

BedZED: Toolkit Part II

A practical guide to producing affordable
carbon neutral developments





BedZED village square

Written by Nicole Lazarus

BioRegional

BioRegional Development Group

BioRegional Development Group is an independent environmental organisation working with industry, retail and public sectors to bring sustainable practice into the mainstream. Established in 1994, BioRegional work in housing, construction, forestry, paper, textiles, energy and food industries to create sustainable living solutions that are easy, attractive and affordable. By using local resources wisely, we can increase our quality of life whilst leaving space for wildlife and wilderness.

This report is intended to be of practical use in reducing the environmental impacts of new developments. BioRegional will be glad to hear from any readers with feedback and examples of its application.

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First published October 2003. Reprinted May 2009.

Acknowledgements

This report has been written with the essential input of the BedZED Project Team:



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Zedfactory

Zedfactory is an initiative by Bill Dunster Architects to produce carbon neutral buildings as a standardised product. ZED homes, workspaces or public buildings can be ordered "off the shelf" with standard designs and a guaranteed maximum price, just like buying a car. The **ZED in a Box** standard products are the new generation designs, based on BedZED but improved to take advantage of lessons learnt in buildability, value engineering and customer satisfaction. The **ZEDteam** are working with suppliers and contractors to produce a range of **ZEDproducts**, specialised components and trade packages that maximise environmental performance but achieve assured quality and volume discounts through standardisation and repetition.

The **ZED on a Sheet** spreadsheet package makes quantified environmental benefits, build densities and build costs instantly transparent and can be used as an open book planning tool by local authorities or developers to trade environmental savings for planning gain.

1

Introduction

This is a practical guide to producing carbon neutral developments and how to afford them. It is based on the achievements at the Beddington Zero (Fossil) Energy Development (BedZED), describing measures taken on that scheme to reduce environmental impact. It includes technical descriptions, monitoring results and financial mechanisms that have allowed the innovations at BedZED to become a reality.

This Toolkit is produced in conjunction with a ZEDfactory publication, "From A to ZED", which introduces the new "ZED in a box" design and the new range of ZEDproducts and ZEDtools.

The development of BedZED and "ZED in a Box", has given the ZEDteam a vast bank of knowledge and practical experience in producing carbon neutral developments. These reports are designed to encapsulate that knowledge and to save others time.

BedZED

BedZED is a mixed-use scheme in South London initiated by BioRegional Development Group and Bill Dunster Architects. BedZED has been developed by London's largest housing association, the Peabody Trust. The scheme comprises 82 homes and 2,500m² of commercial or live/work space. The scheme was completed and occupied in 2002.

The scheme helps people to live more sustainably, perhaps even within their share of the earth's renewable resources, without sacrificing a modern, urban and mobile lifestyle. It challenges conventional approaches to housing by tackling sustainability in every area from the outset.

Heat, electricity and water demands are greatly reduced. Facilities and services are designed to make it easy to reduce waste to landfill, to recycle waste and to reduce car use. BedZED achieves the high densities recommended in the Urban Task

Contents

1	Introduction	1
2	Summary	3
3	Need for carbon-neutral developments	4
4	Planning gain	7
5	Thermal	10
6	Electrical	18
7	Water	22
8	Transport	31
9	Renewable Energy	37
10	Quality of Life	42
11	Project Balance Sheet	44
12	Conclusion	45
	Appendix	47

Force report whilst still providing a healthy internal environment with generous access to green space and sunlight.

In addition to the sustainability of the finished BedZED product, every aspect of construction was considered in terms of its environmental impact. Materials used in construction were carefully selected for low environmental impact, sourcing locally where possible and sourcing reclaimed and recycled materials where possible.

This approach at construction stage succeeded in reducing the embodied environmental impact of BedZED by some 20-30%. It is documented in The Construction Materials Report available from BioRegional.

Structure of this report

Following the Introduction and Summary, chapter 3 looks at the need for Carbon Neutral Developments. Then the report looks at the following “areas of innovation” with a chapter on each:

- 4 Planning gain
- 5 Thermal demand
- 6 Electrical demand
- 7 Water demand
- 8 Transport
- 9 Renewable energy supply

Each chapter describes the measures taken to improve environmental performance in that area. Monitoring results from the first year of operation at BedZED are reported. The costs, savings and benefits associated with each measure are quantified.

There is an additional chapter 10 discussing all the factors that affect the Quality of Life of ZED occupants. Based on interviews and monitored lifestyle habits at BedZED, this identifies all the benefits of living there, attempting to place a value on these benefits and assessing how much of that value can actually be returned to the developer in the form of increased property value.

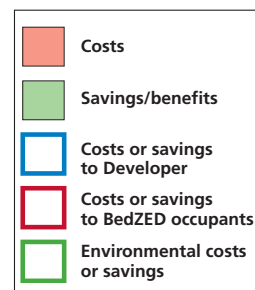
The total costs, savings and benefits from each area are brought together in the Project Balance Sheet and Conclusion.

This report is funded by the DTI's Partners in Innovation programme. Data from this report has also informed an eco-footprinting analysis, funded by WWF-International.

Methodology

The study that has led to this Toolkit set out to analyse the relative costs and benefits of the various measures taken at BedZED to improve sustainability. From the developer's point of view, the study has looked at the additional build costs as compared with the added revenue achievable through planning gain and property prices. From the occupier's point of view, it looks at financial savings in the form of lower bills and also looks at whether occupants value the features as enhancing their quality of life. From the environmental point of view, the study also reports savings that benefit the wider community such as reduced CO₂ emissions and water savings.

All of these costs and savings to different parties are summarised in colour coded diagrams. Red and green boxes show costs and savings respectively. Blue, red and green borders to the boxes show which party experiences the cost or the saving, the developer, the occupant or the “Environment” respectively.



All figures are based on experience at BedZED. Build costs are supplied by Gardiner & Theobald quantity surveyors, the cost consultants for BedZED. Rates are taken directly from BedZED construction costs but do not include additional expenses that were part of BedZED's research and development.

The information is intended to be applicable to future developments of any size. To make the information transferable, all figures are converted into apportioned costs and savings for a terrace of six plots containing 18 units of 1,2 and 3-bedrooms. The reader must use his or her discretion in applying these figures to different sized developments. Bulk buying affects material costs significantly and for much larger developments, economies of scale will be possible for renewable energy solutions and for on site wastewater treatment. Similarly, a green lifestyles programme benefits from a larger scale development as many facilities become more viable and cheaper for residents.

All costs and savings are given relative to a “conventional” development. Costs are compared with buildings compliant with 2000 Building Regulations, supplied by Gardiner & Theobald Quantity Surveyors. All bill savings and environmental savings are compared with typical UK average except for thermal performance. New build homes are now theoretically 44% more thermally efficient than typical UK housing stock so savings are reported in comparison with both new 2000 Building Regulations and with UK average housing stock.

All environmental savings are monitored savings after 1 complete year of occupation. The only exception to this is the renewable energy section where predicted CO₂ savings are quoted.

2

Summary

Carbon neutral developments are needed both for political reasons to reduce pressure on fossil fuel reserves and because of very clear evidence about the affects of carbon emissions on climate change. To meet the Royal Commission's recommended carbon reductions will require radical measures in all areas. New built developments need to be designed holistically with mixed use functions, integrated transport solutions and on-going viable green lifestyle initiatives.

With a carbon neutral commitment from the start, a new development's carbon emissions can be reduced in all aspects of people's domestic and working lives without sacrificing convenience or mobility. In fact on the contrary, BedZED has shown how substantial environmental savings can go hand in hand with an improved quality of life.

Low fuel bills accompany the carbon savings. Reduced car dependence is not only cheaper but frees up time for other activities. The car-free streetscape at BedZED is peaceful and conducive to neighbourly chat and children playing. Through its imaginative, practical community schemes, BedZED has created real community spirit and happy living and working environments.




Monitoring results from BedZED's first year of occupation show that building performance and transport patterns have been very much as predicted. Table 2.1 shows comparisons with the national average and, for space heating and hot water, with new homes built to 2000 Building Regulations (in brackets).

	Monitored reduction	Target reduction
Space heating	88% (73%)	90%
Hot water	57% (44%)	33%
Electricity	25%	33%
Mains water	50%	33%
Fossil fuel car mileage	65%	50%

Table 2.1

Carbon neutral buildings currently cost more to build. Facilitating carbon neutral lifestyles requires investment in infrastructure and on-going initiatives. For a ZED specification 6-plot terrace, with 100% renewables, 100% waste water recycling and full Green Transport Plan, this report

has calculated costs and savings compared with new homes built to 2000 Building Regulations:

	DEVELOPER	Added build costs £685,127
		Potential added revenue £688,000
	OCCUPANTS	Reduced bills £3,847/year
		Added value qualitative
	THE PLANET	CO ₂ savings 147.1 tonnes/year
		Water savings 1,025m ³ /year

If carbon neutral developments are rolled out on a significant scale, the build costs will be greatly reduced through bulk buying of specialist components and through a build up of on-site skills. Until these economies of scale are achieved, the added costs can be recovered through planning gain and market opportunities for added value.

In housing, the market for sustainable buildings has been clearly demonstrated at BedZED. FPD Savills have showed that buyers are willing to pay up to 20% premium for innovative design and "green" features such as those at BedZED (see Table 2.2).

Unit type	Average current sales figures (Aug 2003)		% Difference
	Local market	BEDZED (estimated)	
1 bed flat	£125,000	£150,000	20.00%
2 bed flat	£175,000	£190,000	8.57%
3 bed flats/terraced houses	£225,000	£265,000	17.78%
4 bed semi	£300,000	£350,000	17.78%
Average	£206,250	£238,750	15.75%

Table 2.2

Readers of this Toolkit can cherry pick ideas and introduce "green add-ons" to their work or, even better, you can go all the way for a carbon neutral specification and reap the rewards of added value. Read this Toolkit in conjunction with ZEDfactory's "From A to ZED" publication and BioRegional's Construction Materials Report and you should have all the information and contacts you need to produce Carbon Neutral Developments.

Good luck
Nicole Lazarus

Need for carbon-neutral developments

If everyone in the world enjoyed the same level of natural resource consumption as a typical UK citizen, we would need three planets to support us¹. This is clearly unsustainable.



The UK has only fifteen years of North Sea gas left. Once this is gone we will be reliant on fuel reserves from potentially insecure sources. Political instability has led to expensive military resources being committed in the Middle East where fossil fuel supplies are most at risk. War is both an environmental disaster and a major loss of human life. Somehow an increasing human global population competing for limited resources needs to avert more violent conflict in the 21st century.

The reality of climate change and global warming will make fossil fuel use increasingly unacceptable. Renewable energy sources will be initially more expensive until they attain the economies of scale needed to achieve lower manufacturing costs.

Renewable energy sources can only provide a useful percentage of our annual energy demands if we can reduce the amount of energy we need

to run our lives. This means we can only wean ourselves off fossil fuels if we reduce demand for energy to a point where it can be met by renewable energy sources.

One fifth of the UK's CO₂ is generated by foodmiles, with the average UK meal having travelled over 2000 miles from farm to dinner plate. Making green lifestyles easy for people is as important as running homes and workplaces off renewable energy. As well as green buildings, we need local food initiatives that are good value and more convenient than the supermarket.

The environmental impacts of individual residents make up only 60% of the UK's total impact. Some 40% of the UK's carbon emissions are associated with "shared" infrastructure and services, and by-products consumed in the commercial sector. These broad "shared" headings include the emissions from all facilities except homes eg. hospitals, schools, offices, factories, government buildings and retail centres. Just like homes, all these buildings can be built to a high environmental specification and can drastically reduce their CO₂ emissions. For example, the office units at BedZED use only 60% of the energy consumption of a typical office.

UK Carbon Emissions

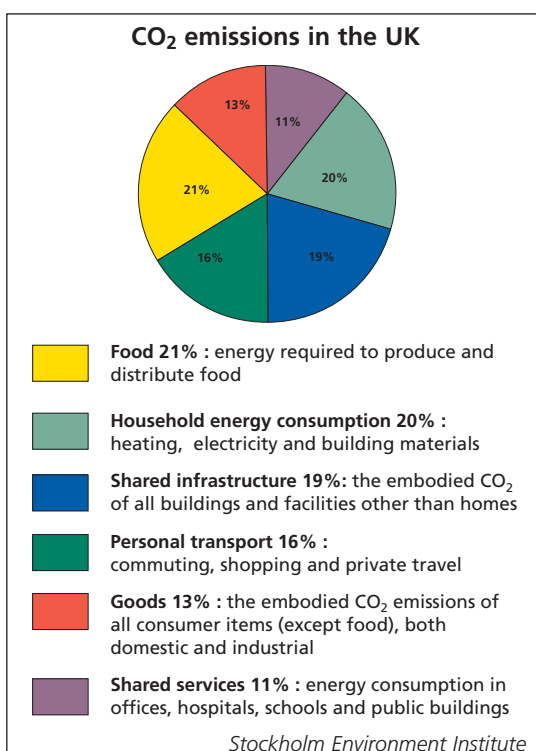
Global climate change is caused by human-induced emissions of carbon dioxide and other greenhouse gases. Global temperatures have already risen by 0.6°C and are predicted to rise between 1.4°C and 5.8°C by 2100.



The average UK citizen is currently responsible for 12.3 tonnes of CO₂ emissions per year². CO₂ emissions from fossil fuel burning make up 80% of UK greenhouse gas emissions. The next most significant contributor is methane.

The UK's Royal Commission on Environmental Pollution has recommended that we reduce our CO₂ emissions by 60% by 2050 compared with 1997 levels. This is an ambitious target and to meet it, all sectors will need to contribute to the reduction.

Under the Kyoto agreement, the UK has a greenhouse gas reduction target of 12.5% by 2010. In addition, the current UK Labour government has committed to a target of 20% CO₂ reduction from 1990 levels by 2010.

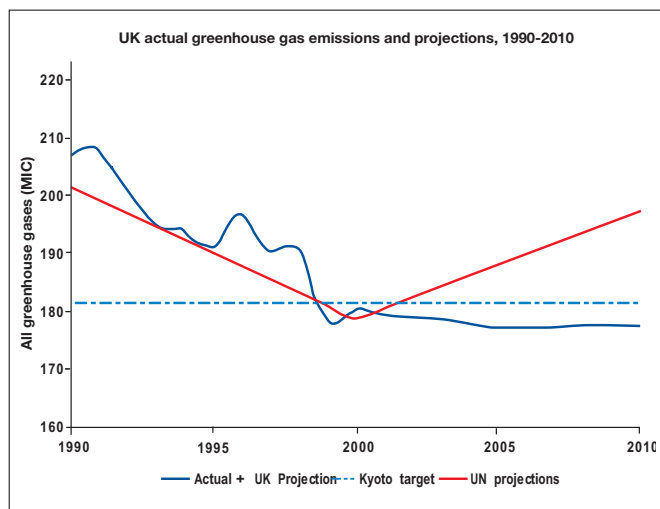


"The CO₂ produced by electricity generation in the UK has been steadily falling as we decommission inefficient old coal fired power stations, use more of the new gas fired power stations, buy more from France's nuclear generation, and get increasing efficiency from the UK's nuclear generation.

In the early and mid 1990's the government quoted figure was 0.72 kg CO₂/kWh (ECON19). In late 1998 this was lowered to 0.52 (ECON19:1998) and in 2000 it was published as 0.46 (ECON19:2000)."

Chris Twinn, Arup

These factors are almost wholly responsible for the fact that UK emissions in 1999 were 9.5% lower than in 1990³. Predictions of future UK emissions are shown below.



"Curbing the UK's dependence on fossil fuels is technically feasible, but far from easy. Reductions in energy use, large-scale development of non-carbon energy sources and fundamental changes in electricity networks will all be necessary. If the demand for energy can be reduced, that makes it easier to avoid programmes of new nuclear power stations."

Royal Commission on Environmental Pollution's Report

"Business as usual" projections from DTI predict growth in total energy consumption at 1% per year to 2010. This includes the largest growth in transport at 1.7-1.9%, with domestic energy demands growing at 1% per year. The growth in domestic demand is strongly affected by the trend for more of the UK population living in smaller households, so increasing the number of households. Table 3.1 shows how energy consumption per person increases significantly with reduced household size.

Household size	electricity consumption %	Gas consumption %
1	100	100
2	137	129
3	165	142
4	180	156
5	192	175

Table 3.1 As household size increases, the amount of energy consumed per person decreases. Source: ECI from Carbon UK 2002

The Royal Commission's 60% reduction target will need to come from:

- reduced energy demand and
- switching to renewable energy sources.

In the housing sector, demand reduction can be achieved by:

- improving the efficiency of the existing housing stock,
- building new homes to a much higher thermal efficiency

These measures can be combined and carried out in various relative amounts to achieve the same aim. For example, if we were to go over to 100% renewables, then we would not need to improve the efficiency of our buildings. If we knocked down all our housing stock and built zero energy homes, we would not need to invest in renewables. Of course, renewables are a limited resource and we cannot knock down all our houses. The sensible approach is a combination of energy efficient home improvements, ultra low energy new build and increased renewable energy generation capacity.



1 Living Planet Report, WWF
2 Building Research Establishment
3 Carbon UK, ECI 2002

Scenario for reducing London's domestic CO₂ emissions by 60%

BioRegional carried out a study for the Greater London Authority to advise on the measures necessary in the housing sector to meet the Royal Commission target. Using London's predictions for new homes over the next 25 years, and optimistically estimating that existing housing stock is replaced at 1.5% per year, the following measures are needed:

- all replaced stock and all new build is built to ZED standards - ie. 90% reduction in space heating demand and 33% reduction in electricity demand compared to current average stock
- all the remaining housing stock is improved by 20% by 2050
- London will still need 1500MW generating capacity of renewable electricity That's 1,000 70m high 1.5MW wind turbines for London or around 2900MW of gas-fired CHP.

Similar measures will also be needed for offices and public buildings.

"All four scenarios require extensive modifications to the building stock and the transport system to reduce demand. District heating systems, supplied by CHP plants, would be commonplace in urban areas, as would be the use of heat pumps. Electricity networks would have to be restructured to accommodate the much larger numbers of smaller generating plants embedded within them, many supplying electricity only intermittently."

