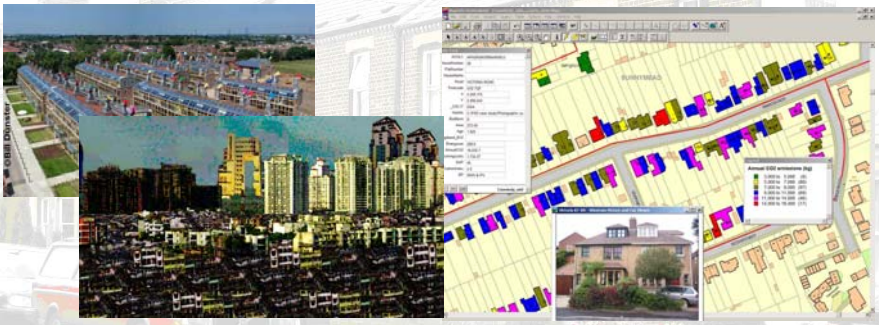
Carbon emission reduction model: a new GIS-based approach

Tempe Sustainability Committee, City of Tempe, 17 April 2009



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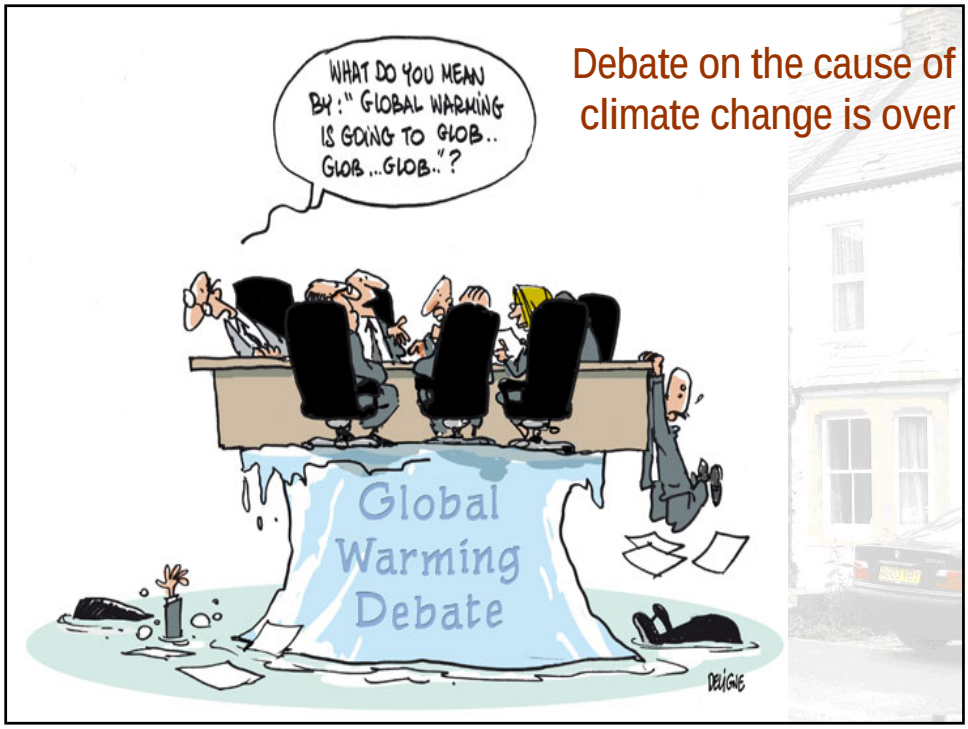
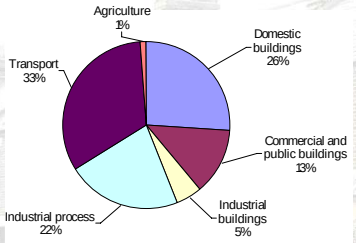
Background to the study


WHAT DO YOU MEAN BY:" GLOBAL WARMING IS GOING TO GLOB.. GLOB...GLOB.."?
Global Warming Debate
DELIGNE
Debate on the cause of climate change is over

CO_2 emissions by sector in UK, USA and India

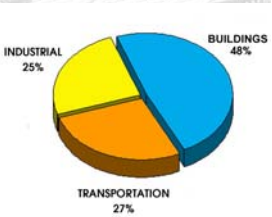
UK



45%

UK CO_2 emissions by sector, 2002

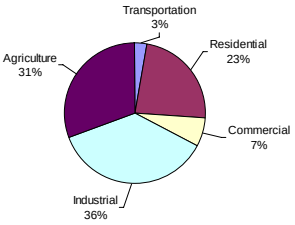
USA



48%

USA CO_2 emissions by sector, 2005

India



30%

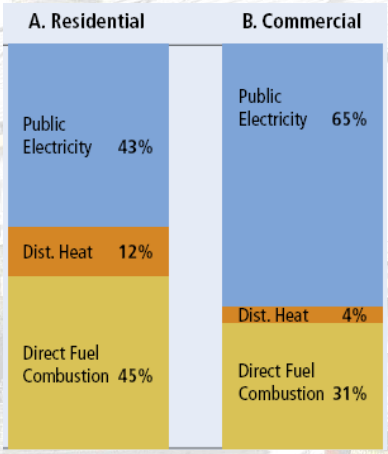
Electricity use by sector, 2005

CO_2 emissions from building energy use

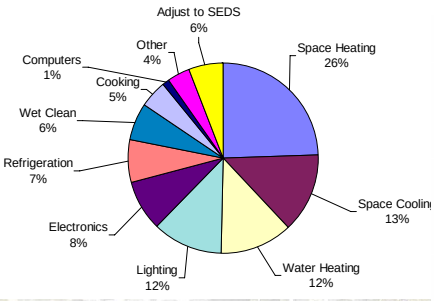
Direct (on-site): Emissions from fuels combustion (space heating)

Off-site: Emissions from public electricity use and district heat consumption.

