BedZED – Beddington Zero Energy Development, Sutton

HOUSING ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GENERAL INFORMATION REPORT 89

CONTENTS

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Main cover photograph courtesy Linda Hancock

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BED ZED

1 INTRODUCTION

Located in the London Borough of Sutton, the Beddington Zero-Energy Development (BedZED) is a joint initiative of the Peabody Trust and BioRegional Development Group. Their objective was to enable people to live sustainably without sacrificing a modern, urban and mobile lifestyle. For example, BedZED incorporates a Green Travel Plan, which minimises the need to travel but promotes alternative methods of transport where travelling is necessary. In the words of the developers, the aim was to make sustainability 'easy, attractive and affordable'.

Apart from producing no net carbon dioxide (CO_2) emissions from energy use, BedZED meets targets across a range of environmental, social and economic concerns:

- environmental – low-energy and renewable fuel, including biomass combined heat and power (CHP) and photovoltaics (PVs), zero net carbon emissions, water saving, reclaimed materials, Green Travel Plan, biodiversity measures, and private gardens for most units
- social – mixed tenure, two-thirds affordable or social housing, lower fuel costs, healthy living centre, community facilities, sports pitch and 'village square', crèche, café
- economic – locally sourced materials, workspace for local employment and enterprise, locally available renewable energy sources.

At the time of its design and construction, BedZED represented state-of-the-art for sustainable housing in the UK. The project won an award for excellence in RIBA's Housing Design Awards in July 2000, two months after construction started.

View along the mews

This General Information Report describes the various elements featured in the scheme. The authors, BedZED architect Bill Dunster and Glyn Carter of co-developers BioRegional Development Group, aim to encourage the kind of holistic strategies essential if architects, developers and planners are to:

- reconcile higher-density living with an improved quality of life
- protect agricultural and green belt land from urban development
- reduce the global environmental impact of urban regeneration in the UK
- support local economies and communities
- source good materials and energy within the local bioregion.

The early sections discuss the issues surrounding sustainability and the background to the project. Section 4 onwards focuses on specific aspects of the BedZED development. Key information on the overall development is shown in Appendix 1 and details of the project partners are included in Appendix 2. References are shown on page 36.

This Report was written while construction was in progress, and is intended to provide information to construction and development professionals. Certain elements of the project may change before completion.

Nothing in this Report represents a description for sales purposes, nor does it form part of any contract, commitment or other form of undertaking.

Pedestrian eye-view of BedZED from the main road

2 WHY SUSTAINABILITY?

LOCAL SUSTAINABILITY IN BedZED

Local economic sustainability is promoted by building networks of local suppliers, with the scheme forming a focus for local economic and community activity.

Sustainable lifestyles are made easy by organising a ZED car pool (including electric vehicles), bulk home deliveries of groceries and direct, cost-effective supply of seasonal organic food from local farms. It is affordable, so there is no call for residents, workers and neighbours to sacrifice their standard of living and quality of life to protect the environment.

LEARNING TO WORK WITH NATURAL FORCES

If human activity is to be sustainable over the long term, the natural systems can provide us with a model. Contrary to Tennyson's view of nature as 'red in tooth and claw', natural systems are actually based on:

- balance between different species
- harmony with the environment
- recirculation of nutrients and energy.

BedZED follows this eco-system approach by integrated planning that exploits the positive links between different elements. To take just one example of this, the way in which land is fully utilised is a key innovation that has spinoff benefits that support affordable car-use for residents:

1. by placing workspaces in the shade zone of the dwellings, workspaces benefit from northern daylight, while the housing gains from a southern aspect...
2. ... this optimises the energy performance of high-density, mixed-use development...
3. ... while creating jobs in residents' back yards (actually, under their back gardens)...
4. ... therefore there is less need to travel to work and less need to own a car...
5. ... but people will still wish to use a vehicle now and again, so BedZED's car pool is planned...
6. ... allowing people who may not be able to afford a car in the first place to have access to one.

Other such links flow through the scheme. It is this integrated approach that makes the low-energy design cost effective, thus maximising the value of the development as a whole.

LOCAL PRODUCTION FOR LOCAL NEEDS

It's not just a question of working with nature on a global scale. We also need to do so on a local level. Especially in Britain, a fertile island with a temperate climate that should be able to meet the needs of its population, it is possible to localise almost all of our activity and impacts down to a regional level. Waste should be processed close to where it is generated (the proximity principle), and recycled locally into new resources. Importing large amounts of food, fuel and other goods wastes resources, contributes needlessly to global warming, and increases transport pollution and congestion. It may even be deemed unethical, with strife, scarcity and famine an ever-present reality in exporting countries.

TARGET DENSITIES FOR NEW BUILD IN THE UK

Taking a snapshot of UK land use, we have the following finite resources to support both the human population and sufficient biodiversity to maintain a sustainable national ecology.

Land use figures for 1971 (Source: Best, 1981)

	Hectares
Arable cropland	5 666 000
Total agricultural land use	11 515 000
Woodland and forest	1 115 000
Urban areas	1 646 000
Total non-agricultural	3 511 000
Brownfield sites	28 800
Total UK land area	23 481 800

The UK currently imports about 70% of its nutritional requirements, and given that our island has been cultivated by humans for millennia, it is safe to assume that most surfaces capable of producing crops are being cultivated. If we also assume that existing woodland and forest are already required for biomass energy, wood for construction and biodiversity, building new homes on agricultural land cannot be sensible for a bioregional, locally sustainable future. New development should be restricted as far as possible to existing brownfield sites, minimising use of the green belt around existing cities and loss of agricultural land.

WHY SUSTAINABILITY?

Furthermore, working at the local and regional levels adds immediate and tangible benefits to the long-term imperative of global sustainability. It maximises local productivity, brings local employment, and reduces the leakage of wealth, and helps bring communities together with a real stake in their collective future. The opportunities for melding environmental and economic systems can best be identified and acted on at this level, and often the local knowledge is already available.

BedZED shows how housing developments can contribute to global and local sustainability by minimising the use of finite resources (see the box top right), ensuring that renewable resources actually are renewed, and maximising usage of the constant energies available from the sun.

The goal of sustainable development is generally recognised. The social and economic needs, especially of those who live in relative or absolute poverty, must of course be met. But this must be achieved in ways that protect the environmental capital that future generations will depend on.

All over the world there are large and small-scale initiatives linking objectives of greater equality and security, social progress in health, education and housing, with environmental protection. BedZED is part of this growing movement.

SUSTAINABLE USE OF RESOURCES

There are two kinds of resources – finite and renewable.

Finite resources, such as coal, oil and minerals, will eventually run out. These we must use carefully and wisely. We must give ourselves time to find substitutes, to avoid sudden disruption that shortages bring to already volatile markets.

Renewable resources include the atmosphere, water, soils, plants, livestock, and indeed we humans and our own labour. We can tap these resources, but not so much that they cannot regenerate themselves. Soils must be kept fertile, forests managed, water kept clean and the atmosphere in balance. Waste and pollution must be kept below levels at which they can harmlessly be absorbed. Other resources are based on cosmic energies – the sun's heat and light (which drive the climate, winds and rain, and enable plants to grow), gravity, tides, and geothermal energy. There is more than enough of these to meet our needs, and we have the technology to exploit them.

UNSUSTAINABLE DEVELOPMENT

As the world's population rises, with aspirations by people for a higher standard of living, the strains on the environment continue to increase.

Burning finite fossil fuels increases the level of greenhouse gases in the atmosphere, contributing to global warming. Sea levels are rising, and weather patterns changing, which, in combination with changing farming practices and deforestation, lead to increased risk of floods.

Mining, logging, unsustainable farming practices, and urban development are threatening species and habitats. Environmental catastrophes such as pollution spills affect not just the natural environment, but also human health and the economy. Disputes over land, oil and water undermine international peace and consume vast quantities of valuable natural resources.

In the developed world our own transport systems cause pollution, with the associated health risks. Although standards of living for many are improved, we must ensure that it is not at the expense of quality of life.

GOVERNMENT TARGETS

The Government has committed itself to a 20% reduction target for all greenhouse gases by 2010, in parallel to its agreement to a 12.5% cut by 2012 under the 1999 Kyoto Protocol on Climate Change. Meanwhile, the Royal Commission on Environmental Pollution proposes a 60% reduction in annual CO_2 emissions by 2050[1].

3 DEVELOPMENT HISTORY

PARTNERSHIP

BedZED arose through four separate strands of activity coming together:

- architect Bill Dunster's work on zero-fossil-energy housing and workspace
- BioRegional's vision of local sustainability
- Sutton Council's commitment to sustainability in the borough, including promoting a model approach to energy-conscious development
- the Peabody Trust's long-term commitment to innovation in construction, providing high-quality affordable housing and minimising fuel poverty.

In the mid-1990s, architect Bill Dunster constructed a prototype passive solar home (Hope House) for his family in East Molesey, Surrey. The house proved to perform well. In parallel, he produced the Hopetown, a design concept for high-density, mixed-use terraces maximising solar gain and maintaining green space with roof gardens. Chris Twinn of Ove Arup refined the building physics and showed how zero-fossil-energy use could be achieved. An indicative cost model by quantity surveyors Gardiner & Theobald demonstrated its financial viability.

