SELF Conserving URBan Environments

The route to delivering sustainability

PI: Professor Margaret Bell CBE
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Sustainable Urban Living Challenges

- **UK POPULATION**: Increase to 80m by 2050-requires 5 million new homes, urban infrastructure and more food (ONS, 2009)

- **FOOD**: Next 50 years more food needed worldwide than over past 10,000 years (UN, 2007)

- **SURFACE TRANSPORT**: Accounts for 23% of UK CO$_2$ emissions and road traffic increasing at around 2% per year (SDC, 2010)

- **HOUSING**: very energy inefficient heating and increasing demand from more appliances- accounting for ~20% UK CO$_2$ emissions

- **BINDING TARGETS**: Reduce CO$_2$ emissions by 67% over 2010 values by 2050 (DECC. 2011)
SECURE Vision

To deliver a *step change* in thinking by enabling *integration of resource-supply-demand-waste systems across city-to-regional scales*

- to create *scientifically informed*, strategic, integrated policies and planning driven by efficient transport; use of land as a resource; using waste as an asset; microgeneration of energy and upscaling systems management from a local/city to regional level.
Components of 2050 Sustainability
Resource-demand-supply-waste systems and pathways to meet government targets

Ecosystem Services
- Supporting: carbon sequestration, trees and soil
- Provisioning: energy from waste, Biofuel, food

Urbanisation
- Land use: buildings, infrastructure, green space
- Transport: demand, vehicles, energy

Domestic Energy
- Supply: microgeneration, biogassification, biofuel
- Demand: heating, electricity, housing stock
WP5: Benefits of Spatial Integration

NERUM 2016

Benefits of Spatial Integration

2016
Local planning

2011
Current policy response

Stakeholder Inputs

Integrated Regional Urbanisation model

Disaggregated & Localised
Sporadic & Undervalued
Carbon Intensive

CO₂ emissions
Total energy use
Imported food/fuel
Resources & waste

Knowledge transfer

SAVINGS

Projection (2016)
Base Case (2011)
WP5: Transitions to 2050

NERUM generic

Integrated & Strategic
Optimised benefits
Carbon Efficient

Implications of sustainability
Vision scenarios (2050)
Transition scenarios (2030)
Projection (2016)

Targets

SEIf ConservIng URBan Environment

NERUM Meet National targets
NERUM Novel
NERUM Local planning

Stakeholder Inputs

2050
2030
2016
Key Research Questions

• How to tackle inefficiencies in the urban system to make it fit for purpose by 2050

• How to effectively scale from local solutions and policies in individual cities to larger-scale efficiency gains at the regional scales.
What SECURE will Deliver

• NERUM, an integrated suite of models to quantify benefits across spatial scales and across themes to optimise regional benefits

• With stakeholder input establish credible 2050 targets for each theme and pathways

• Scientific evidence to justify truly self conserving and efficient transitional scenarios
Emissions 2005 NE Region CO$_2$

Total 37MtCO$_2$e

- Industry: 22,800,000
- Waste: 400,000
- Agricultural and land use: 0
- Aviation and shipping: 2,500,000
- Public and Commercial: 900,000
- Residential: 6,100,000 (16%)
- Road Transport: 4,600,000

WP1 Urbanisation

Dr Anil Namdeo
Newcastle University
NE Transport Models
Transport Emissions Modelling

Road Transport uCO2 emissions using 2005 base fleet emissions

Transport CO₂ emission map 1 km²

Platform for Integrated Traffic, Health and Emissions Modelling PITHEM

Future modelling based on vehicle fleet projections, fuel efficiencies etc.
Public and Private Transport

Freight

Fruit/Vegetables and Food Miles

Biofuel Production

Waste Collection
Urbanization - buildings 5-year building forecasts for the Northumberland region: 2012-2016

(a) Residential (mainly affordable homes)

- Alnwick
- Warkworth
- Rothbury

Dwelling build rate (units yr⁻¹)
- 1
- 5
- 10
- 25
- 50
- 75
- 100

(b) Commercial (mainly town centres)