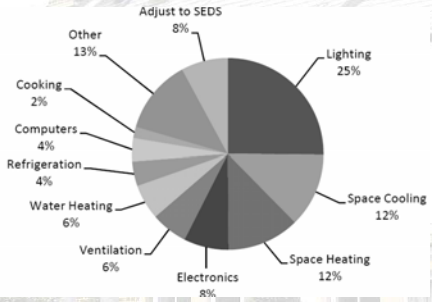
Globally, the building sector is responsible for 42% of electricity consumption more than any other sector.



Carbon footprint: Domestic and Non-domestic buildings



US residential CO2 emissions



US commercial CO2 emissions

Residential sector consumed 37% of all electricity produced in US

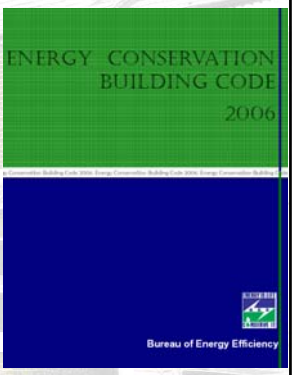
About 80% of all CO2 attributed to the commercial sector comes from electricity consumption.

Most of the focus has been on new-build...

UK

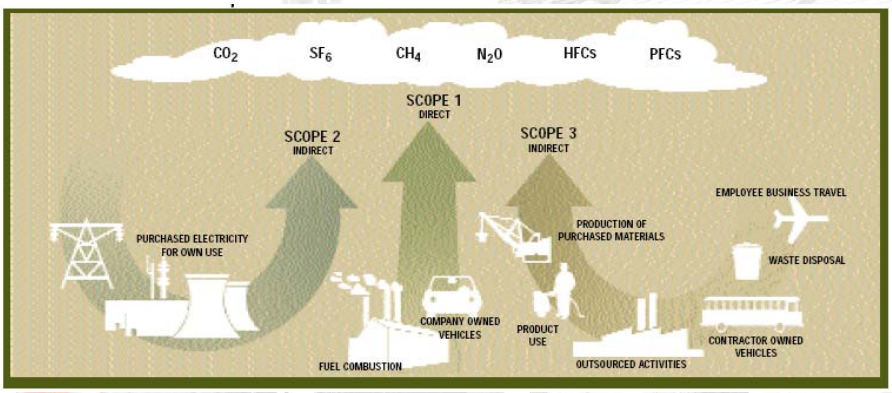
USA

India

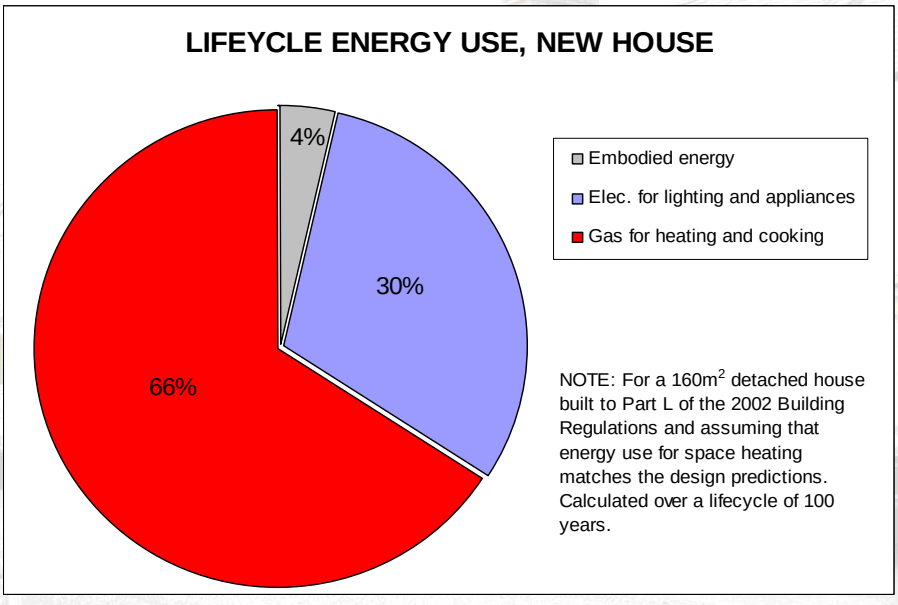


3. New Buildings - 50%
2010 – 60%
2015 – 70%
2020 – 80%
2025 – 90%
2030 - Carbon Neutral
(no fossil fuel energy to operate)

How do you set boundaries for carbon counting?



Life cycle energy use in a typical new house



Key principles: energy efficiency and carbon intensity

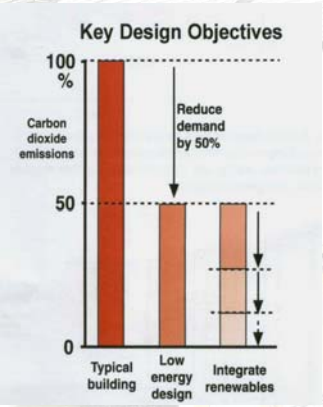
Reduce the demand for energy (heating, cooling, lighting or ventilation).

Provide the reduced demand through low carbon and zero carbon technologies

Decarbonising the electricity supply.

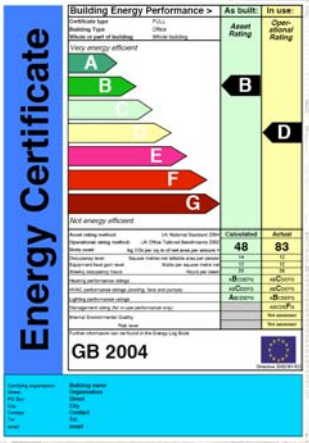
Feedback on actual energy used in buildings through smart metering.

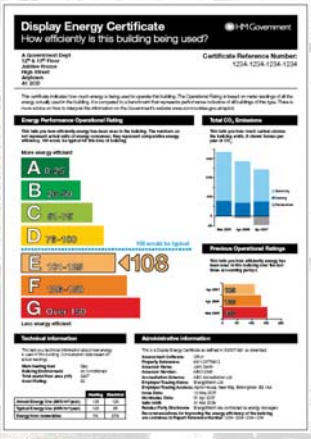
Regular post-occupancy evaluation studies of refurbished projects to provide evidence-based lessons for the building community and users.



