Decarbonising cities and the role of remote sensing for planning, developing, and monitoring low carbon precincts

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Abstract. Although space technologies are extremely useful to environmental researchers, the contribution that they make in monitoring city greenhouse gas emissions is limited to measuring those emissions. Standing alone, satellite technology is incapable of advancing the goal of decarbonisation. This goal will be achieved only if municipalities find local methodologies that reduce carbon emissions. Once these methodologies are implemented, the satellite measurements can demonstrate if remedial actions are succeeding. This paper is based on current work done jointly with municipalities to ascertain where, within urban systems, emissions originate and how they can ultimately be reduced. It both presents remote sensing as helpful to decarbonising precincts and discusses the impact of certain carbon mitigating strategies. Considerable potential exists for the use of satellite measurements and remote sensing to assist local authorities in planning, mapping, modelling, and developing low carbon infrastructure. The challenge is converting satellite-derived data into the kind of information that allows precinct communities, together with other stakeholders, to make decisions that result in low carbon outcomes at the precinct scale.

1. Cities’ facilitation of an emerging green economy: an introduction

The population of cities is growing at an unprecedented rate. Fifty percent of the world’s people now live in urban areas, and this figure is rising progressively. Demographers expect that by 2050, 5.3 billion people, or 70% of the human race, will reside in cities [1]. Left uncontrolled, this rapid urban growth threatens to contribute to many environmental disasters—massive habitat loss and species extinction, depletion of the Earth’s finite resources, such as potable water and precious minerals, extreme pollution and build-up of waste, as well as soaring carbon emissions and global warming. However, ‘smart’ development of our cities promises to minimise humankind’s impact on the environment, for example high density living and urban infill can decrease pollution by making it more convenient for people to walk and take public transport. Because it is imperative for our survival that humanity live harmoniously on Earth, cities must work to become part of the solution through attention to their design, function, and governance.

Society has a pressing responsibility to wean itself from dependence on high-consumption, high-carbon economies and to accept a low-consumption, low carbon existence. Fortunately, this change can be made without jeopardising peoples’ lifestyles; in fact it can actually improve humankind’s social well-being [2]. Decarbonising, which is part of this process, will involve redesigning cities as low carbon centres with circular patterns of urban resource flows that foster community resilience. The restructuring of urban pathways with low carbon infrastructure networks will involve cities collaborating with international, national, and local governments, non-governmental organisations,
research institutes, universities, local communities, and the private sector. Space agencies can also play an important role in this process.

2. International agreement on decarbonised development
In 2009, at the 15th Conference of the Parties (COP-15) of the United Nations Framework Convention on Climate Change, global leaders meeting in Copenhagen made a significant political agreement to work together towards establishing international cooperation and action for the decarbonisation of development. The Copenhagen Accord (CHA) emphasises both that “deep cuts in global emissions are required . . . so as to hold the increase in global temperature below 2 degrees Celsius . . . and that a low-emission development strategy is indispensable to sustainable development [3].” Since Copenhagen, the Intergovernmental Panel on Climate Change (IPCC) has reinforced this agreement by stressing the important role that cities can play in achieving the overall goal of reducing global carbon emissions by facilitating decarbonised development and encouraging the emerging green economy [4].

3. Cities’ contribution to carbon emissions
As major centres of carbon intensive production and resource use, the world’s expanding cities account for a large proportion of rising global carbon emissions. However, discrepancies exist in the reporting of exactly how much they contribute, with some reports overstating emission figures. On the one hand, World Energy Outlook 2008 claims that cities are responsible for 71% of worldwide emissions; on the other, the Clinton Climate Initiative states that they contribute 80% [5]. Even more contradictory, the IPCC avers that cities are more likely responsible for between 30% and 40% of global carbon dioxide (CO$_2$) emissions [6].