Floor space (sq ft)
- 0 - 205
- 206 - 752
- 753 - 2102
- 2103 - 5628
- 5629 - 12451
- 12452 - 29842
- 29843 - 60933

Source: Northumberland County Council
Integrated urbanization model-

Land use:
Transport, Buildings, Greenspace, Waste management

Transport – optimising future infrastructure and vehicles

Buildings – optimising new build versus refurbishment

Greenspace – optimising local food and fuel production and carbon sequestration

Waste management – optimising systems and energy recovery
WP 2
Ecosystem Services
Jonathan Leake University of Sheffield
Jill Edmondson, Maria Avila-Jiminez, Kevin Gaston, Elisa Lopez-Capel, David Manning
WP2: - Ecosystem Services
Overall Vision

• Quantify selected ecosystem services that can contribute to:
  
  (a) Reducing dependance on fossil fuel energy,
  (b) Reducing or sequestering atmospheric CO$_2$ emissions

• Identify potential increases in sustainable local food and biomass fuel production, and CO$_2$ sequestration into soils and vegetation

• Integrate these findings into ecosystem service maps and models to identify optimal ways of benefitting from ecosystem services and contribute to meeting 2050 CO$_2$ emissions targets.
Compile existing ecosystem service maps of the North East

a: carbon storage, b: real agricultural value, c: potential (interpolated) agricultural value, d: woodland, e: tree diversity, f: ancient forest, g: interest for protection, h: buildings
Although greenspaces often comprise > 50% of urban areas in the UK. The majority are small (e.g. gardens) - a large number of people decide how used. A small number are very large - where a small number of people decide how used.
Lawn / flowerbed 54%; Trees and shrubs <1%; Artificial surface 46%; Building <1%

Lawn / flowerbed 34%; Trees and shrubs 6%; Artificial surface 59%; Building <1%

Lawn / flowerbed 41%; Trees and shrubs 49%; Artificial surface 9%; Building 2%

Lawn / flowerbed 0%; Trees and shrubs 0%; Artificial surface 82%; Building 18%
Globally:

4 x more C in soils than in vegetation
3 x more carbon in soils than in the atmosphere

In Leicester - 82% of ecosystem organic C was in soil

Only 18% in vegetation- of which 97% was in trees

Planting trees increases aboveground C storage
- but what is the effect belowground?
Organic carbon hidden in urban ecosystems

Jill L. Edmondson¹, Zoe G. Davies², Nicola McHugh¹, Kevin J. Gaston³ & Jonathan R. Leake¹

¹Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, U.K., ²Durrell Institute of Conservation and Ecology (DICE), University of Kent, Canterbury, Kent CT2 7NR, U.K., ³Environment and Sustainability Institute, University of Exeter, Penryn, Cornwall TR10 9EZ, U.K.

Urbanization is widely presumed to degrade ecosystem services, but empirical evidence is now challenging these assumptions. We report the first city-wide organic carbon (OC) budget for vegetation and soils, including under impervious surfaces. Urban soil OC storage was significantly greater than in regional agricultural land at equivalent soil depths, however there was no significant difference in storage between soils sampled beneath urban greenspaces and impervious surfaces, at equivalent depths. For a typical U.K. city, total OC storage was 17.6 kg m⁻² across the entire urban area (assuming 0 kg m⁻² under 15% of land covered by buildings). The majority of OC (82%) was held in soils, with 13% found under impervious surfaces, and 18% stored in vegetation. We reveal that assumptions underpinning current national estimates of ecosystem OC stocks, as required by Kyoto Protocol signatories, are not robust and are likely to have seriously underestimated the contributions of urban areas.
Urban soil carbon storage has previously only been estimated for the UK using assumptions shown to be invalid by our studies in Leicester.

(Bradley et al., 2005)
Urban soil organic carbon

42 kg OC m$^{-2}$ = 421 tonnes ha$^{-1}$
$R^2 = 0.3272; y = 96.1278e^{-0.0196x}$

Urban soil organic carbon
How much is there?
Could tree planting increase it?

Deep sandy
57 kg OC m$^{-2}$
$R^2 = 0.7914; y = 134.815e^{-0.020x}$

Leicester data
20 kg OC m$^{-2}$

Table 6. Density (kg m$^{-2}$) of carbon in soil of different types of land in the United Kingdom.