EU Directive of Building Energy Performance (EPBD)

- Introducing energy performance certificates (EPCs) when buildings are let, sold, built or refubished.
- Requiring public buildings to display energy certificates (DECs); and
- Requiring inspections for air conditioning systems.

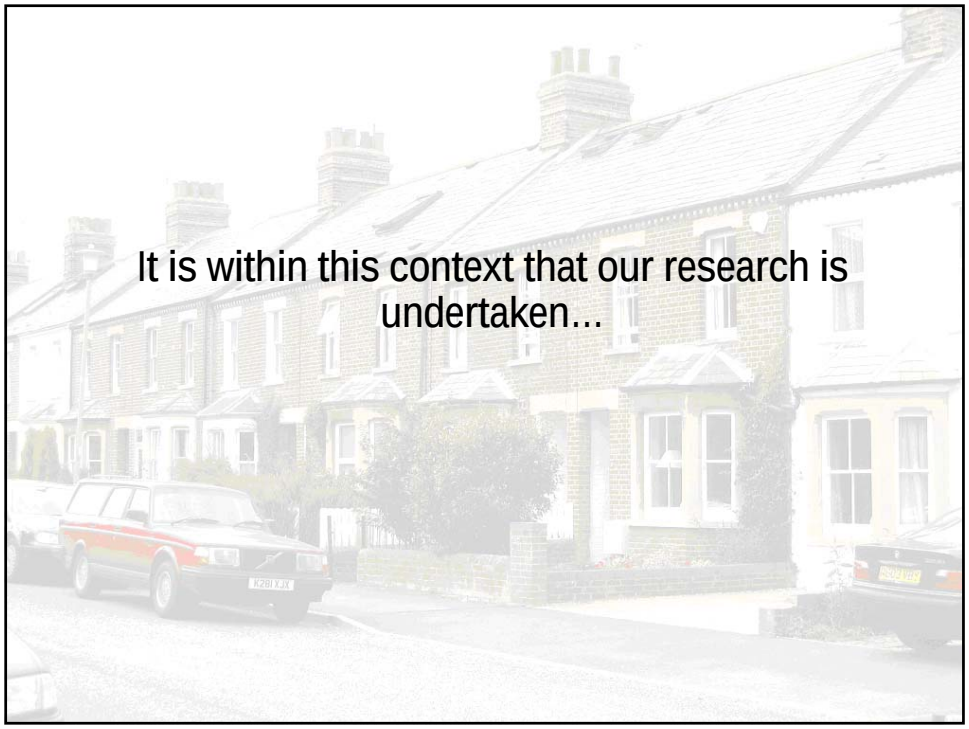




Environmental Sustainability: National Indicators

Following consultation in 2007, the Government has issued a national indicator set (198) against which local councils will begin to report their performance from April 2008.

NI 185	Percentage CO_2 reduction from LA operations
NI 186	Per capita CO_2 emissions in the LA area
NI 187	Tackling fuel poverty - % of people receiving income based benefits living in homes with a low energy efficiency rating
NI 188	Planning to Adapt to Climate Change



Carbon emission reduction planning approach for cities

5-step approach:

- Assessing baseline (existing) CO_2 emissions from all energy-related sectors in cities.
- Establishing ambitious (and realistic) citywide CO_2 emission reduction targets.
- Identifying robust actions to achieve those targets.
- Developing incentives and programmes for implementing the actions.
- Monitoring and verifying the reductions achieved as a result: sharing experiences.

DECoRuM: a *next generation* domestic energy model

Capability to estimate baseline CO_2 emissions from individual dwellings using a locally-relevant approach, and well-established methodologies to ensure credibility.

Aggregates these to an urban scale – street, district or city level.

This enables it to evaluate the potential for domestic CO_2 emission reductions from a whole range of measures on both the demand and supply sides of energy.

An additional and unique feature of assessing the cost-benefits of individual CO_2 reduction measures and putting a financial cost to CO_2 emission reduction.

A mapping tool for representing domestic CO_2 emissions and reductions.

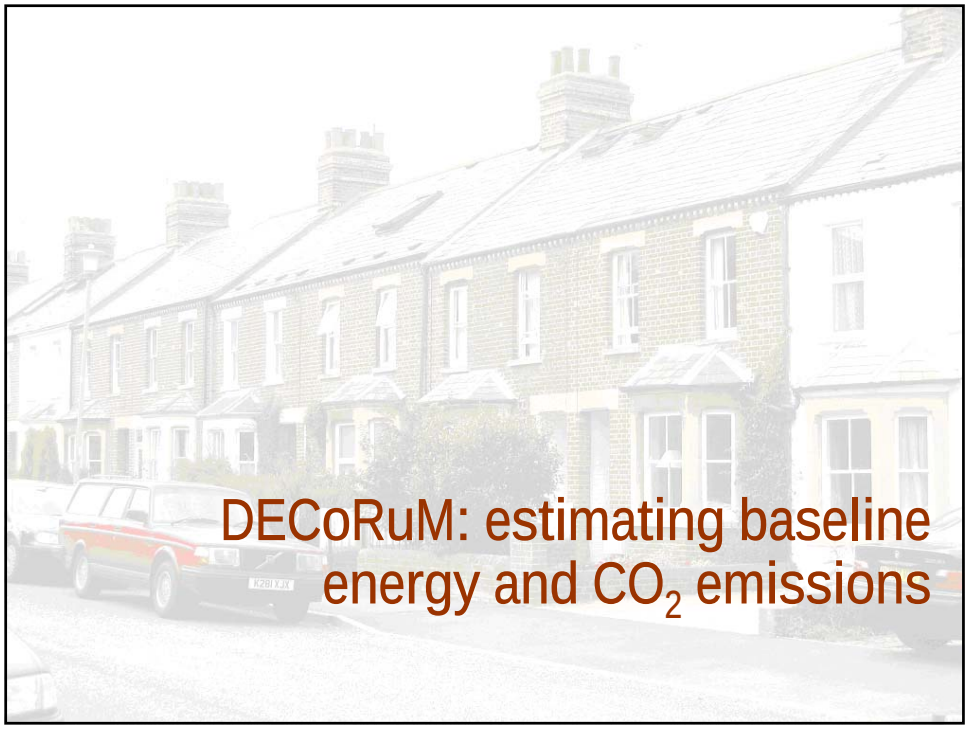
DECoRuM provides local authorities and energy advisers with a tool to address the barrier of counting and reducing emissions locally.