Royal Commission on Environmental Pollution's Report

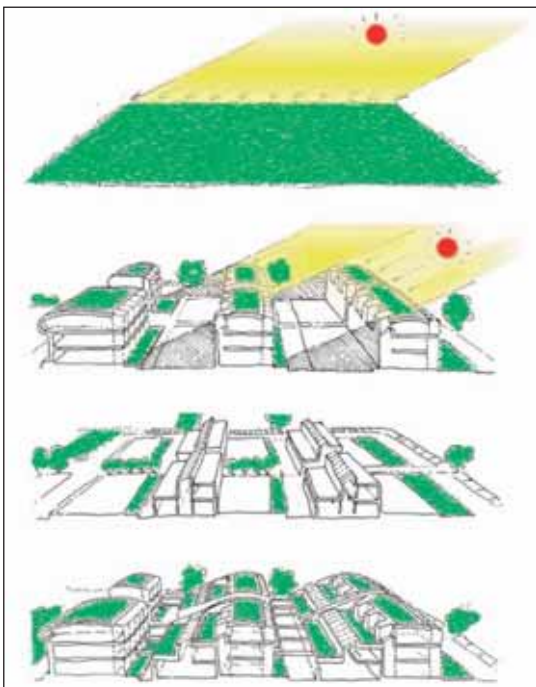
The Royal Commission Report gives four UK scenarios for meeting the 2050 target based on different demand reductions and various deployments of renewable energy sources, fossil fuel plant and nuclear power stations. All four involve a very large expansion of renewable energy sources – the most optimistic being a 10 fold expansion but involving drastic demand reductions. The other 3 scenarios require an 18-20 fold expansion to around 45GW. The report suggests that in 2050, there should be a 36% reduction in total energy consumption compared with 1998 levels.

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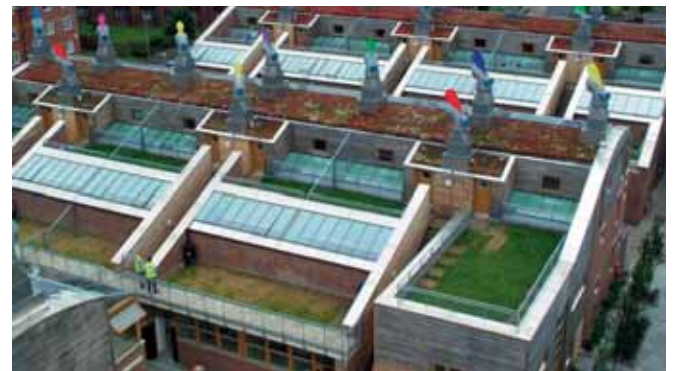
Planning Gain



This section shows how a developer can use a planning gain mechanism to increase density and so boost the development value of a scheme without sacrificing design quality or environmental performance. The added revenue helps fund the higher building specification necessary for carbon neutral development. The BedZED scheme is used here to illustrate.



The BedZED site was originally put on the market with planning permission for 250 habitable rooms (85 habitable rooms per acre) and a limit of 3 storeys. The scheme has increased in value by achieving 271 habitable rooms plus over 2,500m² of live/work units and commercial space for offices, studios and community facilities.



Roofs are colonised as sky gardens



Workspaces lit by north-facing skylights

This high occupation density is made attractive through the unique design where workspace roofs are colonised as gardens. In this way, most units get a private garden at densities that would normally allow only a balcony.

The workspaces are in the shade zone of the south-facing dwellings, lit by large triple-glazed north-lights, leaving the houses to benefit from the southern sun. The scheme is highly optimised and approaches the highest density for

mixed use capable of benefiting from useful amounts of passive solar gain, day-lighting and outdoor space.

The introduction of a Green Transport Plan and Home Zone design principles has justified a reduction in both car parking spaces and land area taken up by roads. This releases land for more housing, workspace and green roofs. See Chapter 8 for more on Green Transport.

Analysis

In order to evaluate the added revenue achieved by this planning gain strategy, BedZED built areas have been compared with those of a theoretical "conventional" scheme built on the same site. The Beddington High Energy Development (BedHED) is laid out to deliver the 85 habitable rooms per acre for which the site was originally given planning permission.

The diagram on the next page shows footprints, floor areas and sales values for both BedZED and BedHED. The residential sales values are the average price for "conventional" new properties in the BedZED postcode area at the time that BedZED went on the market.

In reality, BedZED properties achieved premium values some 17-20% above the conventional new homes in the area. Buyers paid extra for the innovative design and the "green" credentials. This is described in detail in Chapter 10 – Quality of Life.

The diagram shows that the planning gain mechanism can enable a developer to generate an extra £3.7 million in development value on a site like BedZED. This is offset against the costs of an additional 3,009m² of built area of £2.5 million.¹ So added revenue from such a site is £1.2 million, or an apportioned £208,800 for each 6-plot terrace.

The option to build at this higher density can be offered by planning authorities subject to a specified level of green credentials being met. For example, the London Borough of Merton are applying a two tier bidding system for larger sites under their disposal. Developers can bid for the land at standard densities or they can bid for a higher density if they commit to meeting an environmental performance specification dictated by Merton. This allows carbon neutral scheme proposals to compete for land without costing the Council or the developer any loss.

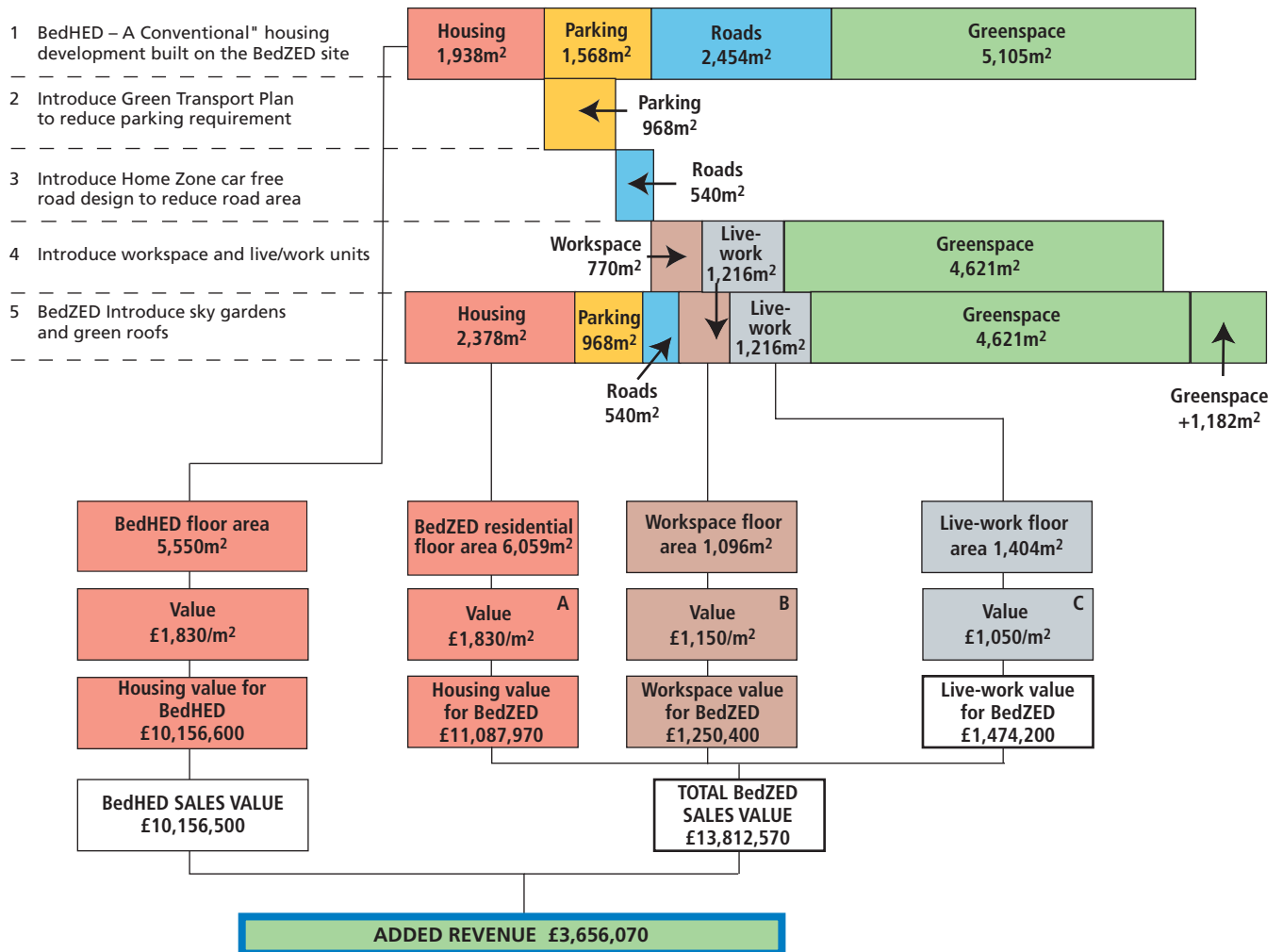


**BedHED – 27 terraced houses and 60 flats.
250 habitable rooms.**



**BedZED – 82 units, 1,2 3 & 4 beds.
271 habitable rooms.**

Planning Gain



A www.landreg.gov.uk

B Sales values achieved, Peabody Marketing 2001

C Estimation based on sales values achieved to date, advised by Peabody Marketing 2002

¹ based on conventional build costs of £950/m² for residential, £850/m² for live/work and £750/m² for workspace

Thermal Demand

Aims

- Reduce space heating demand
- Reduce hot water demand
- Maintain steady comfortable internal environment

Background

Domestic heating and hot water account for 85% of the energy used in UK households¹, 25% of the UK's energy demand and 19% of the UK's total CO₂ emissions. In England, the heating demand is met predominantly by gas which accounts for 79% of households, followed by electric heaters at 12%, oil 3%, solid fuel 4%, and 2% other sources.²

The average energy efficiency of the country's housing stock has risen from a SAP rating of 12 in 1970 to almost 43 in 2000³. The increase is due to improved insulation standards and the replacement of inefficient heating systems, such as open coal fires, by more efficient, mainly gas-fired central heating.⁴

Of course, domestic energy consumption is only part of the picture. Energy used in buildings accounts for 46% of total UK energy consumption, with non-domestic buildings being responsible for more than one-third of this figure. Each year, energy use in office buildings in the UK results in CO₂ emissions of around 2.2MtC.

Building envelope

Housing insulation in Great Britain has improved over the last decade. Just 3% of potential households had full insulation in 1987, compared with 11% in 2000. There has been rapid growth in the use of double-glazing. 40% of potential households had double glazed windows in 1998, more than double the proportion a decade ago. Loft insulation remains the most common form of insulation, increasing from 42% of homes with accessible lofts in 1974 to 91% in 2000. The thickness of insulation selected has also increased with 49% of all households having 100mm+ of insulation.⁵

Heating systems

Condensing boilers are the most efficient (85-95%). They cool and condense the waste gases, recovering the latent heat that would otherwise escape up the flue. They typically add 10 SAP points to a property.³ High-efficiency, fan assisted, non-condensing boilers are the next best thing. They cost less and have an

efficiency of 75-85%⁶. By comparison, boilers over 10 years old have efficiencies of 50-65%. Combination (or combi) boilers of either condensing or non-condensing type do the work of both a central heating boiler and a hot water cylinder but only produce hot water on demand. They save energy because hot water is not stored.⁷



Currently 8% of new boilers bought are condensing, and 92% are non-condensing. The replacement rate is fairly low at 5% per year.⁸ The scope for further demand savings is enormous. The Energy Savings Trust have calculated that if everyone in the UK with gas central heating installed a new condensing boiler, we would cut CO₂ emissions by 18.6 million tonnes per year⁹. This equates to more than 3% of the UK's CO₂ emissions.



Space Heating

ZED thermal design principles

Dwellings are arranged in south facing terraces with triple storey conservatories harnessing passive solar heat gain. Each terrace block sits in a jacket of 300mm of insulation. The southern elevation consists of two skins of double-glazing. Glazing on all other elevations is kept to a minimum and is triple glazed.



Super-insulation with wall tie

¹ DTI, 2002, Energy consumption in the UK

² BRE, 2000 Domestic Energy fact file

³ The Standard Assessment Procedure (SAP) rates the thermal efficiency of a dwelling and is based on estimates of space and water heating costs. A rating of 100 indicates an extremely efficient house.

⁴ DTI, 2002 UK Energy Sector Indicators

⁵ DTI, 2002, *ibid*

⁶ www.green-boilers.com, accessed 8/01/03

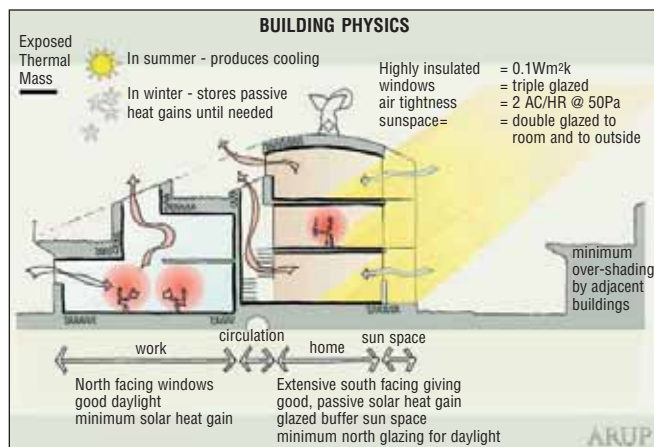
⁷ Lancashire Energy Efficiency Advice Centre, at www.leeac.org.uk/Heating/central_heating_systems.html

⁸ Market Transformation Programme, www.mtprog.com

⁹ Energy Saving Trust 'Quotable facts & figures' document, June 2002, www.est.org.uk

In this way, building fabric heat losses are reduced to such an extent that they can be compensated for by internal incidental heat gains. Every day activities such as cooking and use of electric appliances and people's own body heat are sufficient to keep these super-insulated buildings at a comfortable temperature. This eliminates the need for central heating systems, leading to a cost saving.

Thermal inertia is used to keep internal conditions comfortable. Dense concrete blockwork and concrete floor slabs provide thermal mass that absorbs heat during warm periods and releases heat at cooler times. Exposed radiant surfaces of walls, floors and ceilings are important for this so tiled floors and fair faced walls and ceilings are encouraged.

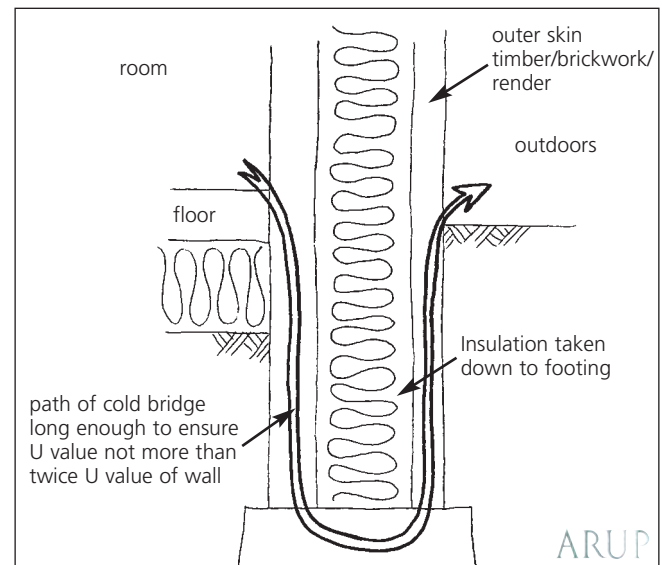


Most heat gains occur in south-facing rooms and in kitchens. It is important that this heat is allowed to spread to other rooms, so internal partitions are not insulated and internal doors are undercut.

All dwellings and workspaces must be kept above 17°C so as to avoid becoming a heat drain for the other units in the same block. So, during periods of inoccupancy, a back-up trickle heat source is activated if temperatures fall below 18°C.

Because the buildings are so well insulated, any part of the construction where the insulation is missing or can be short circuited has a much greater effect than it would do in a standard house. Any cold bridges would make areas of the dwellings uncomfortable and lead to condensation problems. Special care must be taken to avoid cold bridges around windows, doors, entrance lobbies, balconies, skylights and bridges.

Heat losses through building fabric are so reduced in BedZED buildings that heat losses through draughts would become very significant. For this reason, strict air tightness specifications of 2 air changes per hour (at 50kPa) keep building fabric air leakage to a minimum. This is far stricter



Design detail to avoid cold bridge

than standard practice in the UK of 15 – 30 air changes per hour. Air tightness tests are required to check what air tightness has been achieved. BedZED achieved 3-3.5 air changes per hour. See ZEDproduct L in "From A to ZED".

A healthy well-ventilated internal environment is maintained by a passive ventilation system with heat recovery. Wind cowls on the roof combine inlet and outlet ducts that turn with the wind direction on bearings. The cowls harness wind pressure and drive air through the system, with the buoyancy forces of the hot and cold air providing additional help. Inlet and outlet air flows pass over each other in a low pressure drop plate heat exchanger at the base of the cowl. 70% of the heat that would be lost through ventilation is recovered and fed back into the building. See ZEDproduct M in "From A to ZED".



Wind cowls provide passive ventilation with heat recovery

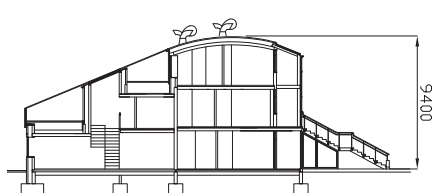
Hot water

As well as reducing the space heating demand, steps are also taken to reduce hot water demand. Sanitary fittings include flow restrictors, spray taps and carefully selected shower fittings.

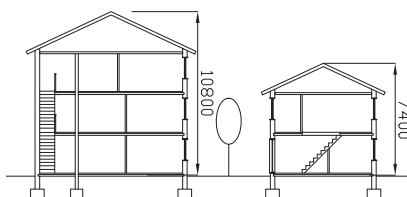
Hot water consumption is very dependent on individual users' habits. In order to raise occupant awareness of heat and hot water consumption, hot water meters are sited in highly visible locations. At BedZED, the Residents Manual, the Welcome Pack and BedZED newsletters provide advice on how to minimise hot water consumption, and monitoring results of hot water consumption are circulated and on display in the BedZED Centre.