Meanwhile BioRegional promoted to Sutton Council the idea of sustainable housing that used local materials and encouraged sustainable lifestyles. BioRegional secured funding from the World Wide Fund for Nature International to promote the model, identify a potential site for the first ZED, and secure a development partner.

In 1998, the council-owned site at Beddington was identified, and the Peabody Trust committed itself to a lead role as developer. The design team was set up to develop a carbon-neutral urban model suitable for a wide range of sites.

BioRegional consulted local stakeholders to assess grassroots support for a ZED scheme on the site. Two exhibitions were held for local people. The vast majority of comments were favourable, and a number of constructive suggestions were made and, where possible, taken up, including the need for sports facilities and space for childcare and community health promotion.

Hope House, architect Bill Dunster's own home and studio, and a prototype ZED house

Dennis Gilbert

LAND SALE AND PLANNING AGREEMENT

The site, 1.7 hectares (3.5 acres) on the Hackbridge/Beddington border, was offered for sale by sealed bid by London Borough of Sutton in May 1998. The planning brief called for up to 305 habitable rooms, and this density limit created the market value of the site. The brief did not require mixed use. A Section 106 agreement would require the purchaser to provide a football pitch and clubhouse, and contribution towards social housing provision.

The Peabody/BioRegional bid included letters of support, a scheme description that quantified the long-term environmental, economic and social benefits, and a summary of how ZED would be a mechanism for the Council to deliver objectives under its environmental and planning policies.

DEVELOPMENT HISTORY

Hope House, interior view of conservatory

The bid was not the highest in cash terms, and after consultation with the Government and legal representatives, Sutton's borough valuer agreed that the Council did have the right to dispose of land at less than market value provided that 'the benefits flowing to the borough outweigh the loss of any capital receipt achievable'.

Sutton Council engaged environmental economists Aspinwall & Co to place an independent financial value on BedZED's benefits over the conventional competitor. The highest environmental factor that could be valued turned out to be reduced CO_2 emissions during an imputed 20-25 year operational life. Based on 50 ECU/tonne (the marginal cost of meeting the EU's target for CO_2 reduction), the value of the ZED scheme over the conventional competitor was between £100 000 and £200 000. Not all benefits could be so rigorously costed, but were clearly present:

- employment opportunities
- educational value
- reduced waste and pollution
- attracting environmental businesses to the area.

In September 1998, Sutton Council agreed to accept the Peabody/BioRegional bid, and the Secretary of State's consent for the land sale was given in January 1999. To ensure that the developers would deliver the promised environmental benefits, the Council required an integrated transport plan, and a scheme specification summarising the main environmental targets.

4 BedZED – CONCEPT, DENSITY, FORM

UK NEW-BUILD TARGETS

The Government predicts a requirement for approximately 3.8 million new homes in England by the year 2021, mainly generated by increasing numbers of single-person households as more young people live alone, by more unmarried or divorced people, and by a growing proportion of older people. This represents a 19% increase in the number of UK households from 1996[2]. If these new dwellings were built at current average densities for new development, they would cover an area of land larger than Greater London.

The Government's target is to build 60% of new dwellings on the 58 000 hectares of existing brownfield sites[2]. This implies a target of 40 dwellings per hectare. However, the issue is not just one of new housing. New urban developments also need open space, community, leisure, health and educational facilities, and locations for employment. So site densities for brownfield housing developments should aim to be higher. There is plenty of scope – even 100 dwellings per hectare is less dense than some of the most lively inner-city areas in English towns and cities (parts of Bloomsbury and Islington in London have up to 200 dwellings per hectare).

At these higher densities all of the required new homes could be provided on just two-thirds of the available brownfield land. With fresh stocks of redevelopment land becoming available through the urban regeneration process, re-occupation of empty houses, and with a gradual increase in suburban densities around public transport nodes, the ZED model shows how it is possible to provide the additional homes without needing to build on agricultural land, while providing new open green spaces within our towns and cities.

01 – A flat, brownfield site: Close to bus routes and a main line railway station

02 – Site sold with outline planning permission for the following residential use: 64 homes @ 3.5 hab rooms per home proposed on a 0.64 ha plot. Three-storey housing @ 100 homes/ha, a car pool and parking shared between workspace and commercial uses

03 – ZEDfactory team propose an additional: 1560m^2 net workspace on the same 0.64 ha plot. Density is 203 workspaces/ha @ 12m^2/workspace, with car pool shared with housing

04 – Integrated live/work community: 100 homes and 203 workspaces/ha: With a shared car pool, parking and skygardens placed on workspace roofs enabling the densification of suburbia around public transport nodes without net loss of amenity.

Funding of carbon-neutral urban infrastructure through planning gain

HOW BedZED WILL CONTRIBUTE

BedZED is a compact mixed-use urban development with 82 units, 271 habitable rooms, plus over 2500 m^2 of space for offices, studios, shops and community facilities. The housing is a mix of one- and two-bedroom flats, maisonettes and town houses. The workspaces provide jobs in a suburban area close to public transport, and give residents an opportunity to avoid commuting, and reduce car use. Rental income from the workspaces funds the slight increases in building costs of an ultra-low-energy, super-insulated specification.

BedZED's developers' view of sustainability means that new development should be restricted as far as possible to existing brownfield sites. Building

BedZED – CONCEPT, DENSITY, FORM

on agricultural land cannot be sensible for a bioregional, locally sustainable future. Especially around cities, we need land for local use and benefit, for food crops, biomass energy, wood products, biodiversity and amenity.

BedZED is a model for integrating solutions to the contradictory objectives of urban planning. It achieves an overall density of 50 dwellings per hectare, 120 workspaces per hectare, and over 4000 m² of green open space per hectare. At these densities nearly three million homes could be provided on existing brownfield land, at the same time as providing all the workspace needed for the occupants.

Without the sports facilities, and by placing car parking under the village square, the ZED model can achieve 105 homes plus 200 workspaces per hectare, staying within a three-storey height restriction. (See Appendix 1 for more details of space and densities.)

A high occupation density (over 500 people living and working per hectare for the core area) is made possible by integrating workspace and housing within a compact cross-section. The workspaces' roofs are colonised as gardens for the adjacent dwelling, giving most units a private garden, at densities that would normally allow only a balcony.

The workspaces are in the shade zone of the dwellings, and lit by large triple-glazed northlights set between the roof gardens, leaving the houses to benefit from the southern sun and useful passive solar gain. A football pitch and small village square provide sports facilities and open space for residents and the surrounding community.

FORM

Four different typologies have been designed at BedZED, loosely based on traditional English urban forms, each with different subdivisions creating a variety of flat types:

- south-facing terraces with front gardens
- terraces with workspace and vehicle mews
- pedestrian-only mews with gable-end entry workspace and café/shop
- housing with space for community activities such as childcare, health and arts.

These are integrated so that one building does not steal sunlight from its neighbours. The scheme is highly optimised, and approaches the highest density for mixed use capable of benefiting from useful amounts of passive solar gain, daylighting, and outdoor space. It therefore could provide a basic model for sustainable urban development, equally appropriate to town centres and (as at Beddington) suburban areas where residential and employment land overlap.

North-south section through the scheme, showing south-facing dwellings and north-facing workspaces

BedZED – CONCEPT, DENSITY, FORM

Site plan

5 TACKLING ENERGY ISSUES

The Government's targets will be achieved by more efficient and cleaner power generation (including CHP); reducing methane and other greenhouse emissions; generating 10% of electricity from renewable sources; and better energy efficiency in households and the service sector. Buildings (including houses, shops and offices, and construction) are responsible for around half of all Britain's carbon emissions, and it is forecast that there will be a 13% increase in household CO_2 emissions from 1990 levels by 2010[3].

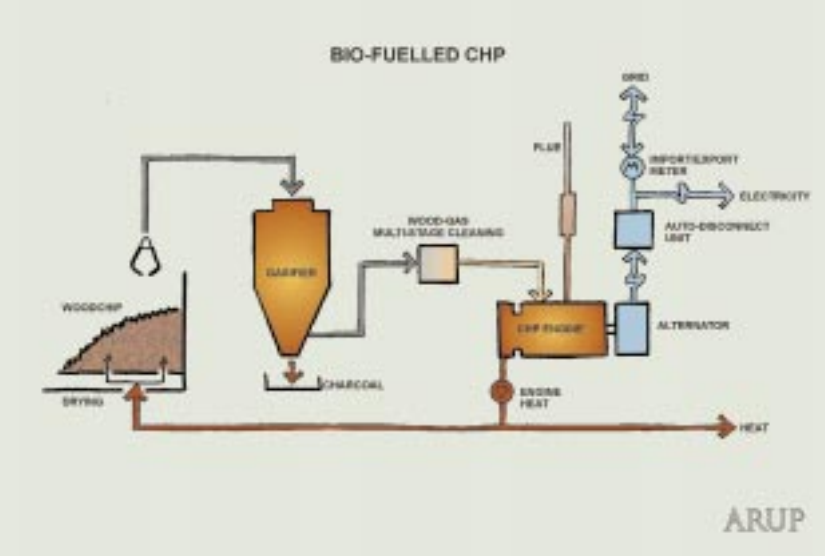
The Beddington 'zero (fossil) energy development' is Britain's first urban carbon-neutral development. It is a powerful argument for the feasibility of a zero-carbon target for all new build. If new development avoids adding to the problem of global warming, there is proportionately less pressure on the far more complex issue of making the existing stock more energy efficient, while still meeting carbon reduction targets.