Core methodologies used in DECoRuM

Methodology used	Details of methodology	Outputs	
Building Research Establishment Domestic Energy Model (BREDEM) –12	Industry standard to calculate energy use for different dwelling types in UK. Estimates annual energy requirement for space heating, water heating, lights & appliances and cooking Requires 95 input parameters	Annual energy use (GJ/year) Annual CO_2 emissions (kg/year) Running costs (£s/year)	Underlying physically-based energy models: BREDEM – 12 linked to SAP 2005.
Standard Assessment Procedure (SAP) 2005	Government's recommended system for home energy rating based on energy costs for space and water heating.	SAP rating (scale of 1-100)	
Net annual cost method	Used by BRE to asses cost-effectiveness of energy efficiency measures.	Net annual cost/tonne of CO_2 saved	Cost-benefit analysis approach

Outputs from DECoRuM

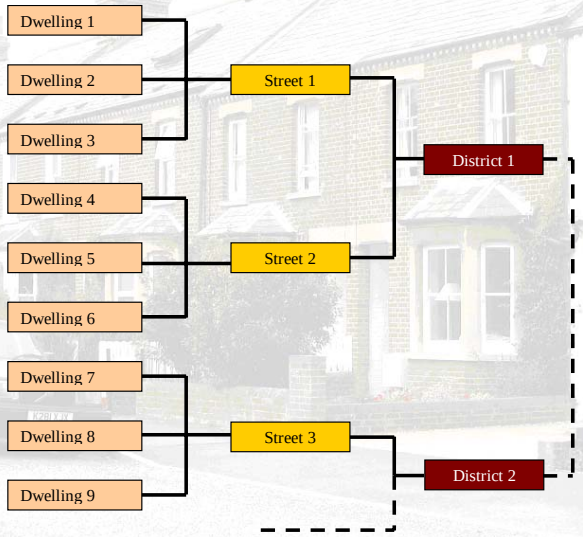
	Outputs	Expressed as
Energy use	Total annual energy use	kWh/year kWh/m^2/year
	Annual energy use by end use	kWh/year
CO_2 emissions	Total annual CO_2 emissions	kgCO_2/year kgCO_2/m^2/year
	Annual CO_2 emissions by end use	kgCO_2/year
Fuel costs	Total annual running (fuel) costs	£/year
	Annual running (fuel) costs by end use	£/year
Energy rating	SAP rating	Scale of 1 to 100



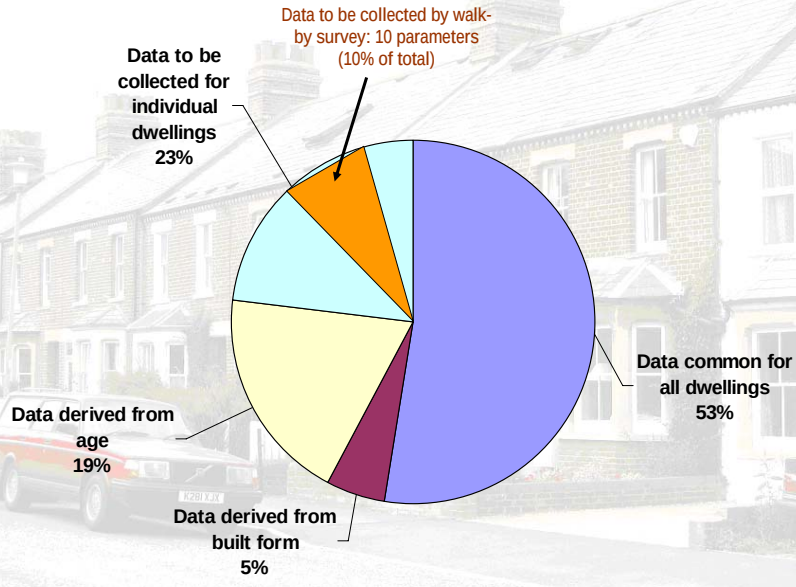
DECoRuM: estimating baseline energy and CO_2 emissions