6 plot terrace	ZED m ²	BedHED m ²
Floor area (gross internal)	1,692	1,572
Concrete floor	1,507	966
Timber floor	185	606
Wall area	500	1,759
Double glazing	527	231
Sunspace rooflights	75	0
Triple glazing	147	0
Rooflight	75	0
Sky garden	300	0
Roof	342	606
Cavity wall copings (m)	127	185
Land footprint	905	606

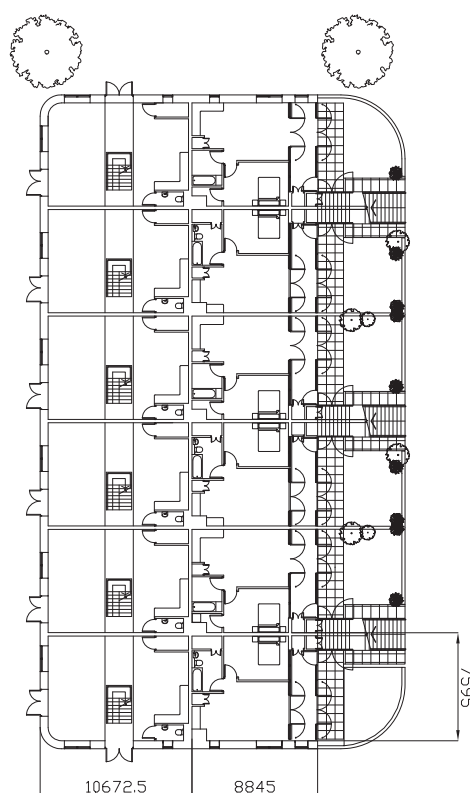
Table 5.1



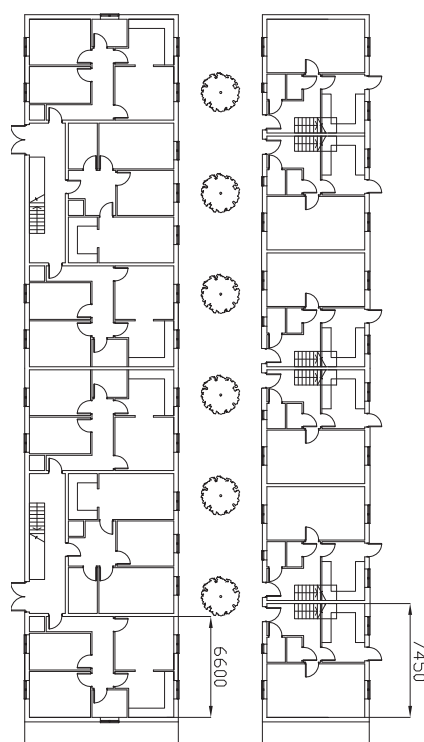
ZED Section



HED Section



ZED Ground Floor



HED Ground Floor

Build Cost Analysis

This section compares a 6 plot ZED terrace with a theoretical 3-storey conventional development called BedHED (Beddington High Energy Development). BedHED is built to 2000 Building Regulations using standard timber frame construction and offering the same accommodation. Both scenarios contain six 3-bedroom maisonettes, and six 1-bedroom flats. The ZED scheme also offers six live/work units while BedHED has six 2-bedroom flats of similar floor area.

Area quantities in Table 5.1 are based on the latest ZED terrace design and the theoretical BedHED design. The build cost unit rates in Table 5.2 are supplied by Gardiner & Theobald quantity surveyors, the cost consultants for BedZED. Where possible, rates are taken directly from BedZED construction costs. Some rates are taken from Spons, the quantity surveyors' guide price handbook. A few are taken from other G&T projects or from quotes by suppliers. Because of the varying sources of these unit rates, additional installed costs may occur, particularly at the interface of different trade packages. Careful site planning and coordination will minimise this. The ZEDproducts initiative has been developed to eliminate this problem. All costs are adjusted to 2002 prices and include supply and installation.

1 Gardiner & Theobald QS

A BedZED costs

B Spons, plus inflationary adjustment to 2002 prices

C Other G&T projects

D Supplier quotes

E Spons with estimated volume discount¹

Building Envelope Cost Comparison

		ZED				BedHED					
6-plot terrace		Area m ²	Description	Unit cost supplied and installed ¹ £/m ²	Total 6- plot cost £	Area m ²	Description	Unit cost supplied and installed ¹ £/m ²	Total 6- plot cost £	Cost difference £	
Glazing	Double glazing	527	timber framed, low-e, argon/ krypton filled	£385 ^A to 555/m ² ^D	£202,895 to £292,485	231	uPVC. low-e 12mm argon -filled cavity	£235 to 360/m ² ^D	£54,285 to £83,160	£148,610 to £209,325	£242,705 to £328,410
	Triple glazing	147	timber framed	£385 ^A to 555/m ² ^D	£56,595 to £81,585	0	None	–	0	£56,595 to £81,585	
	Rooflights (double and triple)	150	aluminium framed	£250/m ² ^{A D}	£37,500	0	None	–	0	£37,500	
Insulation	Wall	500	300mm rockwool	£11/m ² ^{A B}	£5,500	1,759	140mm Crown frametherm roll UF	£8/m ² ^E	£14,072	–£8,572	£46,499
	Roof	642	300mm extruded polystyrene	£45/m ² ^{A B}	£28,890	606	200mm mineral wool	£8/m ² ^E	£4,848	£24,042	
	Ground floor	905	300mm expanded polystyrene	£45/m ² ^{A B}	£40,725	606	60mm polyurethane board	£16/m ² ^E	£9,696	£31,029	
Wall ties	Wall ties	500	2-part	£5/m ² ^A	£2,500	1,759	None	-	0	£2,500	£2,500
Thermal mass	Wall inner leaf	500	Dense blockwork	£45/m ² ^A	£22,500	1,759	Timber frame	£35/m ² ^{B C}	£61,565	–£39,065	–£17,665
	Floors within dwellings	1,507	Concrete	£45/m ² ^A	£67,815	966	Concrete	£45/m ² ^A	£43,470	£9,610	
		185	Timber joists and floor- boards	£35/m ² ^{B C}	£6,475	606	Timber joisted with chipboard covering	£35/m ² ^{B C}	£21,210		
	Roof	642	Concrete	£75/m ² ^A	£48,150	606	Timber joist	£60/m ² ^B	£36,360	£11,790	
Cavity wall copings		127m	Aluminium powder coated	£65/m ² ^A	£8,255	185m	Painted softwood facia with aluminium edge trim	£30/m ² ^B	£5,550	£2,705	£2,705
Sealing mastic			Extra mastic	£200/ floor ^A	£5,400		None			£5,400	£5,400
										Total added cost (average £325,000)	£282,144 to £367,849

Table 5.2

The building envelope cost comparison in Table 5.2 shows that the thermal design of a 6-plot ZED costs around £325,000 more than BedHED. 90% of this additional cost is in the large areas of high specification glazing. The ZED design has 824m² of glazing, 602m² of which is in the south façade, as compared with 231m² at BedHED. The added costs of the ZED insulation and the thermal mass are relatively low (10% of additional cost). If BedZED provided the same area of glazing as BedHED, the additional build costs would be reduced to around £72,000.

The sunspace glazing on the south façade, however, is a key ZED design principle. It provides a low-tech renewable energy generating facility, harnessing passive solar gain. In addition, the excellent daylight levels reduce electricity demand for lighting by 30% (see chapter 6).

Added value to the properties from the south façade sunspaces and the good daylight design is considerable. Anecdotal discussions with BedZED residents suggest that one of the most influential factors in buying a ZED home was the sunspace and the feeling of internal spaciousness that good daylighting creates. A study by FPD Savills property consultants has found that added values of up to 20% were achieved on BedZED units due to their innovative design and their “green” credentials. A good proportion of this can be attributed to the light and spacious design. Chapter 10 on Quality of Life discusses this in more detail and shows that a

6-plot terrace can generate an extra £480,000 in premium sales values, which more than offsets the investment in the building envelope thermal performance.

Associated build costs

Each 6-plot ZED terrace has 10 wind cowls @ £4,050 each which provide wind-driven ventilation with heat recovery. The costs of the wind cowls are offset by not having to install 24 electric fans in the floor of each BedHED dwelling @ £250 each. This gives a net added cost of £34,500.

Special, prefabricated window reveals ensure air tightness around windows. But extra mastic work elsewhere to meet the stringent specification costs £200 per floor or £5,400 for a 6-plot terrace.

Cost savings

The cost saving due to the elimination of the need for any central heating system is around £2,500 / dwelling. Of this, £1,825 is re-spent on the oversized hot water cylinder and the backup system. The net saving is £675/ dwelling or £12,150 for a 6-plot terrace.

Overall, added build costs for the ZED thermal design specification for a 6-plot terrace are £352,750 (£208/m² or £21/ft²), all of which can be recovered in added value due to the light and spacious design.



South facade feature

BedZED Monitoring results

Benchmarks¹

New build

Space heating = 59 kWh/m²/year

Hot water = 3,900 kWh/household/year

UK Average Housing Stock

Space heating = 140 kWh/m²/year

Hot water = 5,139 kWh/household/year

New build homes have lower hot water energy demands than average stock because Building Regulations specify maximum carbon intensities for boilers, leading to installation of more efficient boilers.

Results

During the first winter of occupation at BedZED (2002-03), the Combined Heat and Power plant (CHP) and also the district heating system were still being commissioned. The result was that many residents did not automatically receive regular supplies of hot water from the CHP. Residents often had to manually switch on an electric immersion heater in their individual hot water cylinder.

In addition to this, temperatures sometimes dropped below the minimum 18°C due to the absence of constant hot water in the cylinder. In such super insulated buildings, the incidental heat gains from the hot water cylinder and the towel rail in each bathroom have a noticeable affect on room temperature. When homes dropped below 18°C, thermostats activated the electric immersion in the hot water cylinder and the trickle fan to warm the room. In preference to the noisy trickle fan, many residents bought electric heating appliances as a temporary solution.

Since April 2003, the CHP has been delivering hot water to all dwellings reliably. In the coming winter of 2003-04, all space heating and hot water needs should be met from the district heating system without any need for the immersion heater or supplementary heating appliances.

But in order to report on monitoring so far, data from three different sources has been combined:

- hot water delivered by CHP,
- immersion heater electricity consumption, monitored by sub-meters on individual immersion heater circuits,
- electricity demand of supplementary heaters, estimated by plotting seasonal variations in total electricity demand, interpreted with information from residents about when they purchased and used their heater.

The results show that despite the far from ideal conditions, actual energy consumption across the development is very much as predicted. Hot water consumption is around 6kWh per household per day as compared with a UK average of 14.1kWh and 2000 Building Regulations new homes at around 10.7kWh.

The average space heating demand across the site is 16.2kWh/m²/year. This is 12% of the space heating demand of a UK average home and 27% of a new home built to 2000 Building Regulations. This meets the design predictions of Arup and the BedZED design team.

Temperature and humidity

Temperature and humidity in 25 BedZED dwellings are being monitored for 2 years by The Peabody Trust. Internal temperatures so far have been largely steady at 18-21°C, even through heat waves and cold spells. Homes tend to perform best when their occupants understand the best times to open and close windows and curtains.



Hobo loggers monitor temperature and humidity



© Linda Hancock

¹ See Note 1 Appendix

Savings

Prices

UK and London gas price (per kWh) = 1.64p³

BedZED heat and hot water price (per kWh) = 2.5p
(prices inclusive of standing charge)

The following tables show the average space heating demands, hot water demands and associated bills for a:

- 1-bedroom flat,
- 3-bedroom maisonette,
- ZED live/work unit compared with a conventional BedHED 2-bedroom flat of the same floor area
- 6-plot terrace comprising 6 of each of the above house types, ie. 18 dwellings.

They compare energy consumption and bills for:

- UK average housing stock,
- new homes built to 2000 Building Regulations and
- ZED homes.

Bills for ZED homes are based on average monitored energy consumption and on prices for district hot water at BedZED. BedZED residents pay a higher unit rate for heat and hot water, so bill savings, although significant, are less than if they were paying standard unit gas prices.

³ DTI, 2002 see also note 2 Appendix

1 bedroom flat

Floor area 50m ²	Energy consumption KWh/year		Metered bills £/year		Total bill £/year
	Space heating	Hot water	Space heating	Hot water	
UK average	7,000	5,139	£114.80	£84.28	£199.08
New build (predicted)	2,950	3,900	£ 48.38	£63.96	£112.34
ZED standard (monitored)	810	2,190	£20.25	£54.75	£75.00
ZED standard bill saving compared with:			UK average		£124.08
			New build		£ 37.34

ZED Live/work unit vs conventional 2-bedroom flat

Floor area 99m ²	Energy consumption KWh/year		Metered bills £/year		Total bill £/year
	Space heating	Hot water	Space heating	Hot water	
UK average	13,860	5,139	£227.30	£84.28	£311.58
New build (predicted)	5,841	3,900	£ 95.79	£63.96	£159.75
ZED standard (monitored)	1,604	2,190	£40.10	£54.75	£ 94.85
ZED standard bill saving compared with:			UK average		£216.73
			New build		£ 64.90

3 bedroom maisonette

Floor area 103m ²	Energy consumption KWh/year		Metered bills £/year		Total bill £/year
	Space heating	Hot water	Space heating	Hot water	
UK average	14,420	5,139	£236.49	£84.28	£322.07
New build (predicted)	6,077	3,900	£ 99.66	£63.96	£163.62
ZED standard (monitored)	1,669	2,190	£41.73	£54.75	£ 96.48
ZED standard bill saving compared with:			UK average		£225.59
			New build		£ 67.14

6-plot terrace

Floor area 1,512m ²	Energy consumption KWh/year		Metered bills £/year		Total bill £/year
	Space heating	Hot water	Space heating	Hot water	
UK average	211,680	92,502	£3,471.54	£1,517.04	£4,988.58
New build (predicted)	89,208	71,200	£1,462.98	£1,151.28	£2,614.26
ZED standard (monitored)	24,494	39,420	£612.35	£985.50	£1,597.85
ZED standard bill saving compared with:			UK average		£3,390.73
			New build		£1,016.41

Summary

All the thermal efficiency measures described in this chapter result in a monitored 88% reduction in space heating requirement, reduced hot water consumption, radical fuel bill savings and essential environmental savings.

For a 6-plot terrace, ZED thermal specification costs a predicted £352,750 more than current 2000 Building Regulations. This equates to an additional build cost of £208/m². However, Chapter 10 shows that this cost should be recoverable by the developer in added value due to the high quality, light and spacious interior design.

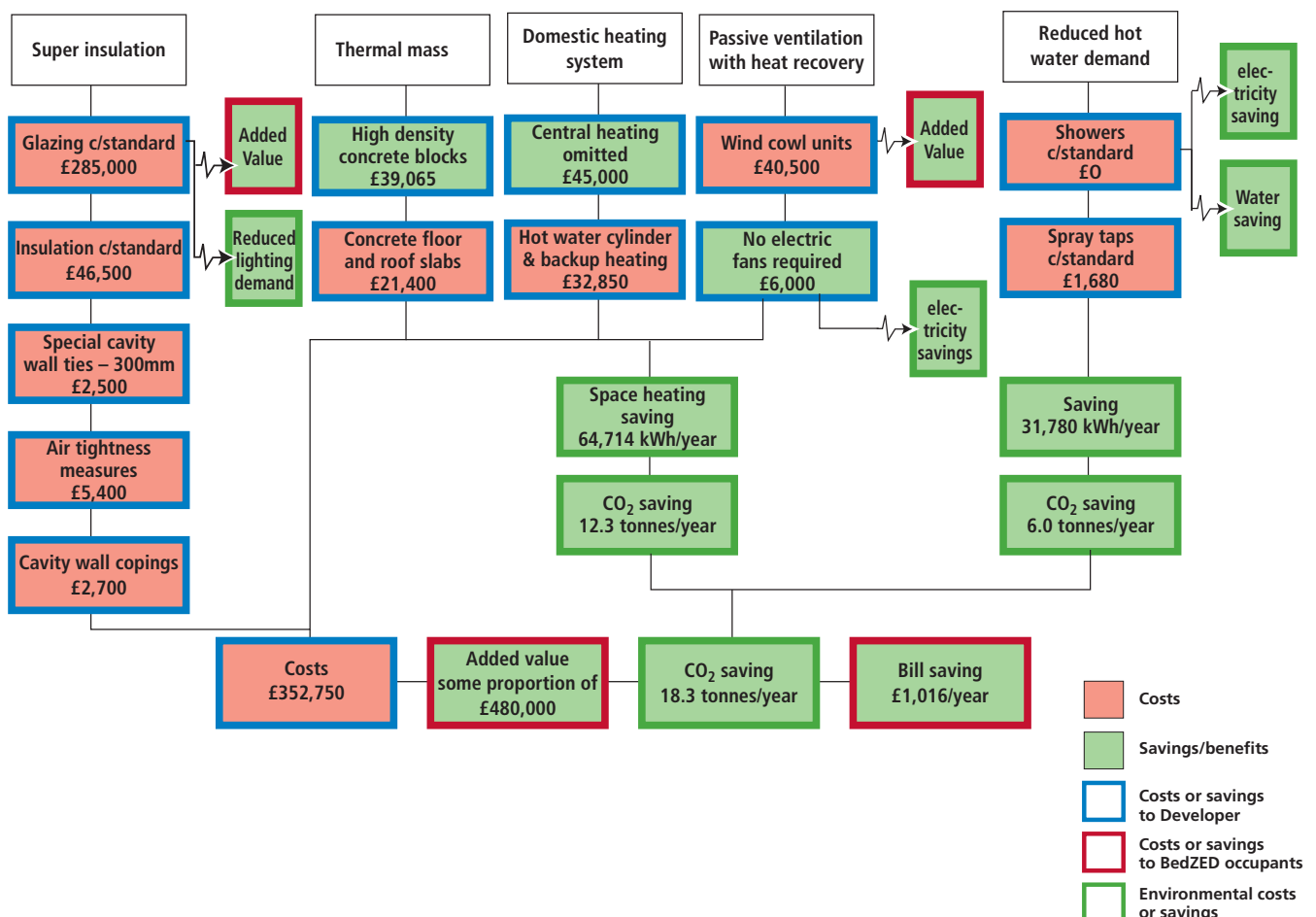
In a 6-plot terrace, annual space heating and hot water savings are around 240,268kWh compared to UK average stock and 96,494kWh compared to new build. The ZED thermal specification saves 46 tonnes of CO₂ per year compared to UK average stock and 18 tonnes compared to new build.

Average annual bill savings for a 6-plot terrace are estimated as £3,390.73 and £1,016.41 compared to UK average stock and new build respectively. The fact that the savings do not come back to the developer who made the original investment is an issue that needs to be addressed at a national policy level through tools such as conditional planning gain, see Chapter 4.

If all UK new build is built to this specification between now and 2050, there is a chance of meeting the Royal Commission's recommended CO₂ reduction targets. Such measures will also assist in tackling fuel poverty.

To achieve the ZED thermal specification requires the following ZEDproducts in "From A to ZED": A5, A6, B1, C, E, F, G, H, I, J, L, M.