This inconsistency reveals not only a degree of uncertainty about the precise quantity of carbon emissions but also a lack of agreement about with whom and where the responsibility lies for their production. For instance, factories located in semi-rural areas outside a city’s boundaries are often the source of stationary energy consumed by city dwellers for their domestic and commercial purposes. However, these emissions are often excluded from the calculation of a city’s total carbon footprint. Obviously, in order to determine the appropriate carbon mitigating actions required to moderate, reduce, or prevent the growth of carbon emissions, it is imperative to identify and measure the output of key sources for which a city is responsible.

4. Space agencies’ measurement of urban carbon emissions
Space agencies are helping resolve some of the ambiguity surrounding the contribution of cities to global carbon emissions. Satellite technology is being deployed to assess city greenhouse gas emissions so that these emissions can be measured and monitored more accurately. NASA’s Jet Propulsion Laboratory Megacities Carbon Project is measuring multi-year emission trends of carbon dioxide, methane (CH$_4$), and carbon monoxide (CO) attributed to several megacities and selected major sectors. After this pilot project’s three year trial, NASA in coordination with its international partners, such as the Japanese Space Agency, may expand it to other cities [7].

Remote sensing, satellite technology is extremely useful not only for measuring city greenhouse gas emissions but also for gaining an initial perspective on the impact that these growing metropolises are having on global carbon emissions. However, the challenge is to account for those emissions generated outside a city’s boundaries for which a city is nevertheless responsible and which should be included in calculating its carbon footprint. These activities in space could be extended further to assist cities with calculating the emissions inherent within the totality of their energy, water, and waste systems and with providing guidance on which portions of carbon emissions they should be responsible for attempting to mitigate.

4.1. Calculating carbon in urban systems
A movement is growing internationally to measure the carbon impact of all urban development and associated infrastructure—energy supply, transport, buildings, water, and waste. More comprehensive data is needed regarding emissions from the material and construction processes involved in the built environment, the use of energy within buildings, the mode and use of transport, the operational energy required for distribution of electricity, gas, and water, and the management of waste [8]. Cities need assistance with acquiring quantifiable carbon data on these urban systems so that they can ascertain where the bulk of their emissions is generated and hence can devise appropriate strategies directed at those areas. Cities could benefit from greater access to remote sensing technology to help with assessing the emissions inherent in urban systems.

5. Decarbonising of city precincts

Municipalities are not simply measuring their carbon emissions; they are also taking dramatic action to decarbonise by implementing new and innovative low carbon strategies intended to reshape the way cities are designed, built, and powered. This process requires local governments to re-examine their urban infrastructure systems, identify the key sources of carbon emissions inherent in the urban fabric, and reconstitute their infrastructure networks accordingly to be less carbon intensive and more resource efficient. If cities are to successfully respond to 21st Century urban challenges and reduce emissions measured from space, they need greater access to remote sensing tools.

5.1. Creating low carbon precincts

Recently, the reduction of carbon emissions at the national level, and to a lesser extent at the building scale, has been the topic of much discussion. However, far less attention has been given to low carbon development at the precinct scale. Neighbourhoods are based on precincts, and new developments within brownfield and greenfield areas are often planned at this finer scale. Moreover, the precinct scale has been recognised as an excellent starting point for initiating carbon-mitigating action within a city [9].

5.1.1. Developing distributed low carbon infrastructure at precinct scale. In cities’ efforts to reduce key sources of carbon emissions in development, a trend is emerging toward a distributed-systems approach to infrastructure. Compared with conventional centralised systems, distributed networks can employ a wider range of technologies for low carbon society construction. These technologies include photovoltaic systems, small wind turbines, and cogeneration (also known as combined heat and power or CHP) [10]. Such systems are proving to be more resource efficient, less carbon intensive, and increasingly more economically viable than is the centralised approach [11]. The precinct scale favours both the construction of waste-to-energy plants and automated solid waste collection systems and the implementation of distributed technology for energy, water, and waste, particularly the use of trigeneration, renewables, recycled wastewater, and collected rainwater [9].

5.2. Planning and developing low carbon precincts – a role for remote sensing

Municipal governments are often responsible for major precinct-planning decisions that directly affect a city’s carbon footprint. However, to make decarbonisation really work at a precinct level, precinct communities, including councils, local business investors, and community stakeholders, require greater access to the appropriate remote sensing tools for planning, developing, and monitoring their low carbon urban systems.