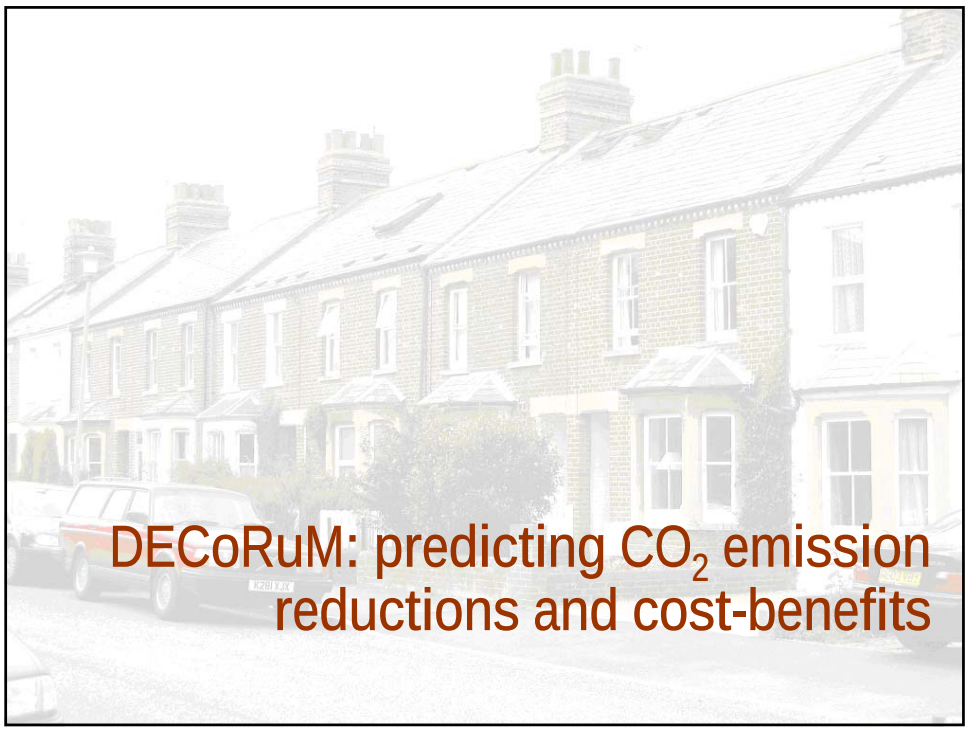
Framework for baseline predictions

DECoRuM baseline energy model estimates energy consumption and CO_2 emissions of individual dwellings as the basic component for calculation, and then aggregates these to an urban scale.