BedZED's zero-carbon 'total energy strategy' is achieved via:

- energy-efficient design of the buildings – reducing heat losses and utilising solar gain, to the point where it is feasible to eliminate conventional central heating systems altogether
- energy-efficient and hot-water-saving appliances to reduce demand – this sets the capacity for the CHP system
- use of renewable energy sources – wood-fuelled CHP (trees absorb CO_2 as they grow, and return it to the atmosphere when burnt); PV power integrated into the sunspace roofs means that BedZED will become a net exporter of renewable energy
- a green transport plan (see Section 6) – minimising residents' use of fossil-fuel cars and the need to commute to work.

REDUCING DEMAND – ENERGY CONSERVATION AND PASSIVE DESIGN

A 300 mm 'overcoat' of super-insulation to the roofs, walls and floors keeps in the warmth, so that sunshine, human activity, lights, appliances and hot water provide all the heating needed. The insulation is outside the structure, avoiding



The biomass-fuelled combined heat and power unit will supply BedZED's hot water and electricity needs over the year

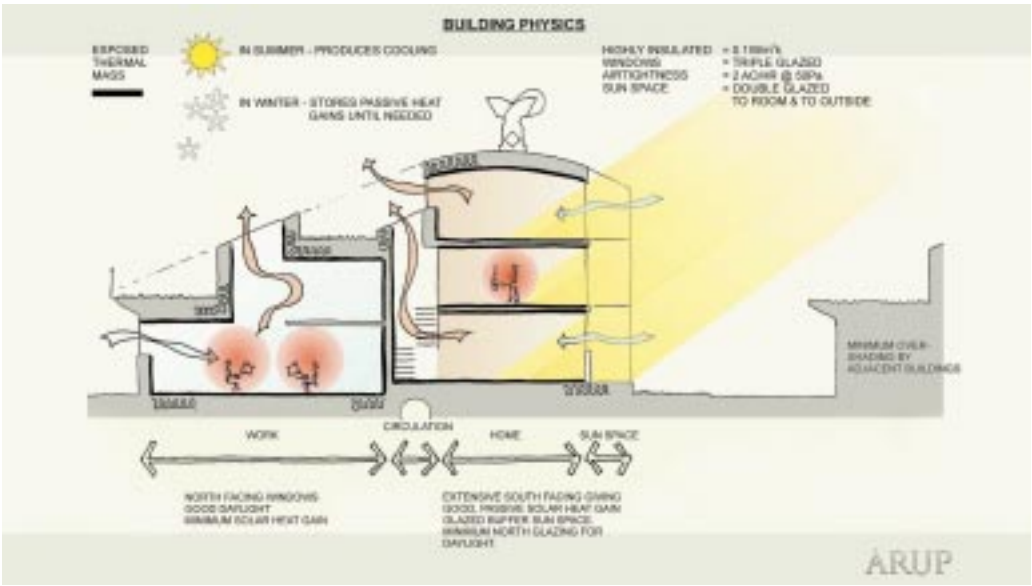
Element	95 Regs	BedZED	BedZED material
Roof	0.25	0.10	300 mm styrofoam
Exposed walls	0.45	0.11	300 mm rockwool
Floors	0.45	0.10	300 mm expanded polystyrene
External windows, doors and rooflights	3.30	1.20	Argon-filled triple-glazing

Table 1 Fabric U-values (W/m^2K) – BedZED compared with housing to 1995 Building Regulations elemental method (Source: General Information Report 53[4], Table 4)

	95 Regs	BedZED target	Note
Space heating	7962 (gas)	0	1100 kWh/yr equivalent from fabric heat storage of passive gains
Hot water	4548 (gas)	3650 (heat)	Consumption largely governed by occupant
Cooking	656 (gas)	590 (electric)	
Lights and appliances	3000 (electric)	2700 (electric)	
Pumps/fans	175 (electric)	20 (electric)	
Total	16 341	3650 CHP heat 3310 CHP electricity	

Table 2 Energy demand (kWh/yr) – BedZED housing compared with housing to 1995 Building Regulations

TACKLING ENERGY ISSUES

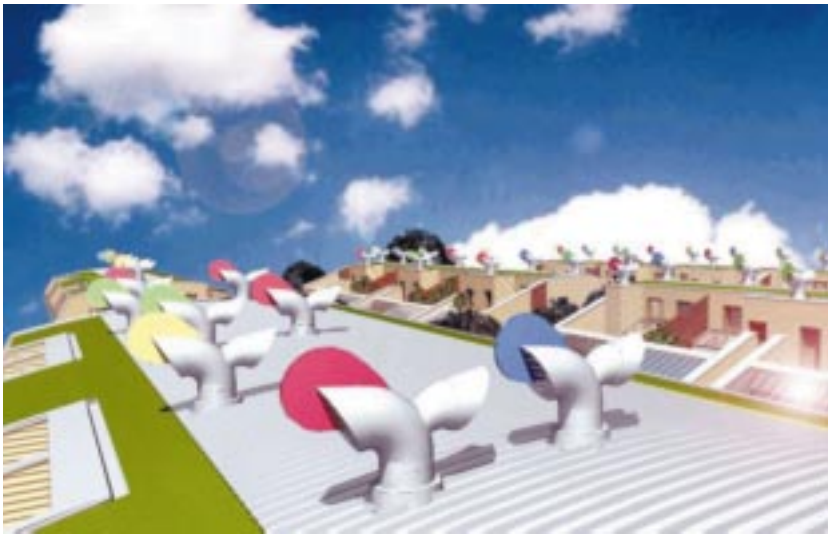


BedZED will be heated by a combination of passive solar and internal gains, with temperatures moderated by a thermally massive structure

thermal bridging and exposing the thermally massive concrete ceilings, walls and tiled floors to the accommodation. This provides enough heat storage to prevent overheating in summer, and to store warmth in winter, releasing heat slowly on overcast days.

Triple-glazed, argon-filled windows with low-emissivity glass, large panes and timber frames further reduce heat loss. Well-sealed windows and doors, together with the concrete construction, give a good level of airtightness. Heat exchangers in the passive, wind-driven ventilation system recover up to 70% of the heat from outgoing stale air.

Specially designed rooftop wind cowls use the wind to draw warm stale air up from inside, and direct fresh air downwards over a passive heat exchanger



Most of the residential glazing faces south to receive maximum sunlight. Unheated double-glazed sunspaces form an integral part of each dwelling. In summer the outer windows open to create open-air balconies. Ground-floor levels of northern blocks are stepped up by 700 - 2000 mm, reducing overshadowing of ground floor windows. The levels are built up using contaminated soil from the site, sealed under the concrete slab.

BedZED homes achieve a theoretical SAP rating – the Government's Standard Assessment Procedure for Energy Rating of Dwellings (1998 Edition) – of 150. Compared to a standard suburban home built to 1995 Building Regulations, a 60% reduction in total energy demand, a 90% reduction in heat demand, and a 50% reduction in energy bills are predicted[5]. A household living in a three-bedroom BedZED maisonette will save up to £240 per year on household energy costs (if billed at normal electric utility unit rates). Typical energy consumption figures are shown in Table 2.

TACKLING ENERGY ISSUES

By placing the spaces for employment and community use in the shade zones of the housing terraces, the tendency for summer overheating of workspaces (due to the occupants, equipment, and sunshine) is avoided, along with the need for energy-wasting fan-driven ventilation or air-conditioning. Large north-facing rooflights ensure adequate daylighting, so reducing the energy demand for artificial lighting.

COMBINED HEAT AND POWER

The CHP unit generates electricity, and distributes hot water around the site via a district heating system of insulated pipes. These deliver constant heat to oversized domestic hot water cylinders, keeping them 'charged-up'. The cylinders have electric immersion heaters for emergency back-up. They are in cupboards within each home and office, positioned centrally so that they can be opened to double up as a radiator in cold spells.

The 130 kW_e (ie 130 kW of electric power) CHP plant satisfies both the electrical and heat demand of the project due to three interrelated factors:

- average loads are reduced
- the design evens out the normal fluctuations between summer/winter and daytime/evening space-heating demands
- the domestic/commercial mix also evens out the daily electrical demand to more closely match the CHP output.

The CHP heat output needed is about 10% of the boiler output for an equivalent conventional project. The flattening of peak loads means that the capacity of the CHP plant can be reduced, and the boiler installation normally needed by a CHP system for peak backup is avoided. Emergency backup is provided from the electricity grid and by stored hot water.

The generator engine is fuelled by a combustible mix of hydrogen, carbon monoxide and methane gases, produced from woodchips by an on-site gasifier. These come from tree surgery waste from nearby woodlands – waste that would otherwise go to landfill. The demand is 1100 tonnes per year, or two 15-tonne lorry-loads a week. In the longer term, tree surgery waste can be supplemented with short rotation willow coppice from the adjacent ecology park. See Appendix 3 for the area of short rotation coppice (SRC) needed to supply BedZED.