Thermal demand for a 6-plot terrace of 18 units



Electrical Demand

Aim

- Reduce electricity demand

Background

Domestic electricity consumption is 115,137 GWh/year in the UK and accounts for 34% of UK electricity consumption and 6% of total UK energy consumption.¹ It contributes 32% of the UK's current 154.5 million tonnes of CO₂ emissions.¹

Domestic household electricity consumption varies enormously (by a factor of 5) according to individual usage habits. Lifestyle variables cannot be controlled by design or specification but, by installing the most energy efficient appliances, significant savings are made in all homes irrespective of lifestyle.



Energy Efficient Appliances

New build housing developments are not usually sold with fitted electrical appliances. Energy efficient appliances are, however, a very simple, mainstream, off-the-shelf way of achieving massive environmental savings without any specialist expertise. They do add extra costs but this can be made up in added value.

Fridges and freezers can be either free-standing or built-in. A-rated free-standing models are better value, being the most commonly sold option and so prices are lower. The best-selling fridges and freezers on the market are in fact A-rated free-standing. However, built-in models give a better looking finish to a kitchen, making homes easier to sell. They are also less likely to be taken out and replaced with a less efficient model. This chapter gives details of both built-in and free-standing options.



By fitting A-rated washing machines, water consumption is reduced by 60%. Based on the national average of 274 washes/year per household,² A rated models save around 250kWh electricity per year compared to average UK stock. They are available at no extra cost and are currently best selling models. It is possible to spend more and save even more water and electricity. Details are in the table below.



ZED homes are fitted with energy efficient compact fluorescent light bulbs throughout. The bulbs only use 20W but give the equivalent amount of light of standard light bulbs that

run on 100W. Typical household demand for southern England is 606kWh/year³ using 100W bulbs. By fitting compact fluorescents, this is reduced by 80%.

Table 6.1 gives current information on best-selling and most energy-efficient models in each type. For future reference, www.saveenergy.co.uk, www.energy-plus.org, and www.greenchoices.org are good sources of information on energy efficient appliances. See also the Environment Agency report, "The Economics of Water Efficient Products in the household".

Visible meters

At BedZED the electricity meters are fitted in a prominent location in the kitchen to raise occupants' awareness of their electricity consumption. Site-wide monitoring results are reported to residents and are on display in the BedZED Centre.



¹ DTI, 2002, Energy Consumption in the UK

² Energy efficient website, www.saveenergy.co.uk, May 2003

³ Electricity Association Study, 1998, cited in BedZED Total Energy Strategy, 2001

Energy efficient appliances

		Energy efficiency rating	kWh/year	Price	Model
Fridges	Typical UK stock		320 ⁴		
	Built in: Best selling model	D	241	£189.00 ⁶	Indesit GSE160
	Built in: Most energy efficient	A	142	£264.71 ⁶	Siemens KI18R40 *
	Free standing: Best selling model	A	153	£127.65 ⁷	Hotpoint RLA30
	Free standing: Most energy efficient	A+	113	£161.20 ⁷	Bosch KTR16420 Logixx
Freezers	Typical UK stock		500 ⁴		
	Built in: Best selling model	C	285	£199.00 ⁶	Indesit GSF120
	Built in: Most energy efficient	B	237	£270.59 ⁶	Siemens GI12B40, *
	Free standing: Best selling model	A	215	£140.42 ⁷	Hotpoint RZA130
	Free standing: Most energy efficient	A+	188	£275.05 ⁷	Zanussi ZFA 96W
Washing machines	Typical UK stock		442		
	Best selling model	A	274	£204.25 ⁷	Hotpoint WMA40
	Most energy efficient	A	164	£369.41 ⁸	Siemens WXL5140 *
Light bulbs	Standard	100W		£0.24 ⁹	Standard
	Energy efficient	20W		£2.83 ⁹	Compact fluorescent

* fitted at BedZED

Table 6.1



Good daylight design

Excellent daylight access in all dwellings and workspaces reduces the need for electrical lighting during daylight. Average annual lighting circuit demand for South of England households is 606 kWh². Low-energy light bulbs reduce this by 80% to 121 kWh. BedZED average monitored lighting circuit demand for 13 houses between August and May 2002 is the annual equivalent of 94 kWh. Adjusting for housesize, a reduction of 21% is either attributed to BedZED's good daylight design or to energy conscious householders.

Removing the need for some appliances

Shower fittings have been carefully selected to give a good quality, powerful shower that is up to modern expectations and thereby avoids the need for occupants to install power showers that require electricity.

Wind driven ventilation cowls avoid the need for electricity-guzzling fans. For healthy ventilation levels, each dwelling would require a 16W fan running continuously on each floor, consuming 139kWh/year. The costs of installing these fans @ £250/dwelling are offset against the wind cowl costs in the thermal chapter.

⁴ DECADE, 1997, cited in BedZED Total Energy Strategy.

⁵ Electricity Association, cited in BedZED Total Energy Strategy

⁶ Bornhill Distributors, bulk price, January 2003

⁷ Swift Electrical Distributors, bulk price, January 2003

⁸ Bornhill Distributors, negotiated bulk price for the BedZED development, April 2001

⁹ Tesco Online, January 2003

Complete energy efficiency fit-out

Buying appliances in bulk and fitting all units with the most energy efficient fridges, freezers, washing machines and light bulbs is cheaper than residents buying individually. Discounts of up to 30% were achieved on BedZED¹. Table 6.2 shows the cost of complete fit out and the energy savings for a 6-plot ZED terrace where each plot contains a 1-bed flat, a 3-bed maisonette and a live/work unit.

The energy efficiency fit-out can be offered to buyers as an extra to the cost of the home. It should not, however, be optional. Residents recover their investment through reduced electricity bills. Depending on which A-rated models are chosen, and valuing electricity at the average UK unit rate of 7.36p/unit, payback periods are 5.2-8.3 years.

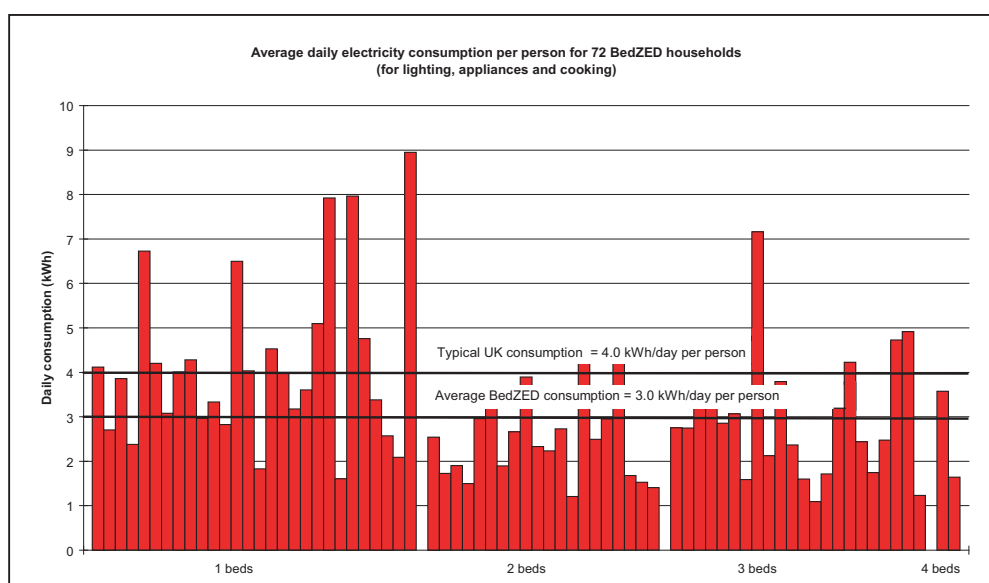
This is a good deal for buyers. After the payback period, they have effectively received free new white appliances and light bulbs.

Monitoring results

The graph shows monitored electricity consumption for 72 BedZED dwellings. The average BedZED electricity consumption up to June 2003 for lighting, cooking and appliances was 3.0 kWh/person/day² as compared with a UK average of 4.0 kWh/person/day³.

Individual appliances			6 plot terrace		
	Saving compared to average UK stock kWh/year	Cost £	Number of appliances	Saving compared to average UK stock kWh/year	Cost £
Fridge	167-207	£127-£265	18	3,006-3,726	£2,286-£4,770
Freezer	263-312	£140-£275	18	4,734-5,616	£2,520-£4,950
Washing machine	168-278	£204-£369	18	3,024-5,004	£3,672-£6,642
Light bulbs	469 / home	£2.83	18 homes, 162 light bulbs	8,442	£458
TOTAL	–	–	–	19,206-22,788	£8,936-£16,820
Annual predicted bill saving				£1,414-£1677	
Additional water bill saving from water efficient washing machine				£306	
Complete payback period for full appliance costs				5.2-8.5 years	

Table 6.2



¹ BioRegional

² Excluding temporary space heaters and immersion heaters (accounted for in Thermal Chapter 5)

³ BRE 2002, Domestic energy consumption by final use – see also note 3 Appendix

Savings

On average, BedZED residents are using 25% less electricity per person than UK residents.

In a fully occupied 6-plot ZED terrace, with an average 36 occupants, the residential electricity savings are 13,140kWh/year, saving 6 tonnes of CO₂ /year.

Prices

UK average electricity price (per kWh) = 7.36p¹ (including standing charge)

The BedZED tariff in January 2003 is 6.4p/day standing charge and 6.41p/kWh. This equates to an average 7.38p/kWh including standing charge.

BedZED's average electricity bill for lighting, cooking and appliances is £80.81/person/year based on 3.0 kWh/person/day.² This compares with £107.46 for the average UK resident and represents a £26.65 saving every year per person³.

Summary

To fit the full range of ZED standard energy efficient appliances in a 6-plot ZED terrace costs £8,936-£16,820 depending on built-in and free-standing options.

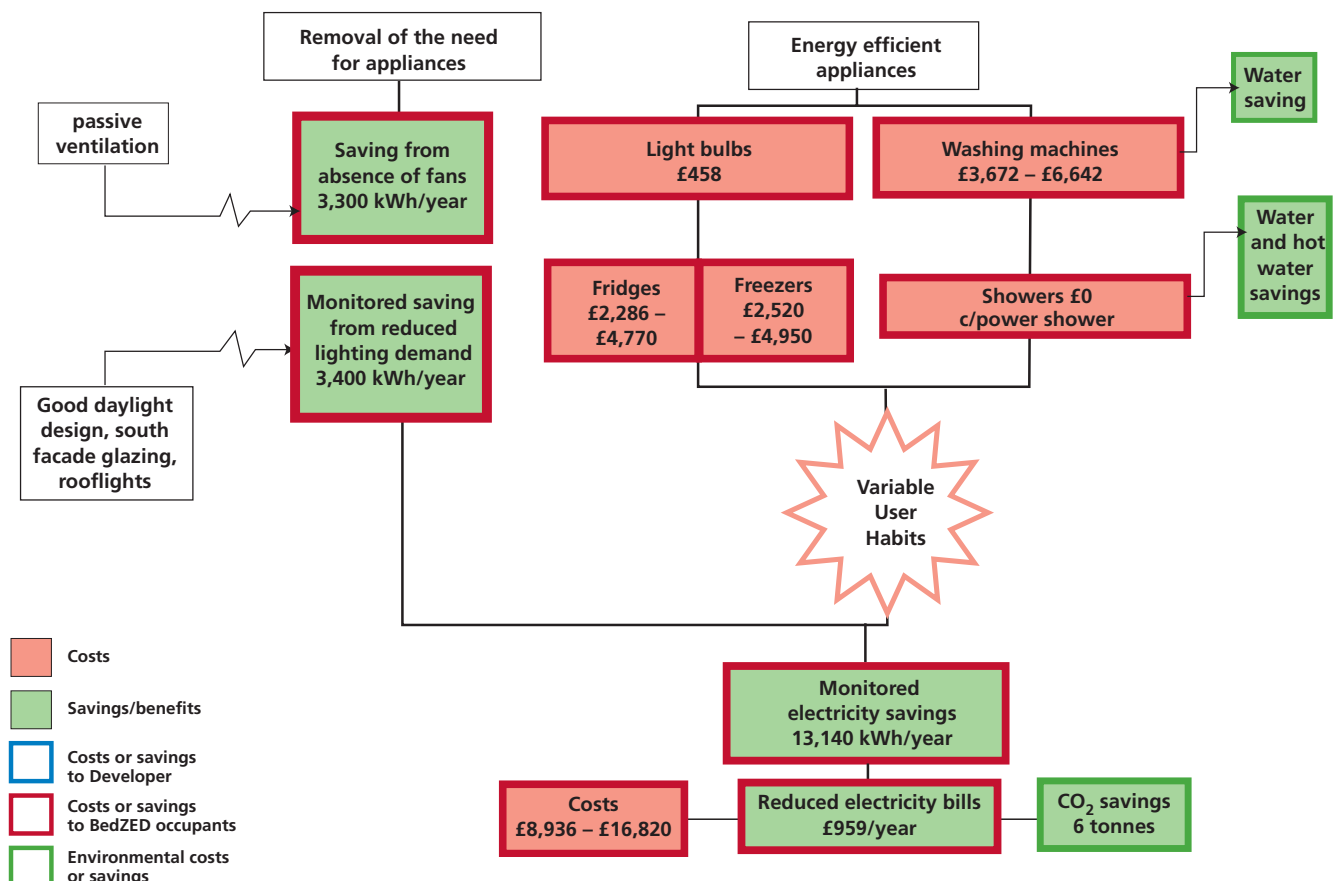
When combined with good daylight design, the removal of the need for fans and some energy conscious behaviour, monitoring shows savings of 13,140kWh/year compared with the UK average. This equates to savings of 6 tonnes of CO₂.

Total average bill savings are £26.65/person/year or £959.40/year for the block, based on monitoring so far.

ZED electricity saving appliances are detailed in ZEDproducts Q4, R2 and S2 in "From A to ZED".

- ¹ DTI, Average annual electricity energy prices, 2002
- ² excluding temporary space heaters and immersion heaters.
- ³ see note 4 Appendix

Electrical Demand for a 6-plot terrace of 18 units



Aims:

- **Reduce water consumption by installing water efficient appliances and encouraging water efficient lifestyles**
- **Reduce mains water consumption by using alternatives**
- **Divert waste water from mains sewage and treat it as a resource**
- **Manage surface water runoff to minimise local hydrological impact**
- **Incorporate high ecological value wetland landscaping into the site**

This chapter describes how water conservation measures and sustainable water management can be introduced to a housing scheme. It covers a number of diverse measures and so is subdivided into the following sections:

- 1 Background
- 2 Reducing water consumption
- 3 Rainwater collection
- 4 Treating "waste" water as a resource
- 5 Savings
- 6 Business Case Analysis
- 7 Surface water treatment

1 Background

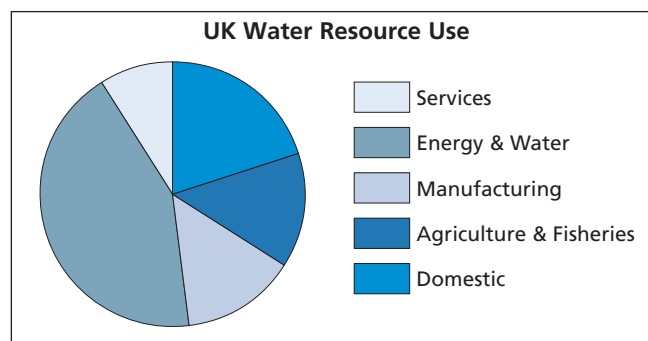
The average UK resident uses over 150 litres of highly treated mains water per day¹, up to a third of which is flushed down the toilet. People in recently built homes with power showers use more like 230 litres per day. Domestic water consumption accounts for 20% of total UK water consumption or 3.2 billion cubic metres per year. This quantity is going up as population increases, more and smaller households are being created and as more water-hungry appliances such as power showers are being used.

While the UK as a whole is not a water stressed region, local and regional areas of the UK are increasingly suffering from water management problems. Some areas such as East Anglia are very reliant on winter rain stored for the summer months and experience shortages if this rainfall is

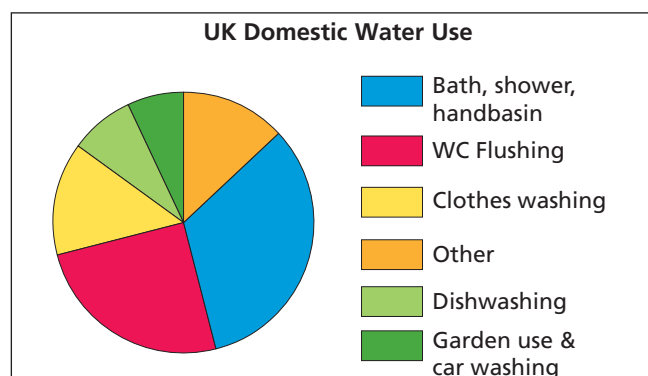
low. Yorkshire experienced extreme water shortages in recent years after low rainfall. Areas such as the South East are getting drier as they become more developed and population density increases, whereas previously industrial areas find their water tables rising as water demand falls.

The total theoretical renewable water resource in the UK is an ample 5,644 litres/person/day² as compared with the total extraction per UK resident of 1,145 litres/day³. But this does not allow for seasonal variations. Not all of this resource is economically accessible. It is also a very regional resource and cannot be economically transported over large distances.

Climate change is now probably unavoidable and will make rainfall less predictable with possibly 50% drier summers and 30% wetter winters by 2080. Storms are likely to increase by 5-20% and overall UK average temperatures will increase by 2-3.5°C.⁴ Increasingly erratic rainfall patterns will make water supply management more challenging, so reducing mains water demand will help make unpredictable supplies and local variations less critical.



UK water resource use by industry, 1997/98 - Total abstraction: 16.8 billion cubic metres (Source: ONS)



Source: Environment Agency

- 1 Anglian Water Survey SODCON 1992
- 2 Living Planet Report 2002
- 3 Building Research Establishment
- 4 Sustainability Northwest

2 Reducing water consumption

BedZED residents are charged metered unit rates for mains water, whilst "greenwater" and sewerage are charged according to a formula based on the metered mains consumption and the size of the property. "Greenwater" is a mixture of rainwater and recycled, treated waste water. Reducing water consumption reduces the volume of waste water, so bill savings are made on both mains water and sewerage charges. Table 7.1 shows the current charging structure for water at BedZED. The prices are set by the water and sewerage services supplier, Albion Water, who have invested time and expertise in the scheme. Albion will be adopting the Green water treatment plant and its associated infrastructure, but at the time of writing, this agreement is still being finalised. For every m³ of mains water saved, occupants save £0.586 and additionally £0.4325 on reduced waste water. So mains water efficiency measures are worth a total of £1.012/m³. Low flush toilets save on "greenwater" and waste water at a rate of £0.96/m³.