Data Reduction in DECoRuM

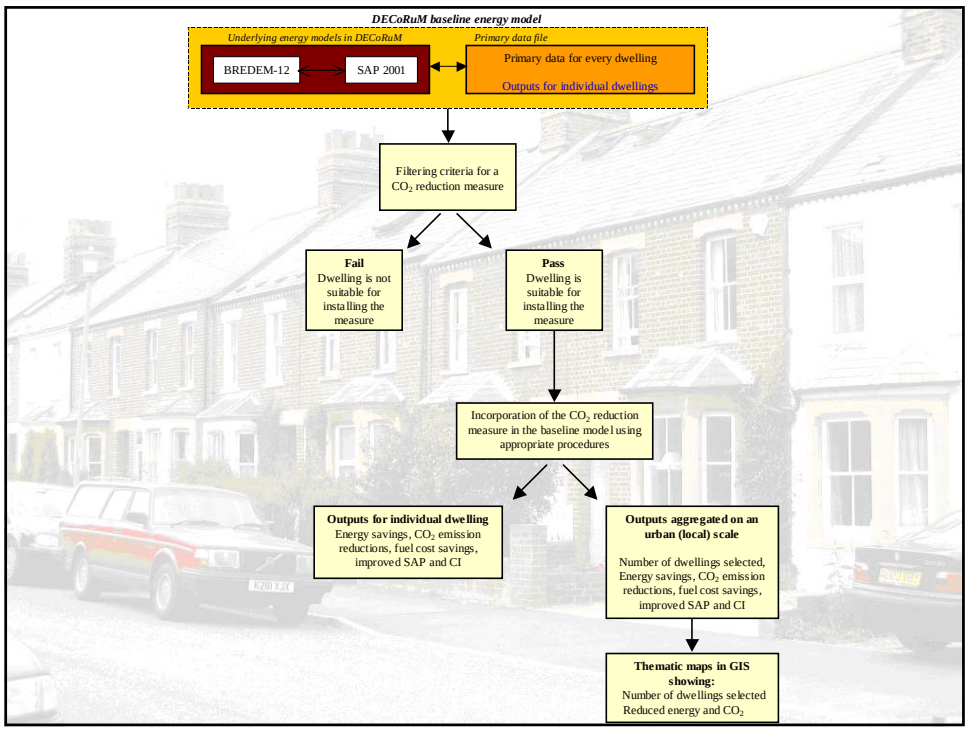




DECoRuM: predicting CO_2 emission reductions and cost-benefits

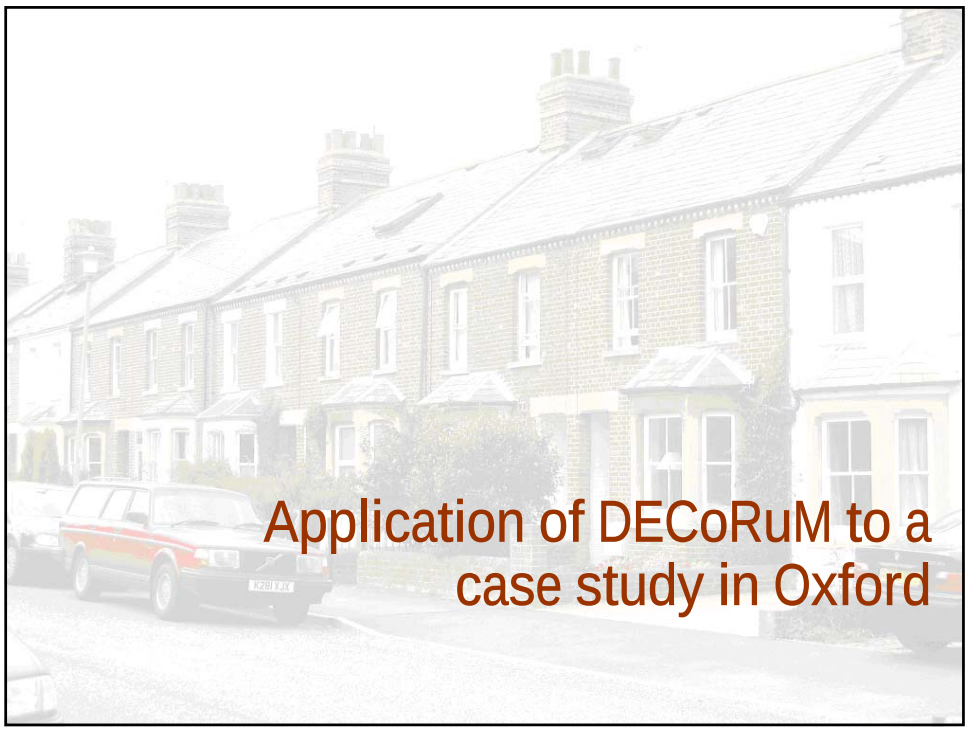
DECoRuM: 30 CO_2 reduction strategies

Strategies for CO_2 reduction		END-USES OF ENERGY IN A TYPICAL UK DWELLING			
		Space heating	**Water heating**	**Lighting**	**Appliances**
	Energy use in 2000[1]	**60 %**	**23 %**	**12 %**	
	CO_2 emissions 2000[23]	**54 %**	**21 %**	**20 %**	
	Fuel used	**Mostly gas**	**Mostly gas**	**Electricity**	
DEMAND SIDE OF ENERGY	**Energy efficient measures**	***Insulation***		***Low energy lighting***	***Energy efficient appliances***
		Roof insulation	Hot water tank insulation	CFLs	*Wet appliances*
		Cavity wall insulation	Primary hot water pipe insulation	Energy efficient fittings	Washing machines
		Solid wall insulation: internal			Tumble dryers
		Solid wall insulation: external			Dishwashers
		Floor insulation			*White appliances*
		Low-e double glazing			Refrigerators
		Draught stripping			Fridge-freezers
		Draught lobby			Freezers
		Heating system			*Brown appliances*
					Video recorders
		Installation of a condensing boiler			Televisions
		Improved heating controls			Electric ovens
					Electric hobs
SUPPLY SIDE OF ENERGY	**Low carbon technologies**	Micro- CHP			
		Ground source domestic heat pumps			
	Solar energy systems	***Passive solar***	***Active solar***		
		Conservatory	Solar hot water system	Solar PV	
	Fuel switching			Green-tariff electricity	

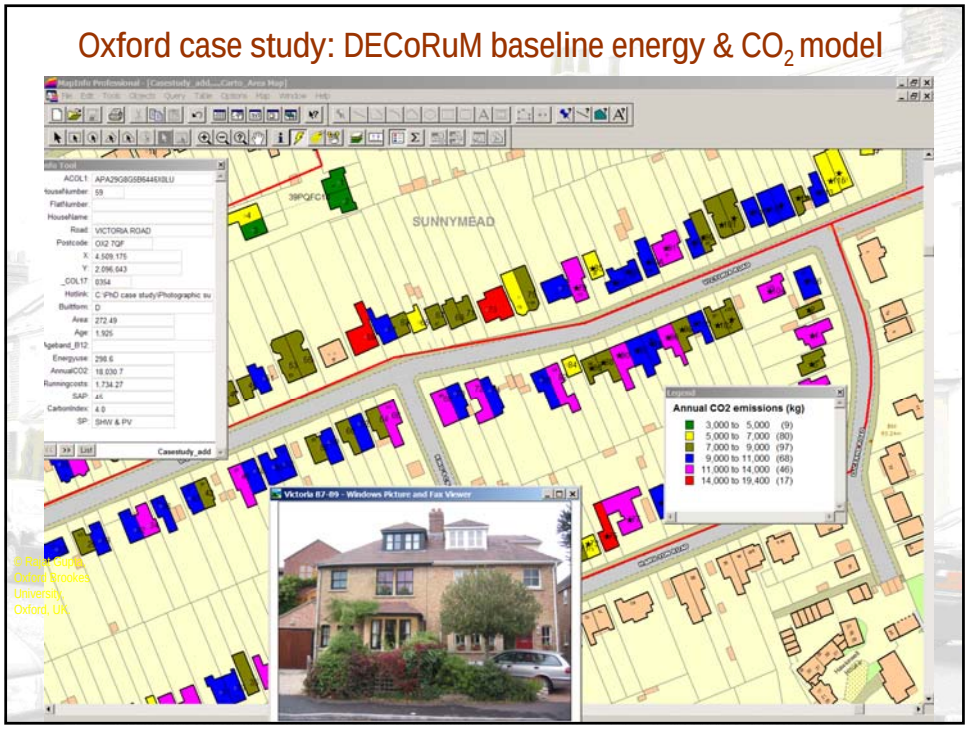


DECoRuM: cost-benefit methodology

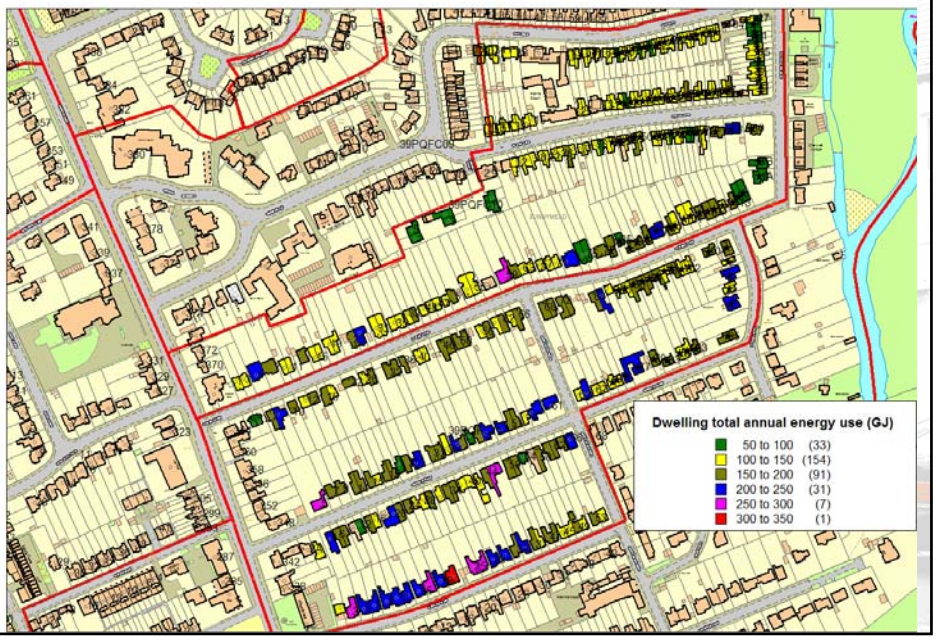
Use	Outputs (Low capital cost high capital cost scenarios)
To assess the cost-effectiveness of deploying various CO_2 reduction measures.	*Net annual cost* is divided by the annual CO_2 saving to give the *net annual cost per tonne of CO_2 saved*
To determine the capital cost of reducing a tonne of CO_2, using a single or a combination of measures on an urban scale.	*Cost for reducing a tonne of lifetime CO_2 emissions*
To be widely used and understood.	Simple payback period