Insufficient technical and financial resources too often hamper local authorities’ decision-making abilities and efforts to implement low- or zero-carbon development. Remote sensing software tools and applications that could perhaps help municipalities model or map various scenarios are often expensive, insufficient and not readily available at this scale. Or, Geographical Information Systems (GIS) technology is presented as a ‘black box’ to protect commercial interests, so users have limited access to manipulating data, configuring scenarios and hence, being in control of making important assumptions linked with urban planning decisions.
Local authorities need remote sensing tools to help them identify where to prioritise their carbon-mitigating actions and to understand the impacts and trade-offs of certain decisions and the investment costs involved in choosing one strategy over another. For example, the majority of a precinct’s emissions may be driven by unsustainable modes of transport or high-energy usage in commercial buildings. If a council can see that energy usage in a central business district drives the bulk of emissions, the council can then determine which energy efficiency measures will have the greatest effect in reducing its precinct’s emissions. Municipal budgets often permit only one or two options for reducing carbon emissions, extending related actions over a period of several years; therefore, in order to gain trust and boost support for future projects, councils need to demonstrate a valuable outcome to the community.

Councils could also benefit from greater access to remote sensing technology for assessing how their precincts might evolve over time with certain staged planning decisions for low carbon development. This assessment includes the measurement of overall precinct emissions, the impact that infrastructure choices may have on local environmental resources, and the potential cost savings that may be realised for local government and the community by the implementation of any given choice. Greater use of drone imagery integrated within simple, easy-to-use GIS modelling tools would enhance the visual platform and assist municipalities to better conceptualise and thus better understand the potential outcomes of certain modelled scenarios.

5.3. Monitoring low carbon precincts – a role for remote sensing
Precinct communities also need to better monitor the impact of their local carbon-mitigating activities. Remote sensing technology holds great promise for accomplishing this goal. Likewise, satellite imagery and data could provide excellent support for the documentation and visualisation of a precinct’s local environment and for alerting a precinct to any changes that might be occurring because of urban pressures that might affect the resilience of newly implemented infrastructure systems. Remote sensing drone technology could be useful for this purpose also. For example, by measuring atmospheric temperatures, a drone could report the impact that a tall building’s biophylic landscaping is having on the reduction of a precinct’s heat island effect.

6. Collaboration between space agencies and precinct communities
Fostering greater collaboration between space agencies and municipalities with carbon-mitigating projects could create a win-win situation. Firstly, creating strong linkages at finer scales between cities and remote sensing agencies rather than establishing the linkages between isolated, hierarchical, and generalised governance systems and these agencies, could open doors for cities to obtain the data that are most relevant to their specific urban or climate change challenges. Such challenges are extremely location-specific and complex, and they require many scales of intervention to effectively deal with emissions reduction. If municipalities can have better access to remote sensing data, they will be better able to detect, quickly respond to, and deal with local issues in their context.

Secondly, expertise to use the technology and understand the data is often lacking within local government. If local authorities and their precinct communities work directly with space agencies, they can communicate more easily with remote sensing specialists and therefore achieve a better understanding of the remote sensing data. Enhanced understanding and knowledge at this level would help close the information gap, improve confidence, and ease the communication flow among all stakeholders involved in the delivery of precinct-level, low carbon solutions. Local authorities and their precinct communities could in turn provide valuable on-the-ground information to improve the accuracy of space-satellite derived data, which, as mentioned above, can have limitations.

7. Remote sensing building capacity for local carbon governance
All over the world, councils are being given both greater autonomy to respond to climate change and greater flexibility to collaborate with organisations and enterprises to build capacity for low carbon development of their precincts [12, 13]. At the precinct level in particular, municipalities are more in
touch with the prerequisites for this development than are the older utility providers that operate on a much larger scale. Therefore, it makes sense that special attention be given to facilitating the way in which local councils implement and manage their infrastructure networks and mechanisms for service delivery [9].

