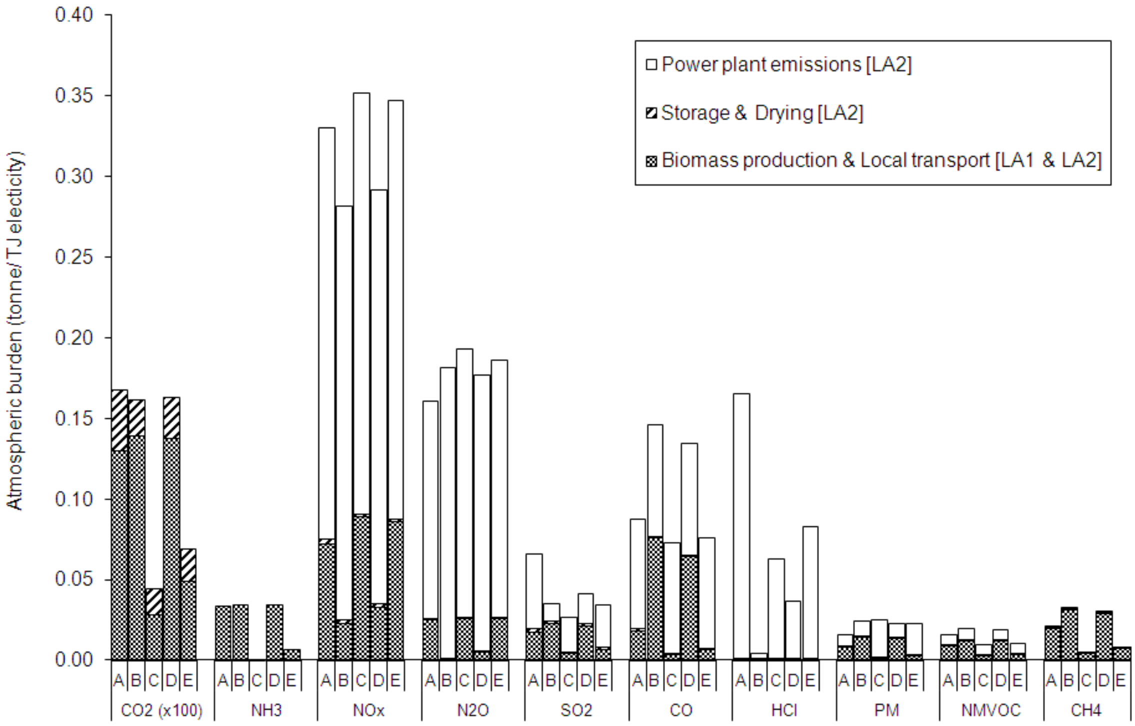

LA 1
LA 2
Biofuel cultivation and Harvest
T
Storage and Drying Depot
Biomass Plant
(Combined heat and power/Community boiler)
T
Landfill

Fig 5(b)


Atmospheric burden (tonne/TJ electicity)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Power plant emissions [LA2]
Storage & Drying [LA2]
Biomass production & Local transport [LA1 & LA2]
A B C D E
CO2 (x100)
NH3
NOx
N2O
SO2
CO
HCl
PM
NMVOC
CH4