Oxford case study: DECoRuM baseline energy & CO_2 model

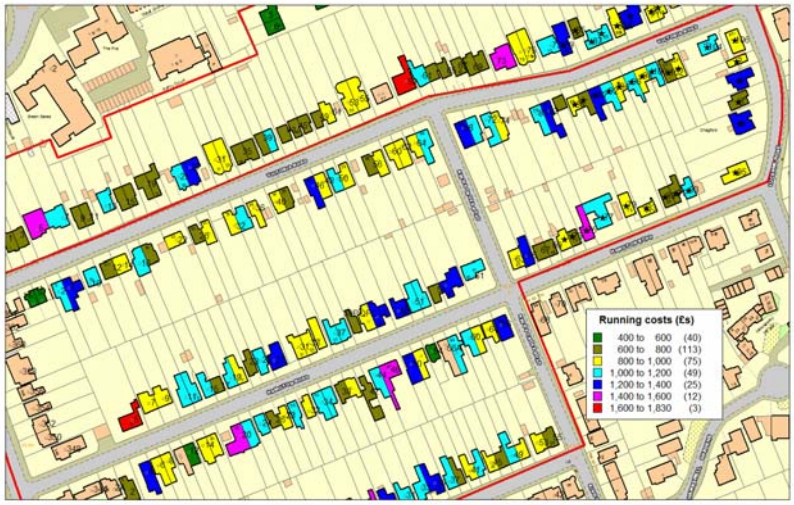


Thematic map showing estimate of total annual energy consumption in the case study dwellings



Thematic map showing SAP ratings for dwellings in the case study

Thematic map of dwellings in the case study showing annual fuel costs

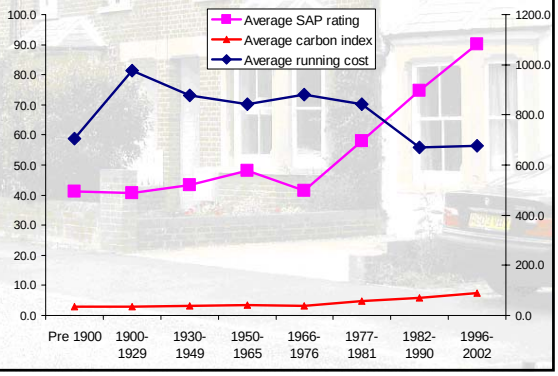


Results from DECoRuM baseline model: by built form and age groups

Built form	Number of dwellings	Annual energy use (GJ)	Annual CO2 (tonnes CO2/year)	Running costs (£s/year)	SAP	Carbon Index
		Total	Total	Average	Average	Average
Detached	58	10985.2	669.1	1074.2	**43.2**	3.2
Semidetached	175	27774.5	1698.5	916.2	**46.4**	3.5
End-terrace	21	2902.8	173.0	747.6	**39.5**	2.8
Mid-terrace	51	5958.8	359.2	656.9	**47.9**	3.6
MT-UP	10	1563.6	95.3	897.2	**41.2**	3.0
Bungalow	3	514.2	31.2	961.7	**36.3**	2.7
TOTAL	**318**	**49,699.1 GJ**	**3,026.2 t**	**£892.1**	**45.4**	**3.4**

Breakdown of energy use, CO_2 emissions, running costs, SAP rating and carbon index as per built forms of dwellings in the case study

Distribution of SAP rating, carbon index and running cost by age-band in case study area

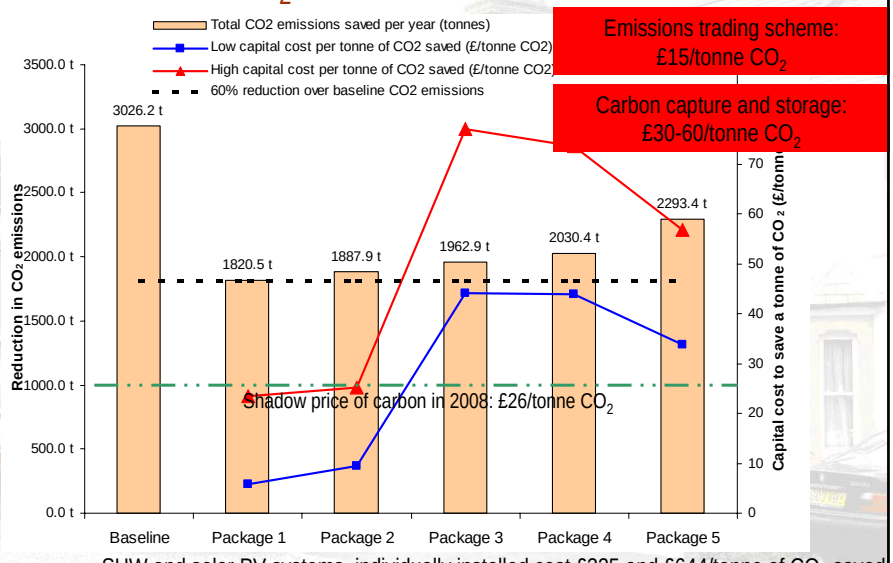


DECoRuM CO_2 reduction model: estimating solar potential

87% of the dwellings in the case study were suitable for installing either a SHW or a PV system or both.