<table>
<thead>
<tr>
<th></th>
<th>Depth</th>
<th>Seminatural</th>
<th>Woodland</th>
<th>Pasture</th>
<th>Arable</th>
<th>Gardens</th>
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<tbody>
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<td>England</td>
<td>0–100 cm</td>
<td>29</td>
<td>17</td>
<td>13</td>
<td>12</td>
<td>6</td>
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</tbody>
</table>

(Bradley et al., 2005)
• No evidence that urban tree planting changes soil organic C storage
• Tree planting could contribute to CO$_2$ sequestration
• Short rotation coppice could replace some fossil fuel for space and water heating

• Locking CO$_2$ into biochar by making charcoal from waste wood and adding to soil
Geochemical carbon sequestration in made ground- (Prof. Manning)

2 types of site:
• Science central (made ground)
• Byker (valley landfill)

Various kinds of urban made ground
Recreational greenspace -remediated land
Brownfield sites - derelict land contaminated with old landfill

>16,000 of England’s 23,800 brownfield sites are located in the North East. Artificial ground (polygons) and brownfield sites (points) are shown.
Geochemical carbon sequestration in different types of made ground

\[
\text{CaO} + \text{CO}_2 \rightarrow \text{CaCO}_3
\]

Ouseburn (3ha) is a former chemical works, and landfill, **brownfield site** underlain by artificial ground. Sites like these can potentially store more than a million tonnes of \( \text{CO}_2 \) per hectare.

Consett (290ha) former steelworks **brownfield site** is landscaped and underlain by iron and steel slag. This has the potential to capture hundreds of millions of tonnes of \( \text{CO}_2 \).

The Science Central (10ha) site is overlain by approximately 1 Mt of **demolition rubble** with the capacity to store tens of millions of tonnes of \( \text{CO}_2 \).
The UK household CO$_2$ footprint (tonnes per year)

The UK is committed to reducing direct CO$_2$ emissions by 67% of 2010 values by 2050.

The impact of UK households through direct and indirect generation of greenhouse gasses (Office of National Statistics 2004).
• Over 90% of the fruit we consume in the UK is imported even when it can be grown here: e.g. 70% apples imported (Food 2030)

• 30% of UK goods vehicle miles are used to transport agrifood products (Pretty et al. 2005)

• In the UK 18-20 M tonnes of food are wasted each year, 8.3 M tonnes thrown away in domestic waste of which 65% is avoidable. Halving household food waste would be equivalent to taking 1 in 8 cars off the road in terms of reduced greenhouse gas emissions (Defra 2010)

• To support our current lifestyles we need 5-10 ha per person (Rees 2003) but there are only 0.3 ha of productive land per person in the UK. This will shrink by 22% as UK population rises from 61.8 to 80 million by 2050.
What crop yields per unit area are usually achievable by typical gardeners for the main fruit and vegetable crops grown in the UK?
MYHarvest – initial data

Annual crops

RHS yield 3.1 kg m\(^{-2}\)

Perennial crops

4-5 kg m\(^{-2}\) maximum
Abundance Sheffield
An average allotment plot can produce enough fruit and vegetables to feed the equivalent of 3 people, but not with all the different fruits and vegetables eaten (no bananas, oranges, etc).
Own-growing and contaminated land: Walker Road allotments - Byker

Research found that soils were contaminated with heavy metals

BUT there was very little transfer of pollutants into vegetables – no significant risk of harm from consumption of crops

The land was contaminated from previous industrial use and waste disposal

The council decided to remediate the site and reinstate the allotment plots but appear not to have done so - but the site could grow biofuel!