London produces 51 000 tonnes of tree surgery waste per year (which could rise if local authorities develop plans for recycling park and garden waste). This carbon-neutral fuel can be commercially viable, and could be used in similar developments while waiting for the price of solar technologies to fall.

Excess electricity production at any time is fed into the grid, which returns extra power (on a green tariff) whenever there is a peak of electricity demand. The designs allow a 5% margin to cover hours that the CHP is out of action (beyond the

		KWh/day peak
Peak winter (design-day) heat/hot water demand	Residential	1720
	Non-residential	1440
	Pre-drying of woodchips for CHP plant	Surplus
CHP heat output		4680

Table 3 Peak heat demand (kWh/winter design day) and heat supply (figures from Ove Arup & Partners and B9 Energy Biomass Ltd)

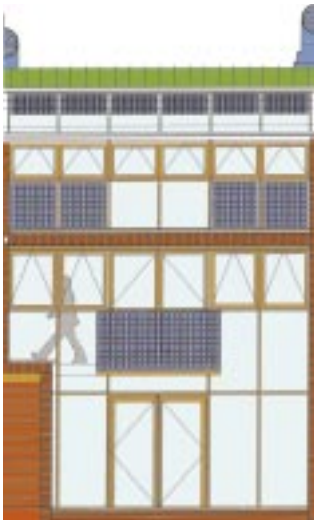
	KWh/yr
Residential	407 000
Non-residential	347 500
Other – eg street lighting	57 500
Total	812 000
CHP electrical output (130 kW @ 18 hours/day)	854 100

Table 4 Predicted annual building electricity demand and supply (figures from Ove Arup & Partners, B9 Energy Biomass Ltd)

	KWh/yr
Fossil fuel demand – 14 conventional vehicles	161 517
Electricity demand – 40 electric vehicles	83 229
PV electricity supply	97 000
Renewable PV electricity surplus (transport)	13 771
Target net carbon emissions (transport)	39.9 tonnes CO_2/yr

Table 5 Transport – annual energy demand targets after 10 years (figures from BioRegional and Ove Arup & Partners)

TACKLING ENERGY ISSUES



Photovoltaic panels will be mounted on south-facing elevations

Woodchip store under construction. An automatic grab will carry woodchips to the gasifier hopper, part of the CHP plant

six hours overnight that it will be turned off, when servicing and maintenance can take place).

Actual demand will depend on users' habits and lifestyles, and will be carefully monitored. Residents can easily assess their everyday energy and water use through meters prominently placed in kitchens – these will also act as a reminder and incentive not to waste energy.

PHOTOVOLTAICS

PV power was originally considered as a means of providing all the building's electrical needs, with evacuated tube solar collectors to provide hot water. With a payback period currently of more than 70 years the CHP alternative was far more cost effective.

The PV financial payback period drops by a factor of about five, to about 13 years, if the electricity is used to displace transport fossil fuel, with its high tax levels. A successful EU Thermie project identified that 777 m^2 of high-efficiency mono-crystalline PV panels could be integrated in the sunspace roofs. These panels generate enough solar electricity to power 40 electric vehicles for approximately 8500 km/year[6]. See Section 6 for more details.

A conventional household's car energy use is comparable to that consumed in the home[4], so for BedZED car energy could greatly exceed domestic consumption, and become the major source of occupants' direct carbon emissions. Using PV power to charge electric vehicles means that residents have a practical option to reduce their direct contributions to global warming to zero, while also reducing urban air pollution. (They will still make indirect contributions, through the food, clothing and other goods they consume.)

TOTAL CARBON BALANCE

A total carbon balance for BedZED has been considered, based on the building energy modelling and the Green Travel Plan targets. Energy use in BedZED's buildings will be carbon-neutral, with surpluses of renewably generated electricity from the CHP and PV panels being fed into the grid. With the phasing-in of electric cars and other Green Travel Plan measures (see Section 6), individual residents will be able to reduce their direct contribution to global warming to zero.

Co-developers BioRegional have calculated that if energy targets (including transport) are met, carbon emissions will be just 4% of the level resulting from an equivalent conventional development[7].

COMPUTER MODELLING

Building physics engineers Arup used advanced computer modelling to analyse the dynamic thermal effects of the building form and materials. The modelling was based on explicit finite difference for unsteady heat flows and radiosity for separate long-wave and short-wave radiated heat flows. It also factored in the body heat of occupants, activities such as cooking and running office equipment, and the effects of energy-efficient appliances. This allowed room condition predictions using real weather sequences and a 'what-if' design scenario.

The modelling identified the importance of thermal inertia using high mass construction for storing the variable winter heat gains until they can usefully contribute to the space-heating needs. It also demonstrated that extensive south-facing glazing does not need external shading, if used in conjunction with large areas of room exposed thermal mass in domestic applications. Extensive use has also been made of balcony and sunspace floors to reduce the amount of high-angle summer sun reaching the inner glazed screen. Large areas of opening windows and doors allow good ventilation of the sunspaces in summer, with opening rooflights and windows on the north elevation encouraging cross-ventilation.

6 GREEN TRAVEL PLAN

A family car covering 19 000 km (12 000 miles) per year produces nearly as much carbon as four people living in a typical modern house[8]. Nationally, transport energy accounts for approximately one-third of the UK's energy consumption, and is growing (while other sectors' energy consumption is levelling off[11]). Achieving zero-carbon buildings highlights the need to reduce or eliminate the global warming effects of personal transport.

There are other, perhaps more immediate, reasons to tackle the growth of traffic. One in 15 children is 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 the conditions.

To formalise their commitment to minimising BedZED residents' environmental impact from travel, the Peabody Trust and BioRegional have committed themselves to a Green Travel Plan as a legal obligation under the planning agreement – the first time this has been part of a planning permission for a housing development.

By reducing the need to travel, and promoting alternatives to the car, BedZED's Green Travel Plan aims for a 50% reduction in fossil-fuel consumption from car use, over 10 years. For the remainder, PV power is available for electric vehicles. This not only means zero carbon emissions, but also zero sulphur, carbon monoxide, nitrous oxides and particulates given off by conventional vehicles, and reduced noise.

REDUCING THE NEED TO TRAVEL

As a mixed-use development, BedZED offers the opportunity for residents to live and work on site, therefore eliminating the need to commute to work. Some of the jobs on site will also be taken by neighbouring residents, further reducing overall commuting impacts.

It is hoped that a telecommuting business centre offering video conferencing and access to expensive equipment normally found in central London offices can be encouraged to set up on site, offering provision to BedZED businesses, and to other local firms.

The opportunity to develop on-site facilities such as a shop, café and community facilities could further reduce the need for residents to travel. Any shop is unlikely to take over completely from the weekly supermarket trip (the nearest supermarket is nearly 2 km away), so to further reduce shopping-related travel, residents will be able to order goods 'on-line' through a community internet facility. Regular, co-ordinated deliveries of BedZED orders will reduce shopping delivery miles. This system can be applied to supermarket-type goods, and to a 'green box' scheme of fresh organic fruit and vegetables, with a possibility of negotiating discounts for large orders to bulk deliveries.

BedZED is close to two rail stations, and has a bus stop on its doorstep; there is also a tram station at Mitcham Junction

GREEN TRAVEL PLAN

PROMOTING ALTERNATIVES TO THE CAR

Walking

Over 80% of journeys under one mile are made on foot[8]. Factors affecting people's decision to walk even short distances include quality of the local environment, levels of pollution, and perceptions of safety from traffic and street crime. Most of these are off site, and beyond the scope of one development to influence. However BedZED's design uses 'home zone' principles, with the road layout keeping vehicles to walking speed, pedestrian priority, drop-kerbs for prams and wheelchairs, good lighting and natural surveillance of paths by the houses. These are all part of making BedZED safer for children, pedestrians and cyclists, and bringing lower levels of air and noise pollution for residents and workers.

Cycling

Around 70% of journeys made by residents of Sutton borough are under 5 km, yet only 2% of journeys are made by bicycle[9]. BedZED will encourage cycling. All dwellings will be allocated cycle storage space. The spaces range from those within homes to lock-on points in workspace areas. There will also be lockable bike parking frames for visitors and employees, and workspace showering facilities. The site has easy access to Sutton's existing cycle network.

Public transport

The development is located on a major road used by two bus routes, which connect to local centres of Mitcham, Sutton and Wallington. Buses also go to Hackbridge station, 0.7 km to the south, and Mitcham Junction 1.2 km north. Both stations connect directly to Sutton and London Victoria, and both are on the Thameslink line to north London. 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 will be widely available, including on-line updates at the community Internet facility. Discounted season tickets will be negotiated for residents and workers.

Subject to demand, the car pool will offer a minibus/people-mover shuttle service to and from the stations at peak times. Again, subject to demand for travel to different destinations or at different times, existing bus routes may be supplemented by Sutton Community Transport.

REDUCING THE IMPACT OF CAR USE

Car pool

It is planned to establish a car pool, to be called ZEDcars, offering residents, businesses, and employees the opportunity to hire a vehicle by the hour. The car pool will be set up with a range of vehicles. This offers the 'mobility insurance' that a car provides, plus extra flexibility, without the expense of owning one.