Dwellings with potential for	Number of dwellings	Percentage
4 m^2 flat plate SHW (available roof area: 4.0 m^2- 9.9 m^2)	38	11.9%
PV (available roof area: 10.0 m^2-13.9 m^2)	46	14.5%
SHW & PV (available roof area: >13.9 m^2)	192	60.4%
None	42	13.2%
TOTAL	**318**	**100.0%**

Potential for CO_2 emission reductions above 60%



SHW and solar PV systems, individually installed cost £335 and £644/tonne of CO_2 saved in a low capital cost scenario. When applied in combination in package 3, the cost drops to £44 /tonne CO_2 saved.

Potential for CO_2 emission reductions from UK housing stock

S.No. of measure	Strategy/Measure	UK LEVEL (24.27 MILLION DWELLINGS)							
		Average CO_2 emission saved per year per dwelling	Number of dwellings selected in UK	CO_2 Emissions saved/year	Lifetime CO_2 Emissions saved	Total cost for selected dwellings		Pounds spent to save a tonne of CO_2	
						Low cost	High cost	Low cost	High cost
		(tonnes CO_2)		(Mtonnes CO_2/year)	(Mtonnes CO_2)	(£s in Million)	(£s in Million)	(£/tonne CO_2)	(£/tonne CO_2)
ENERGY EFFICIENCY MEASURES									
M 1	Roof insulation: top-up from 50/75mm to 250 mm	0.24	4,911,000	1.2	35.9	466.5	726.8	13.0	20.3
M 2	Roof insulation: top-up from 150 mm to 250 mm	0.06	6,187,000	0.3	10.4	216.5	544.5	20.9	52.6
M 3	Cavity wall insulation	1.44	8,696,000	12.6	502.3	2504.4	3330.6	5.0	6.6
M 5	Solid wall insulation: external	2.16	10,615,000	22.9	687.0	0.0	15922.5	0.0	23.2
M 8	Low-e double glazing (in comparison with double glazing)	0.15	11,190,000	1.6	32.6	559.5	1678.5	17.2	51.5
M 9	Full draught proofing (currently with none or some)	0.11	24,193,000	2.7	27.0	532.2	1983.8	19.7	73.5
M 10	Hot water cylinder insulation (currently with none or some)	0.47	5,017,000	2.3	23.4	50.2	175.6	2.1	7.5
M 13	Replacement condensing boilers	1.41	5,720,893	8.1	96.9	1144.2	2860.4	11.8	29.5
M 14	Improved heating controls: room thermostat & cylinder thermostat	0.21	2,510,000	0.5	6.3	150.6	338.9	23.9	53.8
M 15	Energy-efficient lighting (new CFLs and new fittings)	0.14	24,195,000	3.3	39.4	967.8	2225.9	24.6	56.5
M 16	Energy-efficient refrigerators	0.04	10,404,000	0.4	5.8	280.9	364.1	48.3	62.6
M 17	Energy-efficient fridge/freezers	0.10	15,348,000	1.5	26.6	414.4	1028.3	15.6	38.6
M 18	Energy-efficient freezers	0.06	10,544,000	0.6	9.2	284.7	727.5	30.9	78.9
M 19	Energy-efficient washing machines	0.04	22,317,000	0.8	10.1	0.0	2544.1	0.0	252.3
M 20	Energy-efficient tumble dryers	0.04	12,390,000	0.4	6.4	0.0	371.7	0.0	58.0
M 21	Energy-efficient dishwashers	0.02	5,814,000	0.1	2.4	0.0	180.2	0.0	75.9
M 22	Energy-efficient televisions	0.02	42,769,000	0.9	7.3	427.7	427.7	58.5	58.5
M 23	Energy-efficient videos	0.01	23,855,000	0.2	1.7	238.6	238.6	143.0	143.0
LOW CARBON TECHNOLOGIES									
M 24	Ground-source heat pump systems	0.89	1,908,097	1.7	42.5	2919.4	3434.6	68.7	80.8
M 25	Domestic micro-CHP units (small unit: 1 kWe / 6 kWt)	0.69	1,221,182	0.8	12.6	519.0	610.6	41.3	48.5
M 26	Domestic micro-CHP units (large unit: 3 kWe / 9 kWt)	1.85	9,922,107	18.3	275.0	12650.7	14883.2	46.0	54.1
SOLAR ENERGY SYSTEMS									
M 29	Solar hot water (4m2 flat plate system)	0.30	17,554,497	5.2	104.7	35109.0	49152.6	335.4	469.5
M 30	Solar PV (1 kWp system)	0.31	18,165,088	5.6	141.0	90825.4	130788.6	644.1	927.5
			TOTAL	92.3	2,106	150,262	234,539	71.3	111.3
			Equal to	25.2	MtC				
	Potential for each measure at UK level extracted from BRE report								
		UK domestic CO_2 emissions in 2000 (Domestic energy fact file		38.2	MtC				
	Potential for each measure at UK level extrapolated from the application of DECoRuM to the case study in Oxford								
		CO_2 reduction achieved		66%					

DECoRuM: Benefits

- Individual dwelling is represented as the base level of resolution but results can be displayed up to a street, district and city level.
- Pollution hotspots can be spatially located and targeted for improvement.
- Assessment requires no access to the property.
- A robust data filtering process provides accurate and reliable results.
- Cost-benefits analysis enables cost comparison of different measures.
- Helps to estimate the potential for citywide application of solar energy systems.
- A useful visual aid when encouraging householders to install energy efficiency measures

Applications: Local Authorities and DECoRuM

Provides a GIS-based toolkit to enable LAs to develop a carbon foot-printing capability to :

- Assess and map the current carbon emissions of their housing stock.
- Benchmark baseline emissions against typical and good-practice standards.
- Identify 'hotpots' of pollution.
- Establish carbon emission reduction targets.
- Evaluate strategies and technologies to achieve those targets in terms of carbon reduction and cost-benefits.
- Verify and monitor the reductions achieved.
- Help to develop guidelines (solar legislation, solar rights, and building energy standards) to restrict the housing stock's carbon emissions to good practice benchmarks.

RIBA President's medal for outstanding research 2006