BedZED Charges

	Standing charge £/yr	Volumetric charge £/m ³
Potable mains water	19.00	0.5860
Greenwater	Nil	0.5274
Sewerage	38.00	0.4325

Table 7.1

Average UK Charges

	Standing charge £/yr	Volumetric charge £/m ³
Portable mains water	17.58	0.7243
Sewerage	29.35	0.6542

Table 7.2

Source: OFWAT Tariff structure and charges 2002-3 report

According to OFWAT, only 23% of households are metered in 2002-3.

Water efficient appliances

Low flush toilets

A typical toilet uses 7.5 to 9 litres per flush and accounts for 25% of our annual household water consumption¹. ZED homes are fitted with 2 and 4 litre dual flush toilets that save an estimated 11,000 litres/person/year, saving occupants £10.56/person/year.

Low-flush model:

Ifo Sanitar Cerra, cost £185 (2 and 4 litres/flush)

Typical model:

Bathrooms Direct, cost £100 (9.5 litres/flush)

Bathing and showering

Bathing and showering account for 17% of annual household water consumption in the average UK household¹. In order to reduce this in ZED homes, the carefully chosen shower fittings meet people's aspirations of a modern, good quality shower and so reduce the likelihood of power showers being fitted (which can use as much water as a bath). The avoidance of power showers saves around 11,000 litres/person/year or £11.20/year in bills (based on one 5 min shower per day). 200-300 kWh of electricity are also saved. The average UK household does not have a power shower but most new build developments fit them as standard.

Water-saving shower:

Hans Grohe, cost £212 (14 litres/min)

Typical power shower:

Mire Elite 9.8kW, Cost £212 (20 litres/min)

Spray taps

Self-regulating flow restrictors to taps reduce pressure and flow rates and minimise wastage through splashing. This reduces water consumption by around two thirds, saving around 9,500 litres/year or £9.68/year in bills (based on 2 mins full flow per person per day).

Spray taps:

Hans Grohe, cost £90 per pair (7 litres/min)

Typical taps:

Aqualisa aquataps, cost £50 per pair (20 litres/min)

Washing machines

Washing machines account for 21% of annual household water use¹. All BedZED units are fitted with the most water efficient washing machines on the market. They use 39 litres per cycle. In contrast, the typical UK models use 100 litres per cycle. The current best selling A-rated model uses 58 litres per cycle.

The average BedZED household will save 16,700 litres / year and about £17/year in reduced water bills compared with a typical UK washing machine, based on the national average of 274 washes /year per household.²

Typical UK washing machine:

100 litres / 2 kWh wash

¹ Environment Agency

² Energy Efficiency Website, www.saveenergy.co.uk, May 2003



Best selling model:

*Hotpoint WMA40 (A), cost
£288.83 (58 litres / 1.045 kWh
wash)*

Most energy efficient:

*Siemens WXL5140 (A), cost
£369.41 (39 litres / 0.6 kWh wash)*

Complete water efficiency fit-out

Buying appliances in bulk and fitting all units with the most water efficient toilets, showers, spray taps and washing machines is cheaper than residents buying individually. Discounts of up to 30% were achieved on BedZED.¹ Table 7.3 shows the cost of complete fit out and the water savings for a 6-plot ZED terrace where each plot contains a 1-bed flat, a 3-bed maisonette and a live/work unit. A 6-plot terrace typically houses about 36 people. The comparison is with a new build power shower household using 230l/person/day.

The washing machine, which offers both water and electricity savings, can be offered to buyers as an extra to the



cost of the home. It should not, however, be optional. It should be part of a white goods package along with the A-rated fridge and freezer. Residents recover their investment through reduced bills and it pays for itself after a number of years, effectively giving residents the washing machine for free. The costs and payback for the washing machine are accounted for under electricity savings in Chapter 6. It is therefore omitted in the payback analysis below.

Encouraging water efficient lifestyles

Complete water efficiency fit-out brings mains water savings of 40m³/person/year or 1,434m³/year for a 6-plot terrace. Bill savings average at £31/person/year compared with a power shower household. The theoretical payback period is 3.3 years.

The BedZED Residents' Manual gives water saving ideas and information on the environmental and financial advantages of saving water. Any residents wishing to install dishwashers are offered advice on purchasing water efficient models. A highly visible water meter, mounted in all kitchens reminds occupants about their water use.

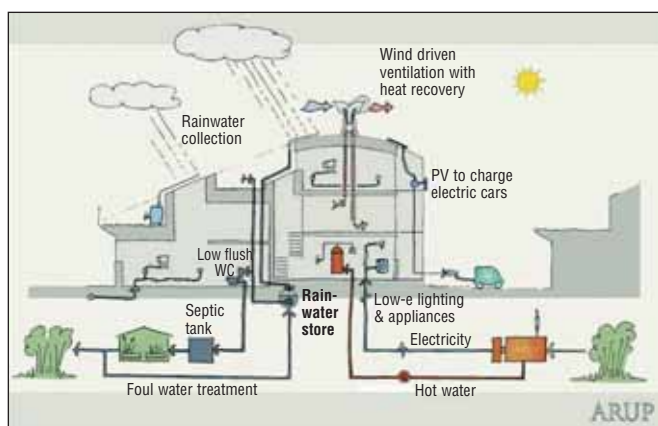
	Individual appliances			6-plot terrace				
	Saving compared to average UK stock with power shower m ³ /year	Cost compared to current best selling model	Water bill saving £/year	Number of appliances	Saving compared to average UK stock with power shower m ³ /year	Cost compared to current best selling model	Water bill saving £/year	Theoretical payback period (years)
Toilet	11/person	£85 extra	10.56	24	396	£2,040	£380	5
Shower	11/person	0	11.20	18	396	0	£403	0
Spray taps	9.5/person	£40	9.68	42	342	£1,680	£348	4.8
Washing machine	16.7/ household	–	–	18	300	–	–	–
Total					1,434	£3,720	£1,131 /year	3.3 years

Table 7.3

¹ BioRegional

3 Rainwater collection

Rainwater from roofs is harvested and stored in 1.2m diameter storage tanks that run along the length of the foundations of each block. The rainwater passes through a fine self cleaning filter in the down pipe before entering the tank. It is then delivered by submersible pumps and used for toilet flushing, irrigation and garden watering points.



There are 472m² of water collecting roof area on each 6-plot terrace. Of this, 144m² is rooflight and 328m² is actual roof. Water is not collected from sky gardens as there is a risk of contamination from pets. The average annual rainfall for the BedZED site is 770mm. ZEDproduct F, in "From A to ZED", offers two roofing solutions:

Either Metal roof:

All rainwater is collected.

472m² @ 770mm/year yields 363m³/year.

Or Sedum roof:

Sedum roofs are covered in semi-succulent plants that absorb rainfall and decrease the amount of rainwater that can be harvested. The BedZED sedum roofs have an absorption capacity of 28 litres/m². With light/moderate rainfall, all rainfall will be absorbed, whereas with heavy rain, there is run-off, but the discharge rate is halved¹. If 75% of all rainfall is absorbed on the sedum, then rainwater yield is:

Rooflights: 144m² @ 770mm/year = 111m³

Sedum roof: 328m² @ 770mm/year @ 25% = 63m³

Total = 174m³

The harvesting of 174m³ or 363m³ of rainwater replaces the same volume of treated mains water.



Cost Analysis for Rainwater collection

Table 7.4 shows BedZED construction costs for 7 terraces of rainwater harvesting equipment.

RAINWATER COLLECTION & STORAGE	
CONSTRUCTION COSTS ²	£
1200mm diameter rainwater storage tanks including all excavation, backfill, bedding surround with selected excavated material, manhole chambers, overflow connections and rainwater filters	120,000
Supply system from storage tanks to WC's and irrigation points including all pipework, pumps and connections	70,000
General rainwater pipework (including aluminium downpipes and guttering) allowing for connection into Rainwater Collection & Storage system	5,000
Stormwater Drainage in connection with collection of rainwater from buildings to storage chambers	27,000
Add General Building Contractors costs, site set-up, management, supervision, overheads, profit and the like @ 10%	£22,200
Total Rainwater Collection, Storage and Distribution Construction Cost	£244,200
Apportionment for 1No 6-plot terrace	£34,886

Table 7.4

Residents are charged for greenwater at about 90% of the rate of mains water so financially they benefit only marginally from the rainwater collection. The system does, however, collect water to the "value" of £191/year for the metal roof design or £92/year for the sedum roof on each 6-plot terrace.

¹ Graham Spall, Ramroof, personal comm Nov'2002

² Gardiner & Theobald QS 2001

4 Treating "waste" water as a resource

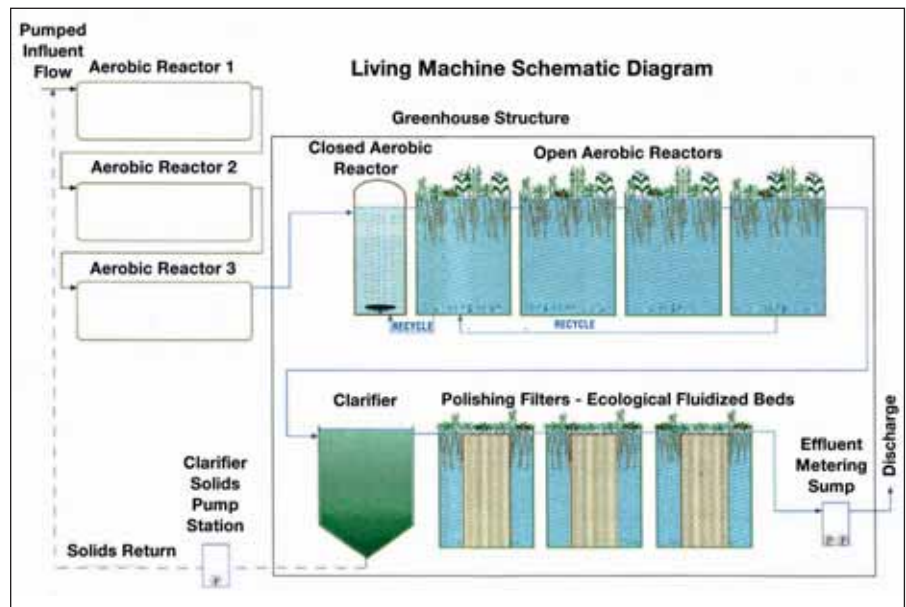
Three systems were considered for the treatment of waste water at BedZED:

- Reedbed
- BioBubble
- Living Machine

A reedbed has no energy demand and virtually no maintenance but it does require space. A reedbed to treat BedZED's wastewater would have needed some 1,400m² of valuable land. This was not possible at BedZED, nor would it be a transferable solution for high-density urban schemes.

The BioBubble is very compact and could even go underground but its electrical energy demand was too high.

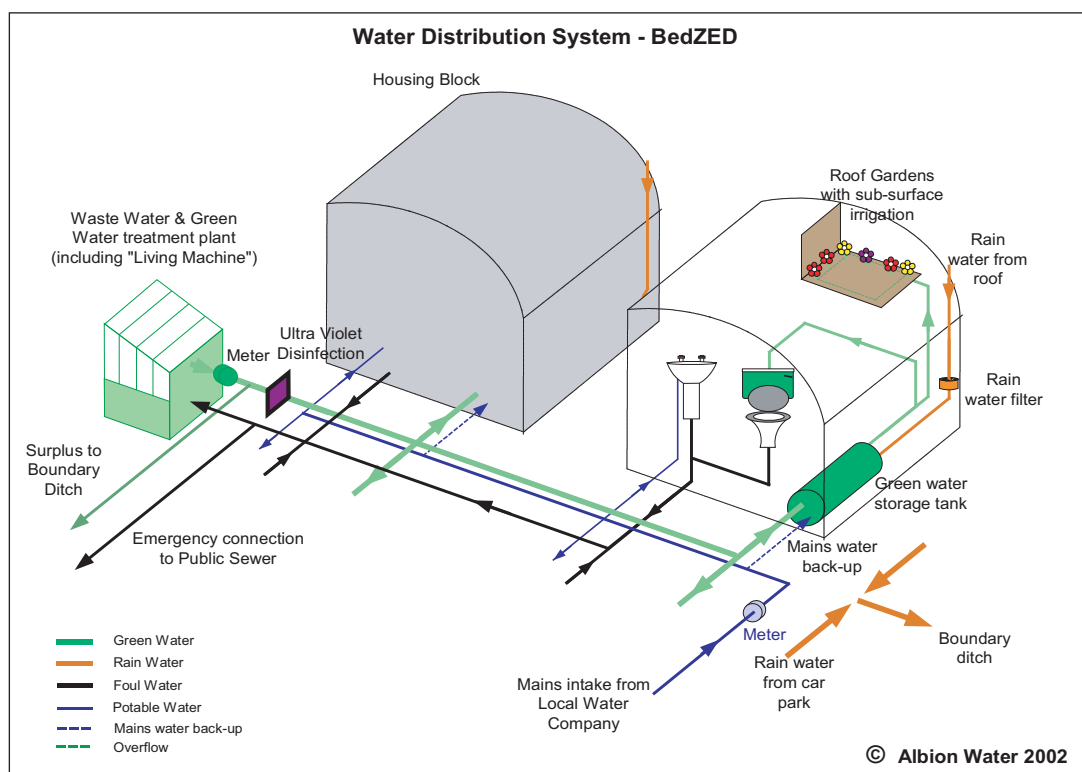
The original preferred option at BedZED was a "turbo-reedbed" housed in a greenhouse known as a "Living Machine", developed by Living Technologies Ltd. With the involvement of Metropolitan Water and Albion Water, the Living Machine design was modified and adapted. The



resultant Green Water Treatment Plant (GWTP) includes some features supplied by Living Technologies.

The system, an activated sludge plant with extended aeration, was installed by Albion Water and is an innovative and attractive combination of traditional and modern approaches to sewage treatment. The process comprises two underground in-line septic tanks followed by a series of treatment tanks that treat the water biologically. Plants are

suspended on rafts in the treatment tanks and they derive nutrients from the treated liquor. The treated effluent is used to supplement rainwater in the greenwater storage tanks for toilet flushing and irrigation. It is disinfected by UV light treatment and subtly dyed with a green vegetable dye. Surplus outflow is discharged to a landscaped water feature at the site boundary. In compliance with the Environment Agency's specifications, the outflow to this natural water course is not UV treated.



This efficient sewage treatment system can be used as an educational facility and is an attractive place to visit. It is important to note that the GWTP has no environmental impact on close residential neighbours since all odours are eliminated within the plant itself and the process is virtually silent.

As a safety precaution, all pipework carrying recycled water is coloured green so as to distinguish it from the mains water system. There is, in fact, a surplus of recycled water from the GWTP and hopefully on the next ZED, one modification will be to use recycled water to meet the demands of the washing machines. This would save a further 200m³/year for a 6-plot terrace.

The GTWP currently uses slightly more energy than a conventional sewage treatment system due to the economies of scale than can be achieved by the latter. This energy use is being addressed with a view to considerably decreasing it. Carbon neutral developments have a carbon neutral energy supply and therefore carbon neutral sewage treatment. However some large scale sewage works generate their own electricity carbon-neutrally from waste methane anyway.

Adoption of the Green Water Treatment Plant

As a licenced water company, Albion Water Ltd has contracted to design, install, operate and maintain the GWTP under a legal agreement with the site developer, the Peabody Trust. Albion Water have invested time and expertise in the BedZED project because they anticipate a future market in small scale on-site wastewater treatment plants. Albion Water will also adopt the water and sewerage infrastructure on the site. Much of this pipework lies under the roads and getting this adopted then allows the local authority to adopt BedZED's highways and landscaping under a Section 38 agreement.



The importance of adoption is to remove the long-term maintenance burden from the Peabody Trust. BedZED will set a precedent in demonstrating adoptability of these innovative elements of the scheme. Future developers who might consider small scale on-site sewage treatment will be able to proceed at a lower risk if they know that they will not be building themselves a maintenance burden.

Cost Analysis for Green Water Treatment Plant

Table 7.5 shows BedZED construction costs for GWTP serving 100 units.

SEWAGE TREATMENT PLANT & INFRASTRUCTURE DISTRIBUTION	
CONSTRUCTION COSTS ¹	£
GWTP – Design, supply and installation, including all associated tanks, pipework, filters etc and commissioning.	135,000
Septic Tanks - Installation including excavation, formwork, concrete and backfill and all associated pipework and connections	46,000
'Greenhouse' enclosure to GWTP including glazed roof, openable lateral panels, drainage runs, service floor, blockwork walls etc.	59,000
Pipework for 'Green Water' return and connections to Rainwater Storage tanks	25,000
Add General Building Contractors costs, site set-up, management, supervision, overheads, profit and the like @ 10%	£27,000
Total Sewage Treatment and Plant Infrastructure Distribution Construction Cost	£292,000
Apportionment for 1No 6-plot terrace of 18 units	£52,560

Table 7.5

¹ Gardiner & Theobald QS, 2001

5 Savings

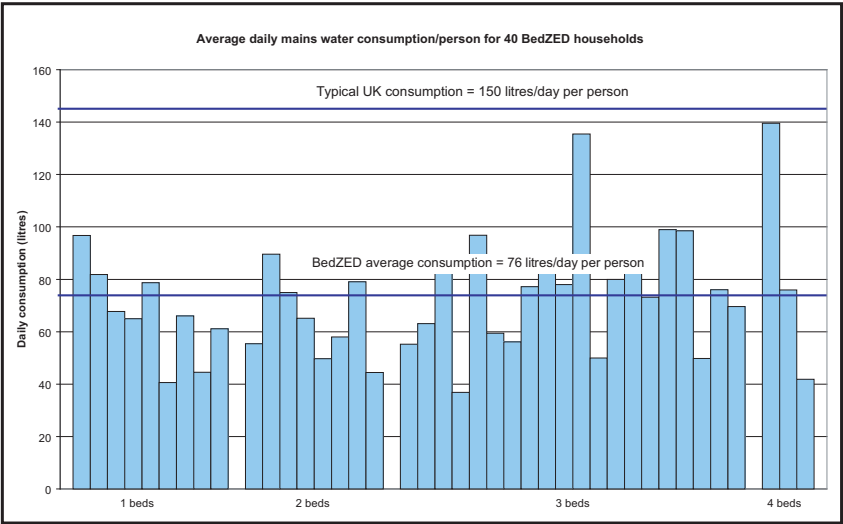
BedZED residents use an average mains water consumption of 76 litres/day. They range from 37 to 140 litres/day. This is a 50% reduction compared with the national average of 150 litres/day or a 67% reduction compared to a power shower household. In addition, they use an estimated 15 litres/day of "greenwater".