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

Car pools are already operating successfully in a number of European countries, and research shows that one pool car displaces around five privately owned vehicles. Complementary usage patterns enable the same vehicles to be shared between the commercial workspace occupants (weekday use) and residents (weekend use). Community car pools are also likely to reduce the number of car journeys made by members, as they make better use of public transport season tickets and bicycles, and because they are more likely to car-share within the pool.

For more or less the same cost of running a private car, a BedZED resident could run a well-serviced bike, travelling regularly by public transport, and have the flexibility of using a pool car or hire car once or twice a week.

Electric cars

Residents who are keen to retain the use of a private car will be encouraged to change to an electric vehicle. Up to 40 electric vehicles will be

GREEN TRAVEL PLAN

powered by 777 m² of PV panels on the buildings, which will be producing 109 kW peak output. It is hoped to achieve this level of electric car ownership over 10 years, with financial support through the Energy Saving Trust's 'Powershift' cashback scheme (which subsidises the purchase of clean-fuel vehicles), a waiver on parking fees, and through the car pool.

On-site charge points will be inexpensively fitted to the kerbside bin-stores and near to parking places. The recharging infrastructure off-site should be further advanced by this time – a free public electric vehicle charging point is already available in Sutton town centre car park.

Car parking

The Green Travel Plan allowed the planning authority (Sutton) to accept parking standards 30% below those required on a conventional development. The parking ratio is 1:1 – one parking space per dwelling (including spaces occupied by pool cars). They are not allocated to dwellings, so empty spaces during the day can be used by employees driving to the site.

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

Ian Aitkinson

A Citroen Balingo electric van at Hope House, with rear floor pan cut back to fit rear bench-seat, side windows and a sunroof. The cost of the van, enough photovoltaic panels to run it for around 5000 miles/year, and the modifications, are still less than the price of a fossil-fuel-powered people carrier, and the electric vehicle has similar functionality in urban areas

The annual travel that can be achieved for the same price as running a car are given below.

Item	Cost (£)
Depreciation	685
Road tax	150
MOT test fee	28
Road rescue service	70
Insurance	250
Annual BedZED parking permit fee	500
Net loss of interest on cash used to buy car	104
Fuel	717
Tyres, servicing and maintenance	250
Total annual cost	**2754**

Therefore a BedZED resident giving up a private car in favour of a pool car could run a well-serviced bike and travel regularly by public transport, taxi and hire car for the same price as running a private car.

Item	Cost (£)
Running a bike:	
– capital cost of £300, depreciating over three years	100
– two inner tubes, lubricant, brake blocks	20
– annual service	50
Five local trips by bus/train per week @ £2 per trip	520
Two minicab journeys per week @ £5 per trip	520
One day car hire per week @ £28.95 per day	1505
Total annual cost	**2715**

(Source: Analysis by BioRegional Development Group)

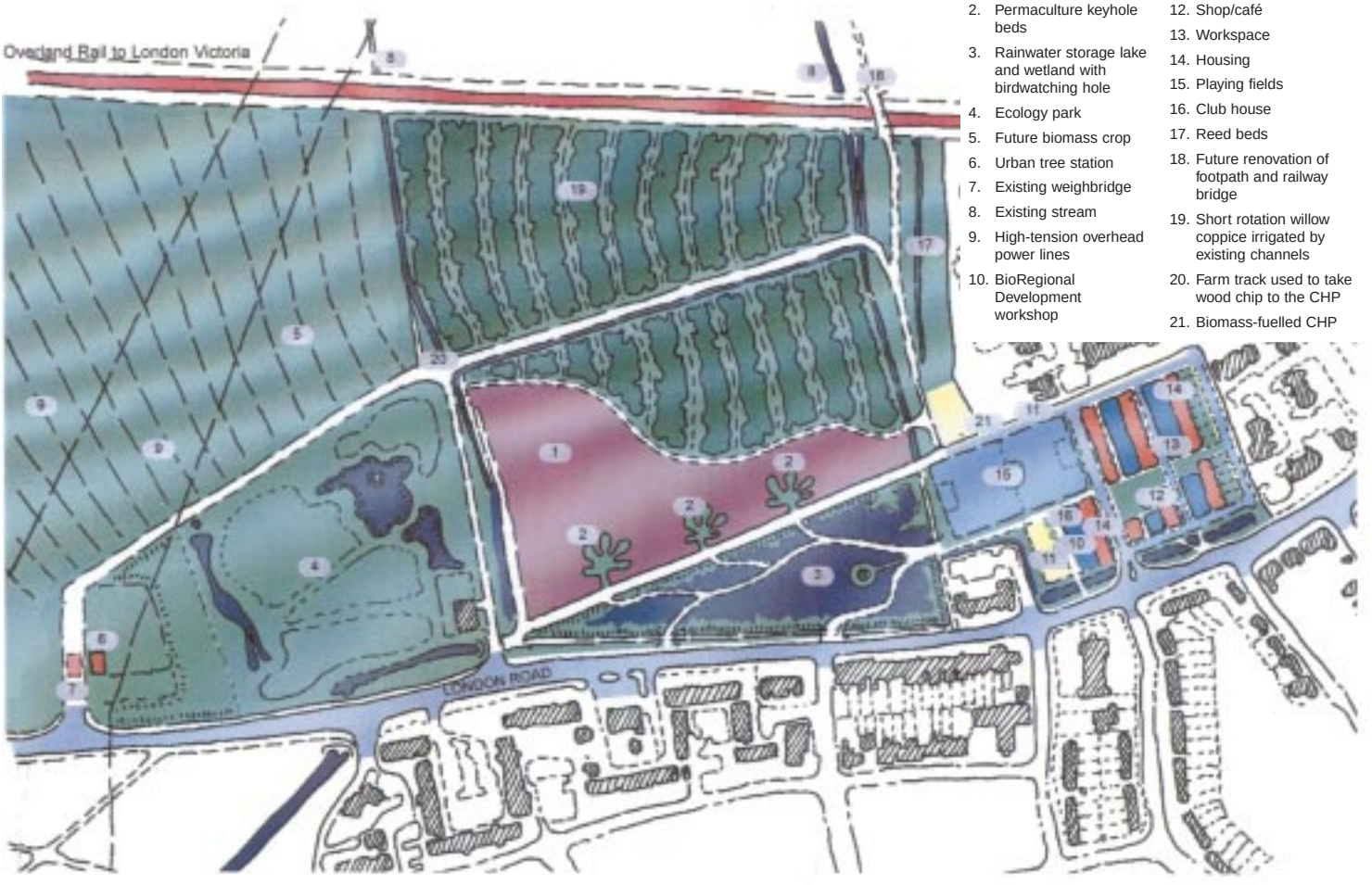
7 GREEN SPACE

BEDZED BIODIVERSITY PLAN

BedZED has aimed to provide the best possible habitat for biodiversity in the urban environment through implementing a number of measures, including the following.

- Existing features of the site have been retained, including the line of mature horse chestnut along the boundary (one tree had to be felled at the access road junction).
- Existing ditches have been developed into water features, eg planting emergent vegetation along the fringes of the ditch, and designing-in shallow areas to encourage dragonflies and water voles.
- Advantage has been taken of all planting opportunities around the site. The village square, the roof garden planters and all site landscaping use native plants, including plants that encourage particular species such as buddleia for butterflies, and night-scented plants for bats.
- Features of the buildings have been designed to encourage wildlife, eg incorporating bat roosts into the weatherboarding, feeding and nesting stations to encourage tree sparrows (which are declining rapidly in the UK), and sedum-planted roofs to provide an insect habitat, which in turn supports birdlife.

Sutton Council and BioRegional are to create a new eco-park next to BedZED



1. Lavender fields
2. Permaculture keyhole beds
3. Rainwater storage lake and wetland with birdwatching hole
4. Ecology park
5. Future biomass crop
6. Urban tree station
7. Existing weighbridge
8. Existing stream
9. High-tension overhead power lines
10. BioRegional Development workshop
11. Parking
12. Shop/café
13. Workspace
14. Housing
15. Playing fields
16. Club house
17. Reed beds
18. Future renovation of footpath and railway bridge
19. Short rotation willow coppice irrigated by existing channels
20. Farm track used to take wood chip to the CHP
21. Biomass-fuelled CHP

GREEN SPACE

Use is made of 'native provenance' – local seed, and trees grown from seed from the area.

The ZED residents' handbook highlights the ecology of the site, identifying local species. It advises on native planting opportunities in the roof gardens, how to encourage wildlife, and how to avoid using garden pesticides and fertilisers.

The BedZED Biodiversity Plan will complement the 18-hectare ecology park to be established on the adjacent site. Play and amenity space, wetlands and wildlife habitats, and economic activity such as lavender growing, urban forestry and wood coppicing, are all proposed for the eco-park.

COMMUNAL OPEN SPACE

Communal open space is provided by a 90 m x 45 m sports pitch, with clubhouse and changing facilities, and a small village square at the heart of the development – this features trees and seating, and is part of the pedestrian route through the development.

As with other community facilities being set up as part of the scheme, these are resources for the whole of the neighbouring community.

PRIVATE GARDENS

The high amenity value at BedZED is not just provided by the public open space. Nor is it provided just by the sunspace/balconies on the southern face of every dwelling unit. Equally rare for high-density social housing, BedZED incorporates private gardens for 71 of the 82 units.