Strengthening the technical resources of municipalities will not only improve governance for low-carbon urban planning and development but also aid in attracting private sector funds for investment in precinct-scale infrastructure projects. Appropriate remote sensing tools will help municipalities demonstrate the impacts of and responses to low carbon development initiatives and communicate these results to potential investors or stakeholders. In addition, they can be used to gain acceptance from the community for any planned projects.

Increasingly, municipalities are working jointly with multiple actors on different levels to implement low carbon development. Partnering with the private sector, creating community ownership models, or involving residents in participatory budgeting are becoming more popular as tactics to attract financing, deal with management, and gain community support for climate change projects. Many organisations—for example, pension funds and insurance companies—are seeking to demonstrate a low carbon profile to their shareholders or board of directors through their investments and operations [14]. These actions are being taken as a result of good marketing decisions, genuine concern for the environment, and a desire to support innovation in the emerging green economy. Thus a strong incentive already exists for private sector engagement with the public sector, and both local government and precinct governance should profit from this interest.

8. Conclusion

Just as urban areas are important drivers of national economies, urban infrastructure systems are the backbone of cities’ economic, social, and environmental development. On the one hand, the pressures of urbanisation are placing great strains on existing city infrastructure systems, and on the other, the production, distribution, and consumption of city resources are significantly affecting the environment in negative ways, particularly with the increase in global carbon emissions. However, an opportunity exists now, during this time of rapid urbanisation, for cities to develop low carbon infrastructure systems. How cities choose their infrastructure today, including the technology and resource production and consumption patterns that shape people’s lives, will ultimately determine the global carbon emissions of those cities [15].

Cities need to invest in the construction and improvement of low carbon infrastructure systems not only to reduce their high carbon footprints but also to meet the demands of growing populations and the need to remain competitive. Critical transport, power, water, and waste systems must be upgraded and redesigned to achieve optimal functioning of services and efficient use of resources at minimal costs and with the least impact on the environment. Identifying and calculating the carbon emissions inherent in city infrastructure systems and then redesigning less carbon-intensive infrastructure networks is arguably the most important way in which to reduce cities’ carbon emissions and thus their impact on the environment.

Decarbonising cities and subsequently their economies requires many different kinds of innovation and activity. The process can be greatly assisted if precinct level, finer-scale development can be a focus, for precincts are where much new development is taking place and where distributed, low carbon systems can work effectively. Fortunately, new governance models are developing that allow precincts to operate with a degree of independence from central governments.

However, if precinct communities are going to have a substantial impact on reducing carbon emissions, they will need an innovative carbon governance model supported by and linked with the appropriate remote sensing technology. Well-planned cities matched with well-planned governance can help to reduce carbon emissions without sabotaging the population’s quality of life. In fact, this combination of forces will enhance the way people live [16]. A new ‘green’ economy accompanied by decarbonised city infrastructure systems will open up new job opportunities, provide clean air to breathe and fresh water to drink, public transportation will be more accessible and efficient, power
bills will be lower and active landfills will be replaced with flourishing green areas for food production and recreation.

In order to accomplish these things, city governments and their communities must have the appropriate tools for planning and developing their low carbon precincts. Remote sensing technology is one such tool; it can assist local authorities and their partners in planning, mapping, developing, managing, operating, and monitoring low carbon precinct networks. Moreover, remote sensing holds enormous promise to enhance a municipality’s ability to attract business people who are interested in investing in carbon-mitigating projects. Working more closely with municipalities, space agencies can assist with converting carbon-sensing data into easily accessible and understandable information so that local authorities can make more informed, appropriate, and effective associated decisions. Similarly, ‘ground-truthing’ activities, such as taking on the ground measurements to improve satellite data can be achieved in cooperation with local authorities working on local carbon-mitigating projects. Developing better access to remote sensing tools that aid in the development of integrated, more efficient low carbon systems for the provision of energy, water, waste, and transport services will help cities not only reduce their overall impact on carbon emissions but also become more resilient to the impacts of climate change.

These are actions that will affect the health of the biosphere for decades to come and thus define the moral responsibility of our generation.

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