Summary

Annually, each resident saves 28.5m³ of mains water compared with the national average. Of this, 5.5m³ are replaced by "greenwater" and cost a similar unit rate. Average UK water bills are £228/household. BedZED households save £104/year or 47% on their water and sewerage bills.

The greenwater system has the potential to supply a further 200m³/year for washing machines.

Water efficient appliances are bought in ZEDproduct B2. Rainwater recycling requires ZEDproducts A7, A8, F. Wastewater treatment and recycling uses ZEDproduct W. All ZEDproducts are described in detail in "From A to ZED".



Average BedZED water bills

Metered charges (per person)			
Mains water:			
76 litres / day = 27.7m ³ /year	@ £0.586/m ³ =	£16.23	
Greenwater:			
15 litres / day = 5.5m ³ /year	@ £0.5274/m ³ =	£2.90	
Sewerage:			
91 litres/day = 33.2m ³ /year	@ £0.4325/m ³ =	£14.36	
Sub-Total		£33.49	
Standing charges (per household)			
Mains water		£19.00	
Sewerage		£38.00	
Sub-Total		£57.00	

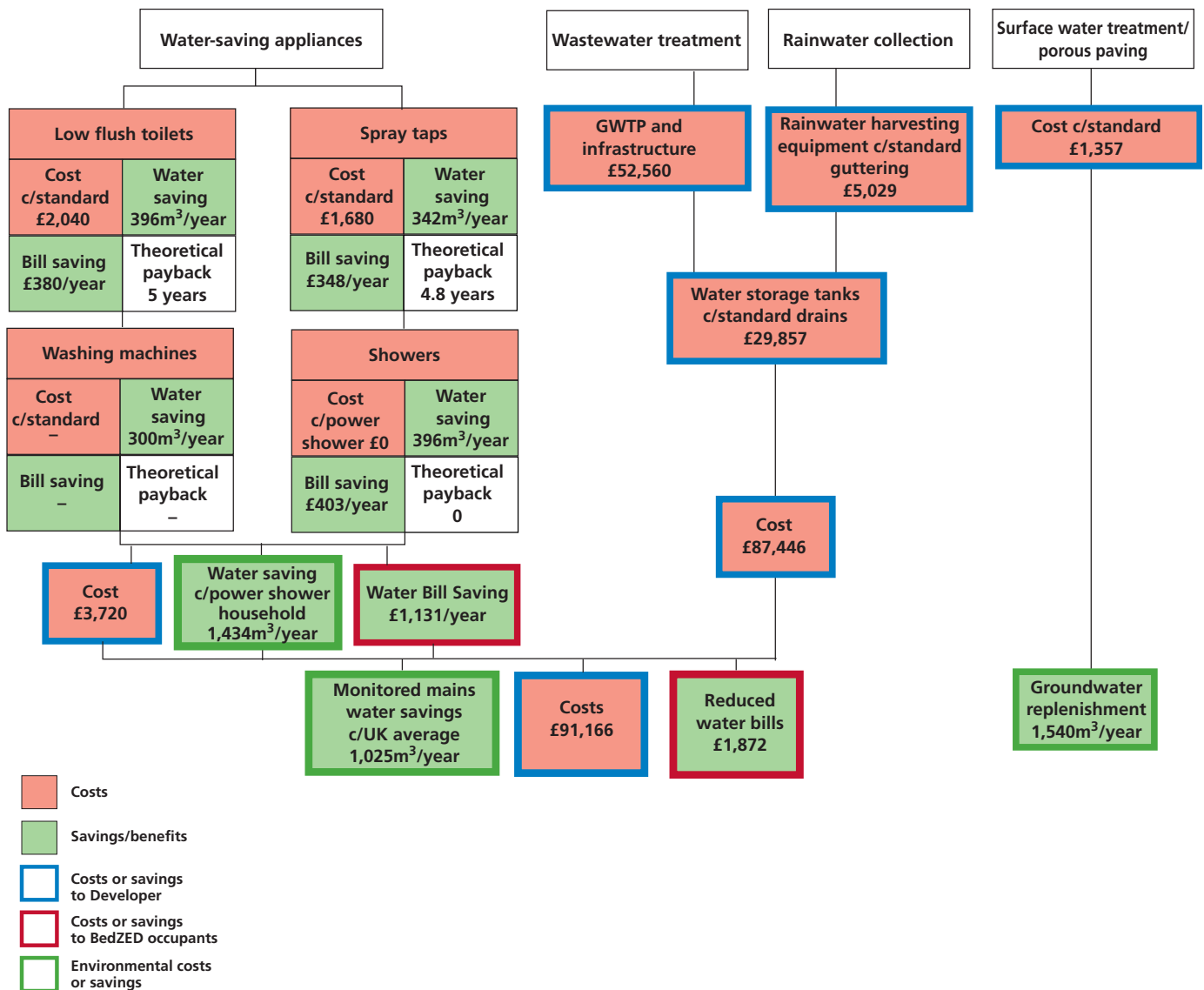
In a 6-plot terrace of 18 households and 36 residents, bills will be £2,232 for the block or an average £62.00 per person. Average household bills are £124.

Average UK water bills

	Water (£/year)	Sewerage (£/year)	Total (£/year)
Metered	91	106	198
Unmetered	112	125	236
OVERALL	107	121	228

Source: OFWAT Water and Sewerage Bills 2002-3

Water Demand for a 6-plot terrace of 18 units



6 Surface water treatment

Background

Winter rain is predicted to increase by 30% due to climate change from global warming. Heavy winter storms may become 5-20% heavier.¹ Flooding in the UK cost insurers around £750 million in 2000, and this figure is predicted to rise with more storms and unpredictable weather. In one weekend in June 2000, rain lasting over 30 hours in West Yorkshire caused flooding and was estimated to cost insurers £12 million. This has led to insurance companies considering black-listing high-risk homes unless more is spent on flood defences. There is clearly a need to design for flood attenuation.

Managing surface water runoff to minimise local hydrological impact

Surface water runoff from sky gardens, roads and pavements would normally be drained into pipes and underground storage tanks from where it would enter the mains sewerage system. This removes much needed water from the natural watercourse and also costs money. At BedZED, this infrastructure has been eliminated by using porous paving over gravel for large areas of the highways and parking spaces. As water drains through these layers it is filtered to remove any petrol or oil contamination from the roads and then returned to the groundwater via soakaways. The substrate to the porous paving has a specific aggregate size distribution in order that the voids between the aggregate pieces provide enough water storage capacity for a 1 in 100 year storm.



BedZED porous paving

Under storm conditions, soakaways overflow into the water feature ditch. A weir and flow controller ensures that water discharge rates do not exceed 7 litres per second to minimise impact on local hydrological characteristics.

The annual rainfall on BedZED's hard landscaping is 770mm. Collecting from an area of some 2,000m², both from the

tarmac and porous paving areas, means that 1,540m³ of water is diverted every year from mains sewerage and allowed to pass through to the natural watercourse.



BedZED water feature

Surface adoption

As with the Green Water Treatment Plant, the Project Team has achieved adoptable standards in the surface water treatment design, allowing a precedent to be set and the local authority will be adopting the highways under a Section 38 agreement. This will remove the long-term maintenance burden from the Peabody Trust.

Cost analysis for surface water treatment

Conventional landscaping with tarmac, sub-base and underground drainage would cost around £40/m² installed¹. The highways and hard landscaping at BedZED cost more but savings were made on underground drainage. Extra costs are estimated at £10/m², contributing to both sustainable urban drainage and also the Home Zone and Green Transport Plan (see Chapter 8). So the extra cost is split 50/50 between the two.

Apportioned extra cost is 1,508m² @ £5/m² = £7,540
Or £1,357 per 6-plot terrace.

Incorporating high ecological value wetland landscaping into the site

The BedZED site was originally fronted by a dry ditch. This ditch has now been lined, profiled and has naturally filled with water. It has been planted to maximise ecological value. As well as providing an attractive feature along the front of the site, the ditch is functional, receiving surplus discharge from the GWTP and providing a final filtering of surface runoff before it leaves the site on its way to the River Wandle.

The surface water treatment solutions are part of ZEDproduct Y in "From A to ZED".

¹ Sustainability Northwest

² Gardiner & Theobald QS, 2001

8

Transport

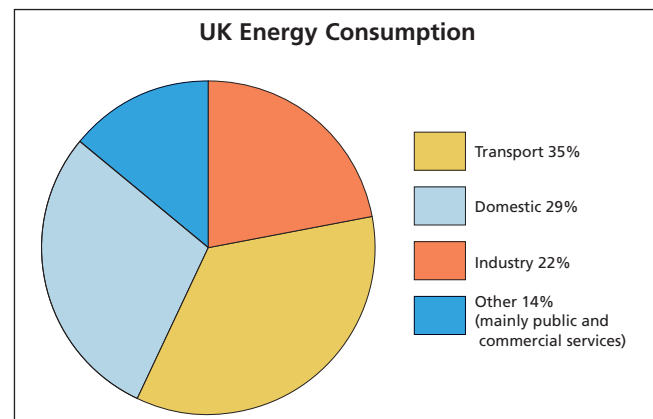
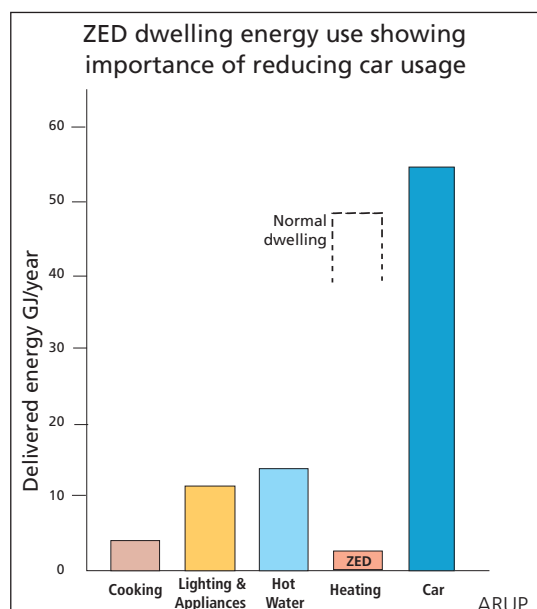
The Transport section of this Toolkit is one of the "income generating" areas of innovation. By designing out the need for private fossil fuel vehicles and achieving very significant environmental benefits, a developer can also save on parking spaces and release valuable land for development or amenity space. Low car developments are known to increase the value of properties and to improve the quality of life for residents.

Aims

- Reduce carbon emissions due to transport
- Create a pedestrian and cyclist friendly environment
- Maintain high standards of affordable mobility



Claudia on tour



Form of transport	CO ₂ emissions (kg/mile)	Eco-footprint /1000 miles (ha)
Petrol car	0.36	0.096
Electric car	0.14	0.03
Bus or train	0.1	0.048
Cycle or walk	0	0
Aeroplane	0.29	0.14

Background

A family car covering 12,000 miles/year produces as much carbon emissions as four people living in a typical modern house. Nationally, transport accounts for one-third of the UK's energy consumption, and is growing (while consumption in other sectors is levelling off). In designing a carbon-neutral development, it is as important to reduce the global warming effects of personal transport as it is to tackle the energy performance of the buildings. There are other reasons to tackle the growth of traffic. One in fifteen children are killed or injured on the road before school-leaving age. Asthma and other respiratory diseases now affect one in four children in London, and although there are many possible causes of such illnesses, there is no doubt that air pollution from cars and lorries exacerbates these conditions.



The Approach at BedZED

BedZED's design takes the emphasis away from the car, placing parking spaces around the edge of the site and keeping the heart of the development car-free. As a Home

Zone, the development has a 20mph speed limit. Pedestrians and cyclists have right of way and can enjoy the quiet, relatively car-free environment that encourages neighbourly chatting and is safe for children playing. Residents and workers benefit from lower levels of air and noise pollution.

Travel needs and patterns are extremely locally specific. BioRegional surveyed the travel patterns of 90 Hackbridge households at feasibility stage. A desk study of local facilities and public transport links was used to design green travel solutions specifically for the BedZED locality.

To formalise the commitment to minimising the environmental impact of travel at BedZED, Peabody and BioRegional committed to a Green Transport Plan (GTP) as a legal obligation under the planning agreement - the first time this has been part of a planning permission for a housing development. The GTP aims for a 50% reduction in private fossil-fuel consumption through car use, over ten years.

The GTP is specifically tailored to the BedZED location. The Plan for other developments should vary according to proximity to public transport facilities, shopping, medical services and schools. It will also depend upon residents' needs and journey patterns.

The BedZED Plan is outlined here to illustrate what can be done.

BedZED Green Transport Plan

The BedZED GTP reduces car use and car ownership at BedZED by:

- **reducing the need to travel**
- **promoting public transport**
- **offering alternatives to private car travel**



Homeport system allowing secure grocery deliveries while customer is out



Local organic produce

Reducing the need to travel

As a mixed-use development, residents can live and work on site, therefore eliminating the need to commute to work. In order to facilitate home working, all rooms are designed to be fitted with cable links that can support TV, telephone and broadband internet links. At the time of writing, there are at least 10 residents working on site, either in the workspaces or from home.

On-site facilities will include social space, bar, sports facilities and clubhouse and childcare facility, further reducing the need for residents to travel. Local shops are unlikely to take over completely from the weekly supermarket trip (the nearest supermarket is nearly 2km away), so to further reduce shopping related travel, residents are encouraged to order goods "on-line" at home or through the free community internet facility in the BedZED centre. Regular, co-ordinated deliveries of BedZED orders reduce shopping delivery miles, with discounts for bulk deliveries. This system has been applied to supermarket-type goods, and to "green box" schemes of fresh organic fruit and vegetables.

Promoting alternatives

Walking

In the UK, 21% of all journeys - generally under 1 km - are made on foot. Factors affecting people's decision to walk such short distances include quality of the local environment, levels of pollution, and perceptions of safety from traffic and street crime. Most of these factors are off-site, and beyond the scope of one development to influence. However BedZED's "home zone" design keeps vehicles to walking speed, gives pedestrians priority, provides drop-kerbs for prams and wheelchairs and good lighting and natural surveillance of paths by the houses. These are all part of making BedZED safer and bringing lower levels of air and noise pollution.



Cycling

70% of journeys made by residents of Sutton borough are under 5km, yet only 2% of journeys are made by bicycle. BedZED encourages cycling by offering

ample cycle storage, a programme of cycling events including Dr Bike maintenance sessions, cycle maintenance classes and guided rides. A resident-led group are offering an on-site cycle repair facility and are working to link in with the local cycle lane network. Cycle information packs were given to all new residents with local cycling advice and information and discounts at local bike shops. There are up to three bike spaces for each dwelling (depending on size), located close to the entrances in the ground floor hallways. There are also lockable bike parking frames for visitors and employees. BioRegional organised a series of cycle events including bicycle maintenance classes and group rides. There are now around 95 bicycles in use at BedZED with 10 residents using them as a frequent means of transport.



Public transport

BedZED is located on two bus routes, which connect to local centres of Mitcham, Sutton and Wallington. Hackbridge station is 0.7km to the south, and Mitcham Junction is 1.2km north. Both stations connect directly to Sutton, London Victoria and Kings Cross. Both are on the Thameslink line to Luton. Mitcham Junction is on the Tramlink route to Croydon and Wimbledon.



To encourage residents and employees to make best possible use of

these public transport routes, information about local bus, rail and tram services is available in welcome packs for new residents and on-line information at the community internet facility in the BedZED centre.

ZEDcars

Many journeys can be undertaken on foot, cycle or public transport but there are some journeys for which a car is the only real option. People buy cars for 'mobility insurance' and then

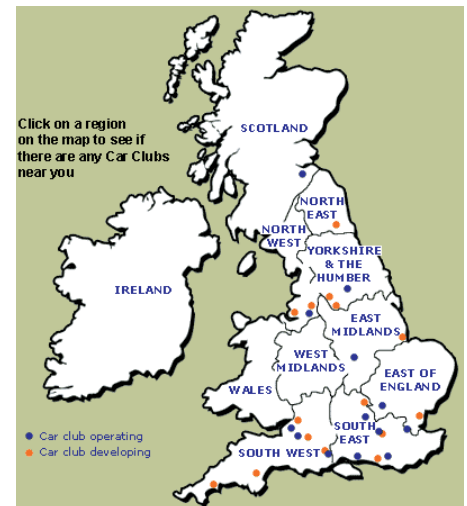
use them for most journeys because of convenience. Having paid for the car's fixed costs, it makes financial sense to use the car for as many journeys as possible.

At BedZED, a car club called ZEDcars was established by BioRegional and Smart Moves Ltd. It offers 'mobility insurance' without the fixed costs. Users pay by the hour and by the mile. This makes it possible for people to walk, cycle and use public transport most of the time but still have access to a car for those journeys that need one.

Car clubs are already successfully operating in a number of European countries. For instance, the 'Mobility' scheme in Switzerland has 18,000 members sharing 800 vehicles throughout the country, whilst Berlin's 'Stattauto' company has 5,000 members sharing 150 vehicles.

Edinburgh's 'City Car Club' shows that a member with an annual mileage of 11,000 - 13,000km could save up to £1500 per year on their motoring costs. The financial benefits of using a pool car rather than a private car are even greater at BedZED, where there is a £200 charge for an annual parking permit.

Research shows that one pool car displaces around five privately owned vehicles. Complementary usage patterns enables the same vehicles to be shared between the commercial workspace occupants (weekday use) and residents (evening and weekend use).





Electric cars

Residents who are keen to retain the use of a private car are encouraged to change to an electric vehicle. 777m² of photovoltaic panels on the buildings, with 109kW peak output, produce enough electricity to power 40 electric vehicles (the 10 year target). On-site charge points are situated next to parking spaces. The recharging infrastructure off-site in Sutton, BedZED's borough, includes a free public electric vehicle charging point in the Sutton town centre car park. Electric vehicle parking is free at BedZED, as compared with fossil fuel vehicle owners who pay £200/year. Electric vehicle owners also receive free fuel as there is no charge for the vehicle charging points.

Car parking

Standard parking requirements for the BedZED scheme, based on the Sutton UDP (1999) would have required a minimum of 121 residential spaces and a maximum of 79 non-residential spaces. The Green Travel Plan allowed the local authority to accept just 84 parking places with three allocated to the car club. Fossil fuel car owners must purchase an annual parking permit for £200.

The spaces are located around the perimeter road, keeping cars as far away from children and pedestrians as possible.