These are in the form of roof gardens on top of the workspaces for the flats, and ground-level gardens for the houses and maisonettes. Access to the roof gardens is directly from the flats, or by private footbridges over the mews between blocks. These gardens form small 'outdoor rooms', and vary in size from 8 m^2 to 25 m^2, with most of the roof gardens at 16 m^2.

A sports pitch and clubhouse for local use are being provided as part of the scheme

8 WATER STRATEGY

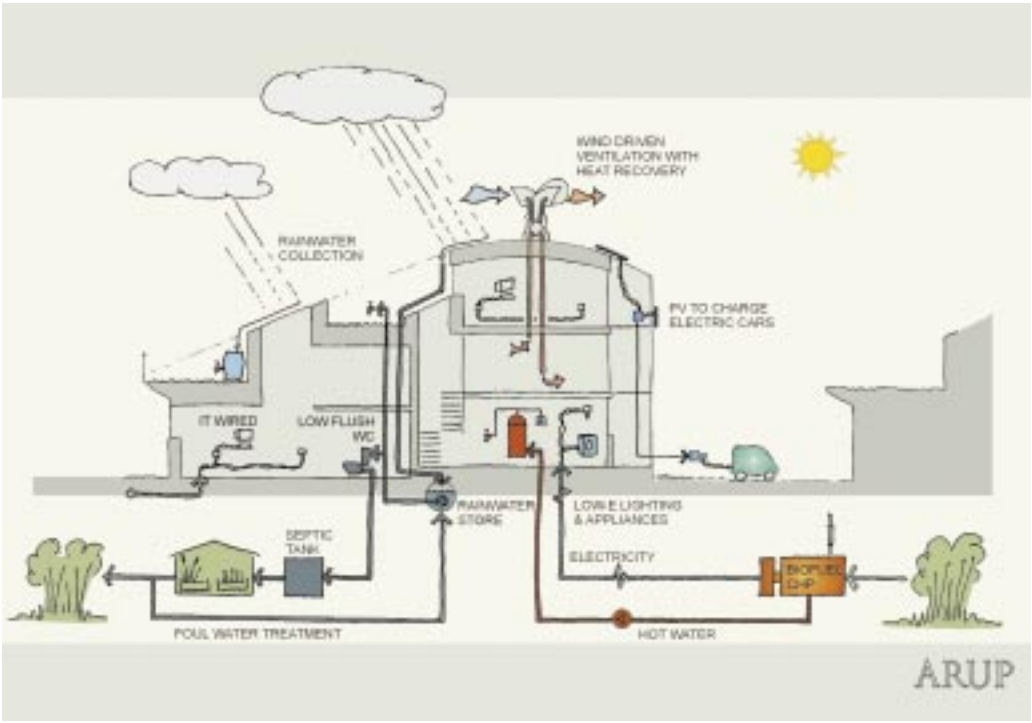
Household water needs have risen steadily during the past two decades to an average of more than 150 litres per person per day. This is all treated to drinking water quality, although most of it will be used for flushing toilets, watering gardens, and washing cars and clothes. With dry summers common in the south-east of England, water has frequently been in short supply during the summer months. High demand, coupled with high levels of runoff when it does rain, result in the paradox of localised shortages, low river levels and shrunken wetlands in summer, and destructive flooding in winter. House building, rising standards of living, and inward migration to the south east will further increase local water demands in future years.

USAGE AND CONSERVATION

BedZED aims to cut the mains water consumption of a typical household by 33%. This is achieved by installing water-efficient appliances and by collecting rainwater for flushing toilets and irrigation.

- Toilets – a typical toilet uses up to 9 litres per flush and accounts for 33% of an average household's annual water consumption[10]. BedZED's 3-5 litre dual-flush toilets save an estimated 55 500 litres of water per household per year compared to the 7.5 litre maximum permitted under the 1999 UK Water Byelaws.
- Showers, baths and taps – no power-showers are fitted, and baths are lower-volume sculpted baths. Single-bedroom flats have showers rather than baths – a common practice that also saves space and energy. Taps are fitted with water-saving flow restrictors.
- Washing machines – water- and energy-efficient washing machines are installed into all dwellings.

Metered water acts as an incentive to conserve use, and residents and workers are constantly reminded about their water use by highly visible water meters in all kitchens. Water-efficient lifestyles are encouraged by giving residents and workers water-saving ideas, and information on the environmental and financial advantages of saving water. Residents following this advice can cut their consumption by up to 50%.



BedZED will cut mains water consumption by using rainwater and recycled waste water for flushing and irrigation

WATER STRATEGY

Savings in mains water usage result in lower water bills. A typical household will save £48 per year compared to an equivalent conventional household. An enthusiastic BedZED household could save up to £106 per year.

It is predicted that, on average, 18% of a BedZED resident's daily water consumption will be met from rainwater. Owing to the unpredictable rainfall, large volume storage tanks are needed – these are integrated into the foundations.

DISPOSAL

Foulwater from BedZED is treated using a small-scale, on-site sewage treatment system. Housed in a greenhouse, this is a biologically based system which utilises the nutrients in sewage sludge as food for plants. This efficient sewage treatment system can be used as an educational facility and, when full of plants, is visually attractive. Water can be treated to a standard that allows recycling back to the underground tanks, to supplement rainwater for toilet flushing. Surplus water is piped to a soakaway into the underlying gravel strata.

Car parking spaces are laid with porous block paving over gravel to minimise surface runoff.

Dual flush WC to save water

As water drains through these layers it is filtered and returned to the groundwater with a lower level of pollutants than would otherwise be the case. Normal drainage systems take runoff water straight to local rivers, so raising the risk of flooding. Runoff from sky gardens, roads and pavements is drained to the front of the site where a dry ditch is being enhanced to give a wildlife-friendly water feature.

Waste water from domestic uses and sewage will be treated on-site with an intensive greenhouse-based reed system (photo of reed water treatment system at the Earth Centre, Doncaster)

9 MATERIALS, LABOUR AND WASTE

MATERIALS

Wherever possible, BedZED uses natural, recycled or reclaimed materials, products with a low embodied energy, and those not associated with habitat destruction.

The developers have seen this project as a particularly good opportunity to provide an income for local, well-managed, and/or Forest Stewardship Council certified woodlands. Buying timber from these woodlands gives financial value in addition to their amenity and wildlife value, promoting long-term bioregional sustainability.

Reclaimed materials include doors and other internal joinery, steel beams and scaffolding poles (for handrails and balustrades), kerbs and paving slabs. Recycled materials include the plastic in kitchen cabinet doors and worktops, and recycled crushed aggregate in the road sub-base.

As much of the material as possible is sourced from within 60 km (37 miles) of the site, to reduce pollution and energy impacts from transportation, and to encourage local industry. A considerable proportion of the high weight and volume materials (which have the greatest transport impacts) have been sourced inside this radius. These include bricks, blocks, aggregate and 50% of concrete materials, imported topsoil, 80% of timber and all the plasterboard.

Local sourcing also encourages use of materials traditional to the area, such as the oak weatherboarding characteristic of the regional vernacular, providing extra architectural interest and reinforcing local identity. Default to a conventional construction product has occurred only when cost or programme requirements make a local product or service not viable.

There are materials on the scheme that cannot be obtained from within 60 km, such as glass and tiles, but where possible, these are sourced from within the UK. This has highlighted problems within the British construction industry, in that

All the structural steel is reclaimed

MATERIALS, LABOUR AND WASTE

some components simply are not available at affordable prices. The argon-filled triple-glazing units are Danish – no British manufacturer was found who could supply the volumes and specification at a competitive price.

LABOUR

BedZED has grappled with one issue raised by the Egan Report[11] that increasing the proportion of building components prefabricated off-site may reduce waste and transport impacts, as well as costs and construction time. Waste can more easily be controlled and recycled in a factory, while bulk material deliveries come to one destination rather than being dispersed to individual sites, with potential reductions on energy use and local impacts. However, prefabrication also risks de-skilling the construction trades, and reducing opportunities for local construction work.

Although there is no formal local labour scheme, local contractors have been favoured and, where possible, local fabrication – such as local joinery firms to manufacture framed south elevations from local timber. The approach included an on-site covered joinery workshop making simple components such as straight flight external staircases, weatherboarding, oak bridges and decking from local and reclaimed timber. This emphasises the value of local labour over distant capital-intensive factory production.

WASTE

Construction waste

With growing pressure on landfill sites, and the extra expense of disposal incurred through the Landfill Tax, it is vital to minimise the amount of waste created, and to maximise the amount recycled. BedZED seeks to tackle this problem both in its construction and when the homes and offices are in use.

The site used to be part of a sewage works, and remaining contamination has been dealt with on-site by placing it under the ground slabs of the buildings. Reusable site topsoil will go on to the gardens. Subsoil that has been extracted for the footings and water storage will be used for the site contouring where possible, with the remainder joining other inert waste to restore adjacent gravel workings into an ecology park.

The UK replaces its urban fabric on average at 1.5% per year. High-performance new construction can be built using predominantly reclaimed materials

Construction works can generate disproportionate quantities of waste. As labour is more expensive than many building materials, there is little incentive to spend time and care using materials efficiently. BedZED's contractors are required to minimise the waste they create, which has been monitored – this in itself can reduce waste, simply by drawing attention to it.