Source: Pless-Mulloli et al. (2004)
Potential under-use of urban ecosystem services

1. Plant more trees to sequester CO$_2$- including fruit trees
2. Plant short-rotation coppice for biomass fuel or biochar or both
3. Increase land for own-grown and community-grown fruit and vegetables
4. Increase the area of gardens used to grow trees or food or both
5. Replace non-recreational mown grassland with trees and own-growing
6. Engineer made ground / brownfields, to capture inorganic carbon in soil
WP3 Buildings and Energy

Prof. Kevin J Lomas and Dr Simon Taylor

Building Energy Research Group,
Dept of Civil and Building Engineering, Loughborough University
DOMESTIC BUILDINGS, 2010

TOTAL HEAT DEMAND (kWh/m²/year)

Space heating + water heating

1km x 1km grid squares

n=239,851

Legend
Heat demand per unit land area kWh/m²/year

Below 0.01 (n = 35,795)
0.01 - 0.03 (n = 27,571)
0.03 - 0.1 (n = 53,081)
0.1 - 0.3 (n = 65,726)
0.3 - 1 (n = 27,231)
1 - 3 (n = 11,694)
3 - 10 (n = 10,346)
10 - 30 (n = 8,015)
Above 30 (n = 393)

Of interest:
• Biomass spatial planning
• Alternative (non-gas) heat supply options
• Matching supply and demand at the local scale, district heating

10% of UK land area accounts for approx. 90% of the heat demand from homes
Where are the best opportunities for reducing demand and CO$_2$ emissions?
Every house is different:
Efficiency measures and costs

Different options to reduce heat loss and increase fuel use efficiency have different costs and pay-back periods from savings on energy use.

Cheap interventions that quickly save energy are often easy to implement- the problem lies in implementation of some of the more expensive retrofit options required to reduce energy demand (and associated emissions by 40% - which are currently estimated to cost £15,000-20,000) per household on average- who can or will pay for this?
PV Import / export

Household electricity consumption and PV generation for a single day

CVP304: Renewable Energy and Low Carbon Technologies,
MSc Low Carbon Buildings Design and Modelling,
Department of Civil and Building Engineering
WP3 Energy and Wastes

Professor David W Graham and Dr Patrizia Franco

School of Civil Engineering and Geosciences University of Newcastle
Wastes

- Transport of waste 6% of HGV movements in UK (Curry, 2006)
- 23 million tonnes of household waste per year in England
- 40% of which sent for recycling, composting or reuse
- Municipal waste used to travel <20 miles (STRAW, 2006) minimising road transport. Recycling is increasing this.

• Today’s VISION (Waste Strategy 2007):
  ❖ Reduce amount of waste sent to landfill
  ❖ Consider waste as a resource (Directive 99/31/EC)
Key Inefficiencies in Energy and Resources from Solid Waste

Recyclables include a very wide range of materials in different physical forms, and the down-stream processing of many recycled materials takes place very far away from the cities where the waste is produced—e.g., paper and glass recycling increasingly involves long distance transport.

- Solid waste stream is complex and includes non-digestible materials
- Biogas from solid wastes is only efficient AFTER separation (e.g., food)
- Inefficiencies: Quality of separation is not good enough

No efficient N and P recovery technologies
The water industry uses a substantial amount of energy in pumping water- and in treating of wastewater in oxidizing systems that require oxygenation and release CO$_2$ from the organic matter, as well as the CO$_2$ associated with power use.

The main emissions of CO$_2$ are associated with wastewater treatment.

Anaerobic digestion and collection and use of biogas is much more energy and CO$_2$ efficient.
WP4: Stakeholder Engagement
SElf Conserving URban Environments

The route to delivering sustainability

WP5 Integration across the scales

Professor Margaret Bell CBE
University of Newcastle
Integrated Modelling Platform
Conclusion

• No previous studies on how to combine different spatial model results from different disciplines
• Land use trade offs- new build zero carbon housing versus transport infrastructure versus greenspace
• SECURE integration for greater conservation and more efficient resource utilisation across scales to meet future urban demands -model across themes
• Optimise delivery of ecosystem service benefits, transport network functionality, domestic energy demand, management and recovery of value from wastes
Conclusion

• Specification across scales implies concrete actions developing base model with series of predictions.

• Methodology
  – collates data in its finest detail
  – classifies the data based on population density at the household level
  – Enables output at different scales (1km$^2$ grids, political boundaries, scientifically optimal boundaries, etc.)

• Leads to outputs that feeds into policymaking, urban planning and environmental management.
Any questions?