An Integrated Solution

Cutting car mileage and using alternatives is very much a lifestyle choice. Individual travel needs and patterns vary and will change over the lifetime of the development. Household car mileages will be monitored annually to review the effectiveness of the GTP.

Cost Analysis

On BedZED, bicycle storage included 13 Sheffield stands @ £65 each and 32 lock attachment points @ £60 each, giving a total cost of £2,765, all installed.¹

The Home Zone design at BedZED cost around an extra £10/m² of highways and hard landscaping compared with conventional.¹ This design included porous paving which contributes to the sustainable surface drainage as well as the Home Zone, so the extra cost is split here 50:50 between the two. Around 1,508m² @ £5/m² gives an extra cost of £7,540.

Installed Infrastructure for electric car charge points cost £13,500.¹

Total capital cost = £23,805

There is an additional cost of planning, introducing and staffing in implementing a full Green Transport Plan. Working with planners, sales and marketing staff and with residents when occupied, this cost is estimated at £45,000 for a site like BedZED. This cost can be met by the developer, by external grant funding or through residents' service charge. At BedZED, grant funding was secured.

Planning gain analysis

Compared to a conventional development on the same site, BedZED used 2,500m² less for parking and roads. This is 22.5% of the BedZED site saved and available for profitable development. On a pro rata basis for land values in the area, this equates to £400,000. But this led to an increased sales value of £4.5 million and added revenue of £1.16 million (see chapter 4).

Added value

The Home Zone and the car club are valued by the BedZED residents and so potentially add value to the development. Chapter 10 quantifies the added value of all the features of ZED developments.

Monitoring Results

Car ownership

National average car ownership levels are 1.0 per household. London residents have 0.9 cars per household whilst Surrey residents have 1.2. (BedZED lies on the boundaries of greater London and Surrey.)

At the time of writing this report, June 2003, BedZED has car ownership levels of 0.61 per household. This shows a reduction in car ownership of 32-50% compared with London and Surrey averages and meets the targets set out in the Green Transport Plan.

¹ Gardiner & Theobald Quantity Surveyors, 2001

ZEDcars

As of June 2003, ZEDcars has 2 cars, one being dual fuel LPG and petrol. There are 35 members, of which 15 are regular users and the rest are occasional users (less than one trip per month). ZEDcars members travel up to 70 miles/month in the club cars, as compared with the average Sutton resident who travels 500 miles/month.

Mileage

The BedZED Green Transport Plan target is to reduce private fossil fuel car mileage to 50% of what would be expected on a 'conventional' development in the same location. The average Sutton residents drives 6,000 miles/year (UK average mileage is 5,354miles/year²).

A survey of BedZED residents in August 2003 gave an average mileage of 2,061 miles/year, just 35% of the local average, so exceeding the GTP target.

Residents have reduced their travel, joined the car club and they use alternative forms of transport. Table 8.1 shows that average BedZED residents have reduced their CO₂ emissions by 1.3 tonnes. Individual residents who have given up car ownership have reduced their CO₂ emissions by 1.8 tonnes.

	Kg CO ₂ ¹ /mile	Typical Sutton resident	Average BedZED resident	Model BedZED resident
Annual car mileage	0.36	6,000	2,061	0
Car club mileage	0.36		75	600
Public transport mileage	0.1		900	1,800
Cycling/walking	0		300	600
CO₂ emissions		2.2 tonnes	0.9 tonnes	0.4 tonnes

Summary

Included in ZEDproduct Z, the ZED Green Transport Plan cost below £70,000 to implement and generated planning gain value of £1.16 million for investment in other areas of innovation. In addition, the environmental savings from the Plan have been measured at 1.3 tonnes of CO₂ per resident per year, or 46.8 tonnes per year for a 6-plot terrace.



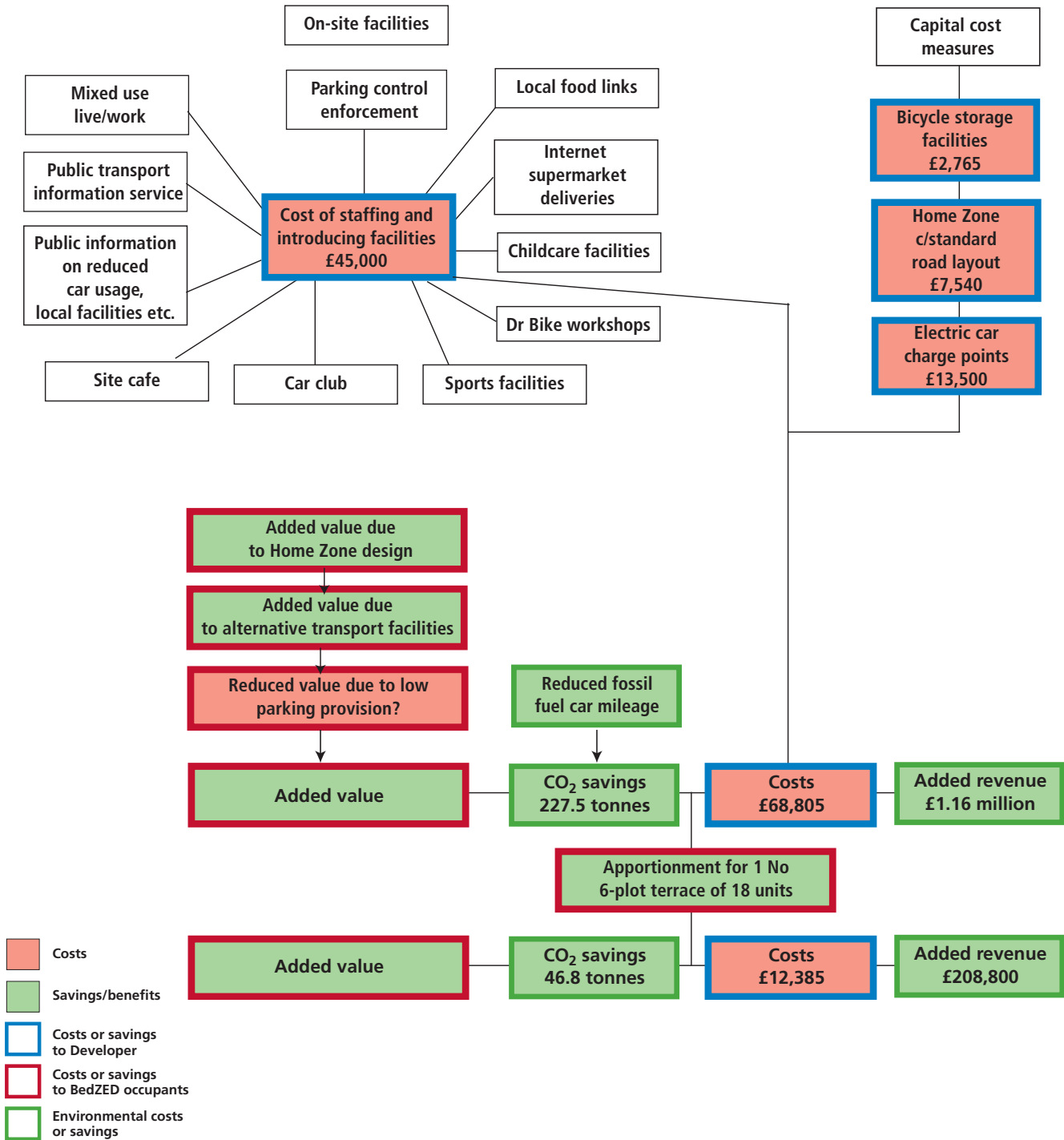
BedZED aerial view

¹ National Energy Foundation <http://natenergy.org.uk/convert.htm> (Source DEFRA March 2001)

² National Travel Survey 1999-2001

Transport

Costs and savings for BedZED's 100 units



Renewable Energy

- To meet all of the development's energy needs from renewable, carbon-neutral sources.

BedZED has achieved both carbon-neutral buildings and the potential for carbon-neutral transport by generating all its energy needs from renewable carbon-neutral sources on the site.

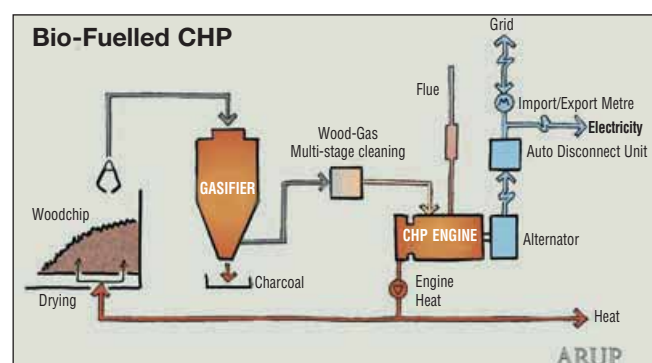
Arup

Table 9.1 shows the predicted energy consumption of a 6 plot ZED terrace based on the first year's monitoring at BedZED. The table also shows the CO₂ emissions that would result if these energy needs were met from conventional

	KWh/year	Tonnes CO ₂ /year
Space heating	24,494	4.7 ¹
Hot Water	39,420	7.5 ¹
Electricity (residential)	39,420	17.0 ²
Electricity (commercial)	19,000 ³	8.2 ²
Total		37.4

¹ Average UK domestic heat and hot water generation gives 0.19kg CO₂ per kWh, BRE
² Average UK electricity generation gives 0.43kg CO₂ per kWh, BRE
³ Estimate based on BedZED Centre office

This reduction makes it realistic to consider small-scale, on-site energy generation. On BedZED, the chosen solution is a biomass CHP plant designed, installed and operated by Exus Energy Ltd (formerly B9 Energy Biomass Ltd). This decision was largely influenced by the fact that the scheme has access to ample urban tree surgery waste that would otherwise be landfilled or burnt. The technology is based on downdraft gasification. Woodchips are fed automatically from a storage area into the drier, which uses waste heat from the engine. Chips are then fed into the gasifier where the chips are heated in a restricted flow of air, which converts them into a combustible gas (gasification). This wood gas contains hydrogen, carbon monoxide and



methane as well as non-combustible carbon dioxide and nitrogen. The gas is then cleaned, cooled, mixed with air and fed into a spark ignition engine. The engine shaft is coupled to a generator, which produces electricity. Waste heat from the engine jacket and the exhaust is tapped with heat exchangers and aims to provide all the hot water needs for BedZED.

The CHP is sized to annually generate as much electricity as BedZED consumes. The mix of residential and office uses helps to smooth out the daily electrical demand fluctuations with an import / export connection to the National Grid. This allows the constant CHP electrical output to be matched to changing demands.

Normally the CHP constant heat output is difficult to match to the fluctuating seasonal building heating demand. By eliminating the need for 90% of the building space heating, the CHP needs to supply just domestic hot water, whose daily total demand is relatively constant throughout the year. However, across each day the domestic hot water demand fluctuates greatly, so heat storage of some form is needed. This is provided in a simple cost-effective way by large domestic hot water cylinders in each dwelling / workspace so that the CHP can continuously trickle-charge them. The demand fluctuations are again smoothed out by the mixed use. The peak site hot water demand is designed to match the peak CHP heat output, so avoiding the cost of peak load boiler plant. The CHP heat distribution pipework is sized to need low pumping energy. Cylinder immersion heaters provide a hot water standby facility.

Arup

When commissioned, the CHP unit will be fully automated, with un-manned start up and shut down and strict, automatically controlled operating parameters. The plant is designed to run 24hr/day for 7 days/week, although at BedZED it will run for 18hrs/day due to noise restrictions (see below). The plant is equipped with automatic de-ashing. Weekly attendances are required for receiving woodchip deliveries, checking and filling oil and water levels. Scheduled maintenance is carried out on a quarterly basis.

There have been considerable delays in commissioning the CHP at BedZED. At the time of writing, it is achieving 18hrs/day running time but requires full time manning. Downtime for equipment modifications are still too frequent but are getting less frequent. All homes are, however, receiving the hot water they need.

Noise

Noise restrictions at BedZED are very stringent due to the proximity of homes (37dBA at 20m). The engine is enclosed

in an acoustic room with silencers on the exhaust and other connections. The

acoustic design was tailored to the particular frequency bands that the plant emits. On paper, it was not possible to meet the stricter noise level requirement that applies between 01.00 and 04.00 am, so the BedZED CHP will automatically switch off at these times. In practise, noise from the CHP is very low and there have been no complaints.



Emissions

BedZED is situated in a smoke control area under the Clean Air Act. This means that only "smokeless" fuels can be burnt.

Alternatively, unauthorised fuels can be burnt in "exempt" furnaces. The BedZED CHP does not produce emissions that are any different to any other gas-fired engine. Its exhaust gas consists of carbon dioxide, nitrogen and water with traces of NOx similar to a gas-fired CHP system. Nonetheless, because the wood gas is generated from an unauthorised fuel, Exus Energy have obtained an Exemption from the DETR.



Fuel supply

Wood chip is a bulky, low value commodity and the efficient handling, processing and transporting of this fuel are critical to the operating costs and therefore the viability of the CHP. At the time of writing this report, the first woodchip deliveries are taking place. Over the commissioning period, woodchip supply practices will be fine tuned for time savings and cost efficiency. When fully operational, the plant will use 20 tonnes/week which is one lorry delivery per week. It is expected that woodchip will cost £28/tonne delivered.

Exus Energy have supplied the CHP as a turnkey package. The equipment comes with a guarantee that, once commissioned, it will be running and generating heat and power for at least 85% of its possible running hours ie. 85% availability. More conventional CHP schemes would guarantee 90% or even 95% availability. The Exus plant is new technology and cannot guarantee such high levels of running time.

The Peabody Trust owns the plant. The operation and maintenance will be carried out by Exus. The BedZED estate is on a private wire system, so occupants can only buy heat and power from the Peabody Trust. Sale of heat and power to occupants will be regulated by OFGEM as would any other energy supplier so unit prices for heat and electricity will be much the same as for conventional supply. The saving for occupants will come from the fact that they will be buying less energy units per year. One possible future development is that after a suitable pilot period, an Energy Services Company will be set up to manage energy supply at BedZED.

Environmental savings

Once fully commissioned, the CHP will generate 726,000kWh of electricity and 1,452,000kWh of heat each year. Not all the heat will be delivered to homes and used. Some will be used to dry woodchip and some will be produced at a time when it is not needed and so will be wasted. An estimated 400,000kWh of hot water will be delivered and used in homes and workspaces at BedZED, replacing gas and saving 76 tonnes of CO₂ each year. All electricity will be used either on site or sold to the grid, therefore replacing the need for other forms of carbon producing electricity generation. This saves 312 tonnes of CO₂ each year on electricity and a total of 388 tonnes/year.

Operational Costs

The late commissioning of the CHP has meant that BedZED has gone through a winter with a high dependence on back-up electric immersion heating. Consequently, electricity use has been higher than planned and Peabody Trust have shouldered unexpected availability charges for using the grid import facility. Residents' bills have still been very low, below the national average but over the winter, Peabody were buying expensive top up electricity from the grid instead of generating their own. With regular 18hrs/day running, revenue from heat and power should start to be more as planned.

At the time of writing, it is therefore only possible to quote predicted operational costs, based on a fully commissioned plant achieving its design output and 85% availability.

Annual running costs

Wood fuel ²	£29,120
Ash disposal ²	£1,500
Operation & maintenance ³	£10,000
Metering and billing ⁴	£8,500
Grid connection charges ⁵	£5,000
Management / administration ⁵	£5,000
Total	£59,120

CHP Cost analysis

Costs for a CHP plant and infrastructure distribution system serving 100 units are tabulated below. Figures are supplied by Gardiner & Theobald, taken from the BedZED project.

COMBINED HEAT & POWER PLANT & INFRASTRUCTURE DISTRIBUTION	
CONSTRUCTION COSTS¹	£
SITE WIDE	
Design, manufacture, supply and installation of wood chip fuelled CHP System	240,000
Apportioned allowance for enclosure for CHP plant	75,000
Infrastructure works for site wide heating distribution	40,000
Super-insulated heating distribution from CHP plant to dwellings	34,000
Sub-total	389,000
WITHIN DWELLINGS	
Heating distribution within dwellings from main supply circuit tee-off to towel rails and to 300 litre Hot Water Cylinder with immersion circuits expansion vessel - calculated on 100 units, @ £1,825 per unit (see ZEDproduct O)	182,500
Saving from omitting central heating system compliant with 2000 Building Regulations @ £2,500 per unit	-£250,000
Net saving taken and accounted for in Thermal Chapter 5	-£67,500
Sub-total	389,000
Add General Building Contractors costs, site set-up, management, supervision, overheads, profit and the like @ 10%	£38,900
Total CHP Plant, Enclosure and Heating Distribution Construction Cost	427,900
Apportionment for 6-plot terrace of 18 units	77,022

¹ Gardiner and Theobald QS 2001

² BioRegional

³ B9 Energy Biomass Ltd

⁴ estimated

⁵ Peabody Trust

Photovoltaic panels

BedZED hosts 777m² of photovoltaic panels integrated into the building fabric. They generate 108,000kWh of solar electricity every year which displaces some 46 tonnes of CO₂ emissions.

The energy consumption and CO₂ emissions associated with the manufacture of PV panels is more significant than with other forms of energy generation. Environmental payback



periods for the invested CO₂ burden for PV are 3-4 years as compared with large scale power stations whose embodied CO₂ is negligible compared with their output. Even BedZED's CHP has a relatively low embodied CO₂ which is paid back in less than 1 year of operation. The embodied CO₂ of the PV equipment at BedZED is 259 tonnes, or 13 tonnes/year if spread over the 20 year design life.