Post-occupancy domestic waste

Once BedZED is occupied, the developers will be encouraging residents to reduce the amount of waste sent to landfill by 60% of a typical household's total waste. This is one of the environmental targets agreed under the Planning Agreement.

Residents will have a set of containers for different types of waste built into the kitchens. There will be multi-material recycling points on site, for metal, glass, paper and card; and there will be provision for community composting linked to the adjacent eco-park. Residents will also be encouraged to reduce their consumption of disposables and over-packaged goods. The recycling system at BedZED is tailored to match Sutton's recycling strategy.

10 SUSTAINABLE LOCAL ECONOMY

BioRegional's principles of local production for local need, and making maximum use of natural resources and labour, apply as much to the broad economy as to the detail of sustainable construction. BedZED does not exist in isolation from the greening of other parts of the economy (such as food production and distribution, recycling industries, and zero-emission vehicles).

SUPPORTING THE REGIONAL ECONOMY

Using materials sourced from within a relatively small radius (60 km) supports the regional economy. As more developments following the ZED model are built around London and the south-east, the ability to meet green specifications will move up the supply chain. A suppliers' network for low-energy, sustainable, reclaimed or recycled materials can be built, and contractors will gain experience of applying these materials and techniques, reducing costs as perceptions of uncertainty and risk diminish.

Similar networks can be established in other regions of the country. This will help provide a market for fledgling green industries in the construction field, such as small-scale renewable energy (solar, wind-power, bio-fuels, etc), transparent insulation, and water treatment. Perhaps future ZEDs will not have to go abroad for large quantities of high-performance glazing.

A 'green box' scheme will make it easy for residents to get fresh organic produce, and help support farmers in the region

LOCAL EMPLOYMENT

BedZED supports the local economy by providing space for over 200 employees. The workspaces are for retail, commercial, professional and service businesses, and light technical and craft activities. Because the workspaces are so close to dwellings there are noise and safety restrictions that rule out some types of business.

It is planned to install information and communications technology (ICT) connections to all workspaces and homes. Although the homes are not designed as 'telehomes', with space designed in for home-working, many of the homes are linked through to their adjacent workspace, forming large live-work units.

ENTERPRISE

The workspaces provide excellent starter units, encouraging new enterprises into the area. In addition, enterprise opportunities are built into the scheme, such as for a shop/café, and childcare. It is hoped that once the car pool has been established by BioRegional, it can be taken over and managed as a business by a group of residents.

The Peabody Trust will be responsible for management of the site, but it is consistent with the Trust's approach for some roles to be sub-contracted to a community enterprise. This could apply to maintenance of the buildings and grounds, and running the water treatment plant.

DEVELOPING A SUSTAINABLE FOOD SUPPLY

It has been calculated that households' indirect contributions to global warming – primarily from the transport of their food – are as significant as their direct contribution from their homes and personal transport[4]. For example, one tonne of strawberries air freighted to London from Israel releases 4.6 tonnes of CO_2, while the same weight of strawberries transported from a farm in Kent would emit 0.014 tonnes of CO_2. One tonne of

SUSTAINABLE LOCAL ECONOMY

apples shipped from New Zealand releases 0.5 tonnes of CO_2. The same weight of produce transported from a farm in Kent to London would emit less than 0.03 tonnes (30 kilos)[12]. (Global warming impacts can be thought of as a proxy for other environmental costs and risks, such as oil discharges, over-packaging, materials, and risk of accidents.)

BedZED residents can reduce their direct global warming impacts from housing and transport to zero, but there is still a need to reduce the indirect ones. As a high-density urban development, BedZED cannot enable families to be self-sufficient in food – nor is this a viable option for cities as a whole. Nevertheless, much can be done to address this aspect of overall sustainability:

- a food-growing project will be established as part of the proposed adjacent ecology park, as well as incorporating allotments within the park design
- new residents will be encouraged to grow food in their sunspaces and on their roof gardens, with a free selection of vegetable seedlings and seeds and a guide on how to grow them
- the BedZED community will have links to organic farms in the region, allowing direct and cost-effective supply of local organic produce
- the food shop will be encouraged to sell local produce, and the success of this will be monitored.

Residents will be able to order home deliveries of groceries via the Internet. These will be regularly delivered in bulk, bringing environmental benefits by reducing the need for individual car journeys to the supermarket (and hence encouraging residents to give up car ownership in favour of joining the car pool).

11 CREATING A SUSTAINABLE LOCAL COMMUNITY

It is not enough for a community to contribute to local and global environmental sustainability if people are excluded and isolated, suffer from poor health, will not go out for fear of crime, and have nowhere to meet friends or watch their children play in safety.

The 'neighbourhood renewal' agenda aims to tackle some of these issues, and BedZED serves as a model for integrating them into new development.

The mix of tenures and high proportion of affordable housing will ensure a variety of different income brackets and professions live at BedZED, and the mix of sizes from small flats to four-bedroom town houses allows a range of age groups, single people and families to move in.

Residents will get exceptionally high amenity values for high-density housing, with glazed sunspace/balconies and private roof gardens

A community forum of residents and businesses will be set up that will deal with issues and problems as they arise, and will look for new opportunities to improve and innovate. The forum will have links to the surrounding community – links that have been established from the outset through the consultation process and through the joint development of the sports facility.

The community will have its own website, access to computers, and it is planned to set up a local e-mail network. Apart from the sports clubhouse, informal meeting spaces are offered by the village square and the café. Safety is promoted by the home zone principles keeping car speeds down and providing pedestrian priority, while security is increased by the high levels of natural surveillance, with flats overlooking the public spaces.

The workspace in one block is being marketed for community use. A crèche/childcare facility, available to employees who want to bring their children close to where they work, and to residents who have to work elsewhere, is proposed. There may also be a base for cultural activity, such as performance workshops in the large communal hall by professionals from the local Charles Cryer Theatre.

HEALTHY LIFESTYLES

By its very nature, BedZED furthers the kind of healthy lifestyle being promoted by health authorities under their public health and health promotion programmes:

- a diet of fresh food is encouraged by the 'green box' scheme, and by easily available produce in the shop
- good storage provision, showers, and links with the local cycle network encourages cycling as a healthy activity
- warm and well-lit houses improve comfort and reduce winter illness, while low fuel and water bills increase disposable incomes
- the houses are low-allergy, damp-free environments – tiled floors making wall-to-wall carpets unnecessary, reducing the risks of asthma and similar illnesses.

12 CONCLUSION – WAYS FORWARD

BedZED can be seen as a model or system for sustainable housing development. The major task for designers and developers will be to spot, exploit and refine the opportunities for integration. As a model, it can be tailored for different uses and locations but the core principles of local sourcing, integrated mixed-use linked with solar design, renewable power, and maximising the community, economic and amenity values, are widely applicable. It is clearly appropriate for urban sites, but may also be relevant to rural situations as part of a sustainable solution to rural poverty and agricultural decline.

The increased demand for more labour in organic food could result in a need for more affordable rural homes in the near future.

NEW HOUSING WITH NO EXTRA GLOBAL WARMING

BedZED is the first attempt in the UK to establish the technical and financial viability of zero net carbon emissions for new low-cost urban housing. When it has been proven in use, it will be a strong argument that all new housing should be zero-carbon, with no additional global warming effect. It could buck the common trend of greater eco-efficiency being forever compromised by higher gross levels of production and consumption.

USE OF PLANNING AND SALE AGREEMENTS

The sale and planning agreements are a useful precedent for local authorities wishing to promote sustainability. Requirements to incorporate renewable energy, green transport plans, mixed-use, and the other environmental benefits exemplified by BedZED, can be included alongside such familiar requirements as for affordable housing and infrastructural improvements. Detailed specifications can and should be included to monitor performance.

Some of the environmental benefits can be quantified in financial terms and used in the comparative assessment of bids in a competitive tendering situation. It would be useful for local authorities and developers if central government produced guidelines on how local authorities may value environmental benefits.

PRIVATE SECTOR SUSTAINABLE HOUSING

In the short term, pressure for sustainable housing is likely to be policy led, and encouraged through the planning system. However, in Europe and the USA, private ecological housing has often outperformed the market average in terms of resale values. BedZED, with its private component, may help establish a similar pattern here, and thus the existence of a niche market for 'green' housing that could become mainstream (analogous to the growth of organic food in the 1990s).

There is, however, an opportunity for an innovative private developer to gain a market lead. This will be invaluable if governments learn from BedZED that zero-energy housing is viable, and impose more stringent standards on new developments through planning guidance and Building Regulations.

REGENERATION AND NEIGHBOURHOOD RENEWAL

Most of the environmental, economic and community features offered by BedZED overlap with the objectives of regeneration and neighbourhood renewal. Green developments have a market appeal, and where environmental and social issues are addressed in a sincere rather than cynical fashion, support from local residents is normally forthcoming.

In some areas image is as much of a problem as the physical fabric. Here, the ZED model could serve as a powerful symbol and flagship for turning round a depressed neighbourhood. As well as demonstrating public commitment to improvement, environmentally friendly housing is more likely than conventional models to attract new residents, especially the young urban professionals and families who are such an important part of the social mix for inner-city areas.