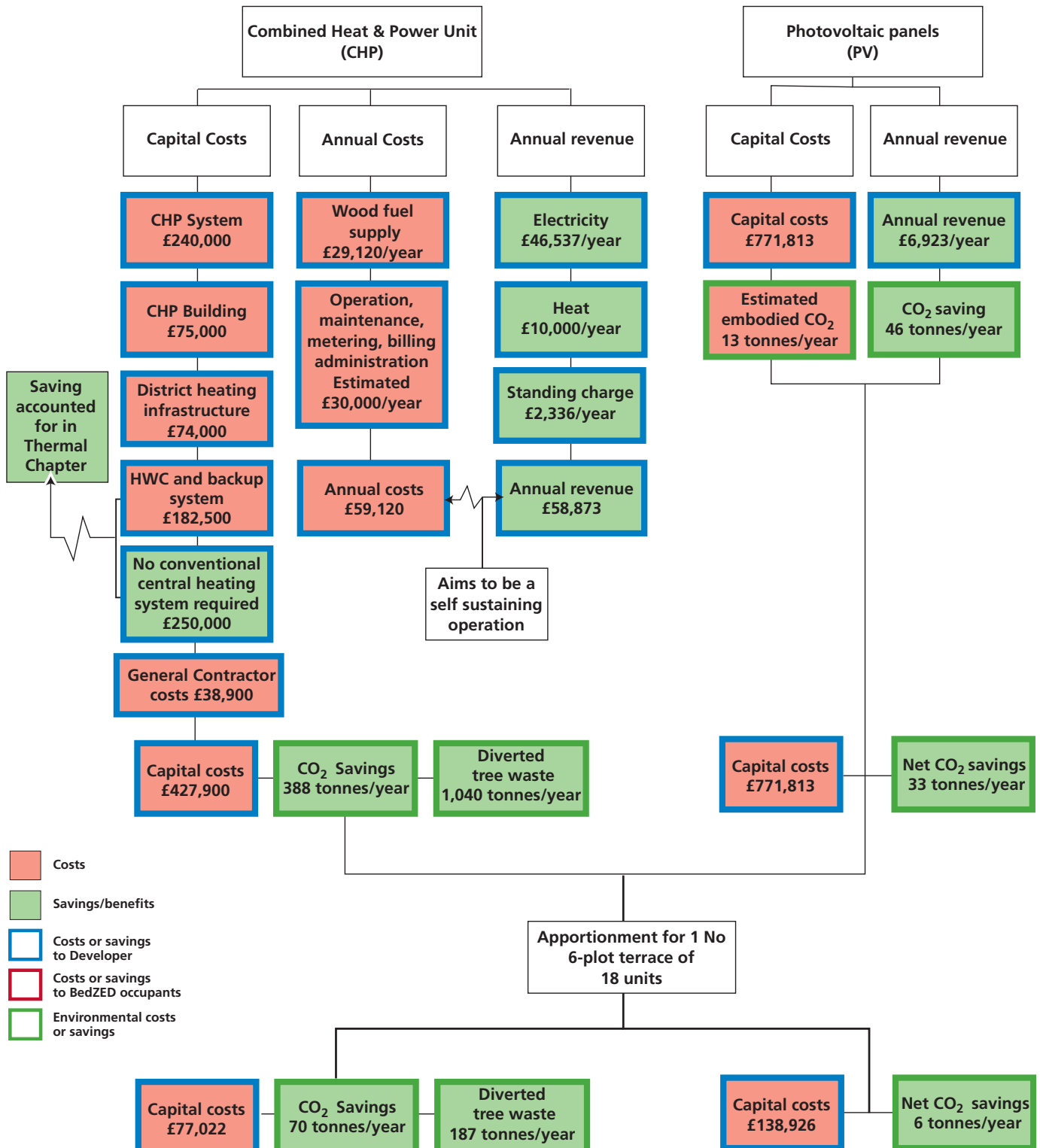


Suppliers of PV equipment have data on the embodied CO₂ of their products as do the Building Research Establishment.

PHOTO-VOLTAIC CELL INSTALLATION & DISTRIBUTION			
CONSTRUCTION COSTS ¹	£	CONSTRUCTION COSTS	£
PV installed within sealed double glazed roof light units	127,957	Extra over installation costs for wiring and drilling PV cables into window frames.	20,000
PV installed within sealed double glazed vertical units (south elevation glazing)	71,593	Electric car charging points connected to LV and street lighting distribution	15,000
PV laminates installed as roof mounted units on prepared concrete deck	140,150	Extra over trunking required for cables from south elevation mounted PV to roof mounted PV, say	18,000
Installation and associated fixings, connections and sundry items (i.e. monitoring, freight expenses etc.)	186,948	Profiled aluminium coping to head of south elevation roof light to act as PV cabling route, say	30,000
	£526,648	Sub-Total	£701,648
INFRASTRUCTURE & DISTRIBUTION		Add General Building Contractors costs, site set-up, management, supervision, overheads, profit and the like @ 10%	£70,165
In situ concrete deck with aluminium support brackets for roof-mounted PV laminates.	62,000	Total PV and Distribution Installation Construction Cost	£771,813
Electrical connections and wiring and connection to LV distribution.	20,000	Apportionment for 6-plot terrace	£138,926
Additional builders' work in connection, say	10,000		

Renewable Energy Supply

Costs and savings for all of BedZED's 100 units



Quality of Life

The ZED concept aims to provide sustainable homes without the hair shirts. Occupants can live and work within their fair share of the earth's resources without sacrificing convenience or mobility. In fact, it offers occupants a higher quality of life, increased levels of convenience, healthier lifestyles and cheaper running costs.

Research and monitoring into how well BedZED is achieving these broad ambitions is on-going. After one full year of occupation, residents are being interviewed about all aspects of BedZED as part of a 3 year social geography research study. The results of this study will report qualitatively on people's expectations and on how they feel their quality of life has been affected by moving to BedZED.

The range of ZED features that may enhance quality of life for occupants are categorised below:

Internal environment

- Good daylight design
- Conservatory
- Good quality design

External environment

- Sky gardens and balconies
- Quiet, safe, low car Home Zone design

Financial savings

- Bill savings - water, electricity and heating
- Car free living - occupants who drive under 15,000km / year are financially better off as car club members than owning a private car

Health

- Low allergy, well ventilated, thermally stable internal environment
- Fresh local produce delivered to the door
- Reduced commuting, excellent bicycle facilities and fewer shopping trips, combined with the quiet, safe streetscape and the neighbourliness has the potential to offer a lifestyle of low stress and more healthy exercise.

Sense of community

- ZED Bar
- Neighbourliness

Convenience

- Car club membership removes the hassle of car ownership and maintenance
- Food deliveries - internet and local farm
- On-site facilities:
- Childcare facilities
- Sports facilities
- ZED Bar
- Ready fitted A-rated white appliances
- Green lifestyle information service
- Community composting service

Possible negative features could include:

- over looking (in some cases)
- over heating in summer (in some cases)
- lack of parking



It is beyond the scope of this report to analyse how many tonnes or cubic metres of happiness are generated annually at BedZED. This chapter therefore reports numerically on how much these qualitative aspects are actually worth in monetary terms. There are three main sources of evidence for placing a financial value on these features:

- Anecdotal discussions between neighbours
- Interviews as part of the research project
- Comparison of sales and resale values against local market prices

ZED features are worth different values (if any) to different people. Some features are more important to some individuals than other features. This report attempts to define an overall average added value rather than assign any specific values to individual features.

Anecdotal informal discussions In neighbourhood chats and conversations at the ZEDbar, BedZED residents have reported that sky gardens are worth around £5-10,000. They also suggest that sunspaces are worth £5,000-£15,000 depending on the dwelling size. Residents say they would be willing to spend this amount extra for having those facilities. For a 6-plot terrace, this provides £150,000 in added value.

Research interviews

The social geography research study is funded by the ESRC (Environmental and Social Research Council) and by the Peabody Trust. Interviews with residents after they have been living in BedZED for one complete year concur with the anecdotal reports, with residents valuing their sunspaces and sky gardens at £10-15,000 each. The study also shows that around 2/3rds of the BedZED residents moved there specifically because of its environmentally friendly living or because of its innovative design. The findings of this study will be published in 2004, available from Kings College, London.

Sales and resales values

A marketing study has been carried out by FPD Savills property consultants to assess whether premium values are achievable on ZED properties. The table below shows a comparison of current sales prices at BedZED with current new build sales in the same postcode. All unit types are showing a premium value over the current market value.

Unit type	Average current sales figures (Aug 2003)		% Difference
	Local market	BEDZED (estimated)	
1 bed flat	£125,000	£150,000	20.00%
2 bed flat	£175,000	£190,000	8.57%
3 bed flats/terraced houses	£225,000	£265,000	17.78%
4 bed semi	£300,000	£350,000	17.78%
Average	£206,250	£238,750	15.75%

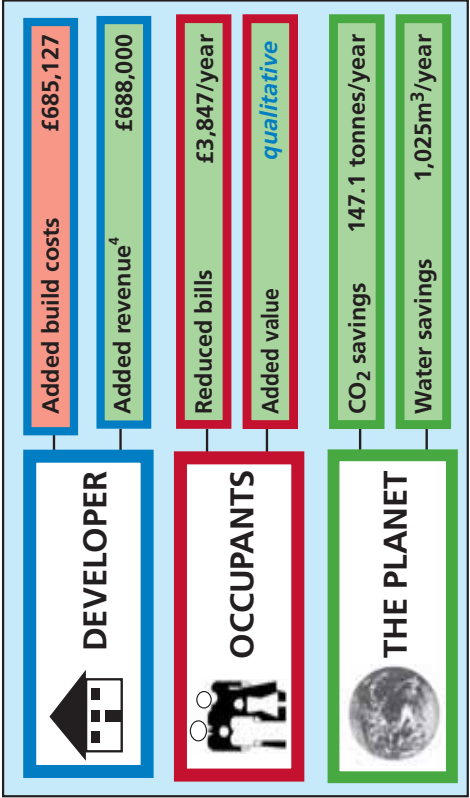
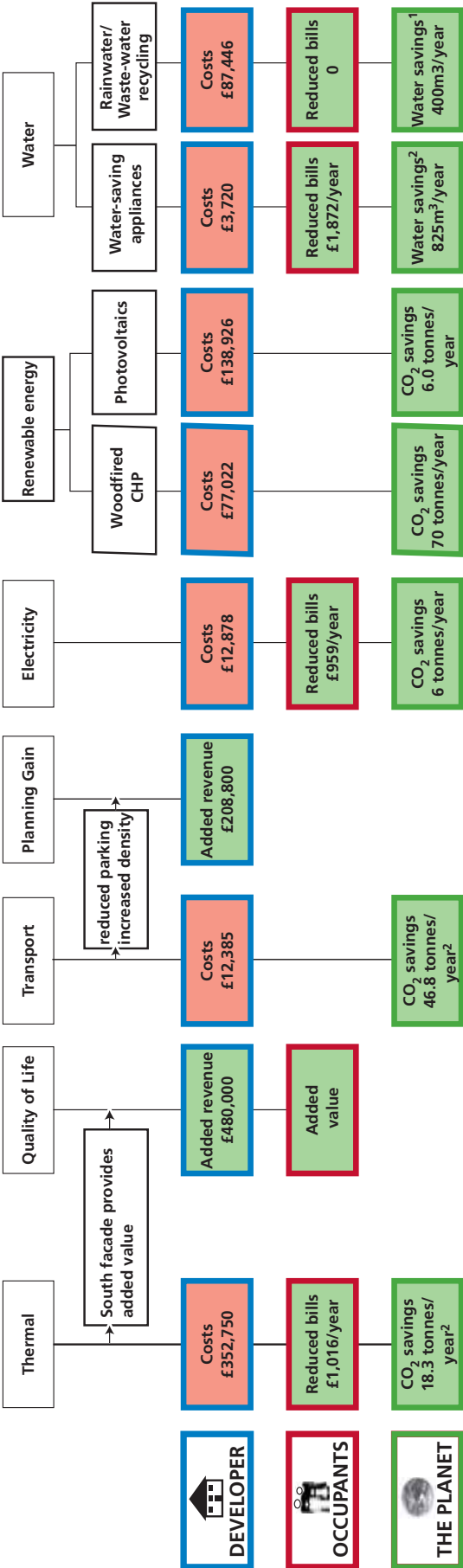
Resale values at BedZED have kept pace with the rising house prices in South London, so maintaining their premium value. The premium values shown above allow a 6-plot terrace to generate a premium of £480,000 compared with conventional new homes (average £27,000 per home). When combined with added revenue from planning gain, only 75% of this premium is required to pay for the additional costs of the full ZED specification.

The Savills report lists all of the features in the list above as contributing towards the premium that the units experience. For more information on resale values and target markets, copies of the Marketing Report are available from Julian Clarke at FPD Savills.



Project Balance Sheet

Cost/benefit analysis for a 6-plot terrace



- Costs
- Savings/benefits
- Costs or savings to Developer
- Costs or savings to BedZED occupants
- Environmental costs or savings

1 assuming washing machines use green water
2 monitored savings
3 predicted when CHP fully commissioned
4 from planning gain and added value

12

Conclusion

Overall

Building a 6 plot terrace to a ZED specification costs a predicted extra £685,127 or £41/ft², compared with a conventional development built to 2000 Building Regulations. However, for each terrace, the ZED planning gain tool allows a developer to generate an extra £208,800 in extra profit. Also, the added value of the light, spacious dwellings with sky gardens and on-site services combined with the attraction of significant bill savings have the potential to bring the developer a further £480,000 in added value. Developers can therefore choose to design for very considerable environmental savings and still recover their costs.

Monitoring results

BedZED has performed very much as predicted, with radical savings in carbon emissions in all areas. The monitoring results are summarised in the table below showing average reduced consumption across the development compared with the national average. Numbers in brackets show a reduction compared with new 2000 Building Regulations. Results are shown against the original aspirations and targets set out when the BedZED scheme was initiated in 1997.

	Monitored reduction	Target reduction
Space heating	88% ¹ (73%)	90%
Hot water	57% ¹ (44%)	33%
Electricity	25% ¹	33%
Mains water	50%	33%
Fossil fuel car mileage	65%	50%

¹Temporary electric space heaters and immersion heaters are accounted for under space heating and hot water.

Thermal Performance

The building fabric specification which is accounted for in the Thermal chapter adds an extra £342,615 to the build costs of a 6-plot terrace, or £20/ft². This makes up 60% of the additional build costs. The building fabric is however designed for a 120 year design life and, with proper maintenance, will deliver annual carbon savings throughout that time.

Of this, some £285,000 is from the glazed south façade and the roof lights. The daylight design of

the ZED properties is one of the main features that bring added value, so this build cost element must not be considered for CO₂ savings alone. It must be offset against the potential added value, demonstrated by FPD Savills in chapter 10.

Transport

The Green Transport Plan in a ZED development costs only £12,385 for a 6 plot terrace, but results in 46.8 tonnes of CO₂ savings per year. In terms of lifetime, it is difficult to predict over how long these carbon savings will be delivered as they are dependent on individuals and their lifestyle choices. On the one hand, enthusiasm could peter out after just a few years and people could get back to using their cars in line with the national average. Alternatively, congestion charging, fuel price rises and the rapid growth in car clubs we are currently seeing could mean that these savings go on being delivered for decades.

The Green Transport Plan is essential for the planning gain tool. At BedZED, every square metre that was saved in parking or road space, due to green transport measures, was built on and used to generate the added revenue that balances the added build costs.

White Appliances

For a very modest £12,878, a terrace can be fitted out with the most efficient electrical appliances, saving residents £959/year and cutting CO₂ emissions by 6 tonnes/year. Similarly, water saving appliances cost a modest £3,720 and save residents £1,872/year and 825m³ of water/year. These measures are easy and off-the-shelf but they only deliver savings over the lifetime of the appliance ie. around 5 years. To fit out homes with the best A-rated appliances requires no specialist expertise and hardly any effort. A simple websearch using the details in this report to find the best current models is all that is required to make these significant savings.



Water

Rainwater and wastewater recycling facilities added £87,446 to the cost of a 6-plot terrace at BedZED. They do not result in any bill savings to residents but they could save some 400m³ of mains water every year over the lifetime of the plant. There is significant potential to reduce the added build costs for these items. For example, a developer may choose to opt only for waste water treatment and recycling and omit the rainwater collection. This would save on rainwater harvesting equipment. It would also mean the storage tanks could be much smaller. They would be designed for steady flow instead of erratic rainfall patterns, so the large volume storage function would be removed. Alternatively, a developer could design for rainwater harvesting and storage and omit the wastewater treatment and recycling. Conventional mains sewage is very energy efficient compared to small scale treatment plants and where mains sewage connection is cheap and convenient, it is difficult to justify the extra expenditure of a small scale plant on environmental grounds.

Renewable Energy

The renewable energy generating equipment at BedZED adds £215,948 capital costs but also saves 76 tonnes of CO₂ per year. This annual carbon saving will be delivered for the design life of the CHP and the PV panels (20 years). As renewable energy solutions develop and achieve economies of scale, they will be cheaper and will reduce in risk. Developers should take advantage of the many grant funding opportunities available in this area, particularly for photovoltaic panels, when choosing the best solution. ZEDproduct R in the "From A to ZED" offers a number of options for this, including solar hot water systems and wood pellet boilers as well as the wood-fired CHP and photovoltaics used on BedZED. In the future, it is hoped that as energy prices rise and volume production of these technologies bring capital costs down, these will be self-financing, paying back their capital cost investment with revenue from energy sales.

Appendix

Note 1 – Baseline thermal data

The baseline thermal data is based on predictions by BRE for new build houses under 2000 Building Regulations, calculated with the SAP method and standard occupancy. Predictions are based on five house types: detached, semi-detached, bungalow, terraced, and flats. The baseline comparative space heating requirement for new builds used in this report of 59 kWh/m²/year, is an average for semi-detached, terraced, and flats as these are the most comparable to a ZED 6-plot terrace.

The BRE hot water baseline data for new build is given per household, based on average floor areas with standard occupancy, and also calculated using the SAP method.

The UK average data is based on BRE data for total UK households energy consumption for space heating divided by the number of households.

Note 2 – Comparative bill data

Heating and hot water bills range between £2.51 and £3.79 /m²/year. If the typical UK household is 100m², the average UK household spends £314/year on heating and hot water (assuming gas provides this energy). London households are consistent with this national average.

Homes built to 2000 building regulations are more efficient. They are also smaller at 89m² for a 3.5 bedroom semi. Annual bills are predicted to be £1.74/m²/year or £155/year.

Note 3 – Baseline electricity consumption data

The BRE's data for UK average energy consumption for lighting, cooking and appliances is 4kWh/person/day. This is irrespective of whether cooking is gas or electric. It is therefore directly comparable with the BedZED electricity consumption for lighting, cooking and appliances.

Note 4 – Baseline electricity bills

The average UK household spends £256 /year on electricity (at 7.36p /unit including standing charge), with the average London household spending £251 /year (at 7.23p /unit, including standing charge). These are based on national average electricity consumption levels for cooking, lights and appliances. Electricity charges range from 4.5 to 10.5p /unit including standing charge.

About BioRegional

BioRegional is an entrepreneurial charity, which initiates practical sustainability solutions, and then delivers them by setting up new enterprises and partnerships around the world. We assist and encourage others to achieve sustainability through consultancy, education and informing policy.

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Published by BioRegional Development Group, BedZED Centre, 24 Helios Road, Wallington, Surrey, SM6 7BZ. Registered charity no. 1041486