THE IMPORTANCE OF INTEGRATION

It is a common mistake to try to be 'more sustainable' by adding eco-friendly elements piecemeal on to a conventional project. The contradictions and trade-offs that arise limit the effectiveness of each component and of the finished whole. One lesson

CONCLUSION – WAYS FORWARD

of BedZED is that it is no more expensive, and may even be cheaper, to aim for complete eco-friendliness, rather than to stop half way.

For example, increasing the insulation thickness on a standard home will still require the installation of a central heating system. If, however, super-insulation is adopted with high levels of thermal mass integrated into the building structure, together with efficient south-facing glazing, then it is possible to reduce heat losses so that no central heating is required. This saving helps cover the cost of the super-insulation, while provision of energy-saving appliances by the landlord reduces demand – and bills. Savings from not having to install and maintain heating, air-conditioning and mechanical ventilation systems in the workspaces can help offset the cost of CHP. This in turn offers further efficiency gains over conventional individual boilers, while links with local woodland managers and waste authorities help to make biomass viable as an energy source for urban areas.

This does not just apply to environmental design. Throughout the programme, the designers and developers found new links between different aspects of the scheme, and new ways of knitting them together and reinforcing the benefits. Sports facilities, nurseries and shops, community facilities and car pool have been integrated, helping to regenerate the area outside the site boundaries. A wide range of different size homes and different tenures provide a healthy social mix, and make it easy and affordable for all generations to participate in a low-impact lifestyle.

Coupled with high density, such mixed-use and integration maximises the value of land, and yields income which pays for the higher build specification. In a public sector context, it achieves best value for a site.

MASTERPLANNING

For ZED-type developments to be implemented on a significant scale, sustainability must be central to masterplan briefs. Masterplans must reflect the

CONCLUSION – WAYS FORWARD

key importance of solar gain, close integration of residential, employment and community uses, and transport, biodiversity and water-saving strategies. Favourable criteria for shading and aspect, plot use, drainage and access must be set, and aspects of urban design such as height, built form and street frontage must be compatible. If these are not considered from the outset, it will be all the more difficult to make a sustainable development viable.

INCREASING DENSITIES

BedZED's core blocks achieve a density of 105 units, plus around 200 workspaces, per hectare. This probably represents the highest density of naturally lit mixed use urban grain capable of benefiting from useful amounts of passive solar gain, at the same time as providing good amenity and private gardens for most homes.

At these densities, around 3 million new homes could be provided on the existing stock of 28 800 ha of derelict brownfield land, staying within a three-storey limit, using traditional construction techniques. The UK currently replaces its urban fabric at around 1.5% a year. If ZED standards become commonplace, it will be possible to achieve a broadly carbon-neutral urban infrastructure by the start of the next century, with no loss of agricultural land.

SUSTAINABILITY INDICATORS

As a result of the Egan Report[11], Key Performance Indicators are being introduced to the construction industry to measure productivity and quality. It is essential also to measure the environmental, social and economic sustainability of a project. Several organisations, including councils, CIRIA, and Movement for Innovation (M4I), have drawn up checklists or indicators to aid this process.

The ZED team has applied this approach to BedZED to draw up the Performance Indicators in this document (see Appendix 1). The team is developing these into a more detailed list of 120 such indicators for new housing, drawing on the experience and issues raised by BedZED and similar projects. The indicators include benchmarks for standard, good and best practice, and are designed to assist planning authorities when drawing-up briefs and assessing proposals, and developers to meet sustainability requirements.

CONCLUSION

While reversing global warming trends is vital to the future, planning communities that do not address all aspects of modern life – for example building houses with no regard for where people will work and play – is itself unsustainable.

An holistic sustainable development strategy encompassing a wider range of issues is able to reduce costs and minimise problems at the planning and design stages. Providing that the financial and lifestyle benefits of this rather more wholehearted approach can be demonstrated to both developers, businesses and residents, it may be possible to bypass the incremental approach to innovation with its marginal benefits, and leapfrog directly to environmentally, socially and economically sustainable communities.

APPENDIX 1 – KEY INFORMATION AND SUSTAINABILITY PERFORMANCE INDICATORS AS AT JANUARY 2000

KEY INFORMATION FOR BEDZED AND ZED MODEL

Two sets of figures are given. The first column gives gross figures for BedZED as designed and built. The second column gives figures for BedZED's high-density core of six block plus the village square. This is to show the densities achievable by ZED as a model for sustainable high-density mixed-use development.

	BedZED actual	ZED model (BedZED core)
Gross area of site (ha)	**1.7**	**0.64**
Number of dwellings	82	63
Total floor area (m^2 gross external)	10 388	8235
Residents	244	198
Habitable rooms	271	225
Area of sports pitch (m^2)	4335	–
Area of village square (m^2)	538	538
Area of roof/ground-level private gardens (m^2)	2058	1638
Area of primary circulation (m^2)	3207	1160 *(ie 50% perimeter routes)*
Area for car parking (m^2/number of parking spaces)	986/84	–
Area of work and commercial space (internal m^2)	2369	1559
Area of outdoor private garden/home (m^2)	25	26
Area of public open space/home (m^2)	60	3.5
Total number of workers (@ one per 12 m^2 floorspace)	196	130
Densities		
Population density (residents/ha)	148	309
Homes/ha @ 3.5 hab rooms/home	47	100
Habitable rooms/ha	164	352
Public open space, excluding roads, pavements (m^2/ha)	3000	840
Employment density @ 12 m^2 per employee (workspaces/ha)	119	203
Total site population density (people/ha)	267	512

APPENDIX 1 – KEY INFORMATION AND SUSTAINABILITY PERFORMANCE INDICATORS AS AT JANUARY 2000

SUSTAINABILITY PERFORMANCE INDICATORS

1 Site location indicators

Indicator	BedZED performance
Ratio of site previously used for buildings or industry	100% of site previously used for sewage treatment
Pedestrian travel distance to railway station	0.7 km – easily walkable
Number of bus routes within 100 m of site boundary	Two
Pedestrian travel distance to nearest bulk food shop	3 km (1.9 miles) to large supermarket
Pedestrian travel distance to nearest doctors/health centre	100 m
Pedestrian travel distance to nursery facilities	0 – proposal for on-site facilities
Pedestrian travel distance to nearest café or pub	0 – proposal for on-site café
Pedestrian travel distance to nearest infant, junior and senior schools respectively	0.6 km, 0.6 km and 2 km
Opportunity to grow vegetables within 150 m	Yes – adjacent eco-park, and roof gardens

2 Energy indicators

Indicator	BedZED performance
CO_2 emissions – kilograms per square metre of floor area (This ideal measurement of global warming impact is complex to calculate in advance, makes hidden assumptions, and is dependent in practice on occupants' behaviour. The following are more easily measured indicators)	Zero
Installed capacity of active renewable energy harvesting systems (eg wind, PV, wood, solar)	47 W/m² (peak)
Installed capacity of CHP per m² floor area: (a) fossil fuelled; (b) renewable-fuelled	21 W/m² thermal; 14 W/m² electric
Installed capacity of heating/hot water systems: (a) fossil fuelled; (b) electric (also indicates level of thermal insulation and airtightness)	Zero
Installed capacity of lighting systems	5 W/m²
Installed capacity of mechanical cooling systems in workspace or housing	Zero
Installed capacity of pumps, fans, etc	0.6 W/m²
Energy meters installed at occupant-readable position	Yes
Design includes energy targeting	Yes
Installed area winter-sun-exposed window	0.08 m² glazing per m² floor area
Installed area of daylight-exposed window	0.16 m² glazing per m² floor area
Hours per year rooms are above summer peak temperatures*	Zero
Ventilation efficiency* per m² floor area (8 litres/sec/person)	0.33 litres fresh air (averaged)

(*the last two indicators check that energy efficiency is not achieved at the cost of comfort)

3 Travel/transport indicators

Indicator	BedZED performance
Covered bike space per home	1.42
Charging facilities for electric vehicles	26 charge points

APPENDIX 1 – KEY INFORMATION AND SUSTAINABILITY PERFORMANCE INDICATORS AS AT JANUARY 2000

4 Materials

Indicator	BedZED performance
Ratio of recycled or reclaimed materials to new materials in construction	Target 50%
Ratio of new timber certified by recognised assessor (eg FSC)	Target 100%
Embodied energy of construction materials per hectare of built area	Data available post-construction
Proportion by weight of construction materials sourced from within 60 km	Data available post-construction
Domestic recycling: facilities for household separation waste at source	Yes – three/four compartment bins in kitchens for target 60% recycling of domestic waste

5 Green/open space

Indicator	BedZED performance
Sun-exposed garden area	0.13 m^2 per m^2 of residential floor area

6 Water saving

Indicator	BedZED performance
Water consumption per person (This ideal measurement is complex to calculate in advance, and is dependent in practice on occupants' behaviour. The following are more easily identified design aspects)	
Water meter installed in occupant-readable position	Yes
Flow restrictors on all water outlets	Yes
Water capacity of flush toilets	3/5 litre dual flush
Domestic hot water at mains or equal pressure (to avoid power showers)	Yes
Low-water appliances provided	Yes
Water leak detection	No
Rainwater/greywater collection for irrigation	Yes
Rainwater recycling for indoor use	Yes
Greywater recycling for indoor use	Yes
On-site foul water treatment	Yes
Surface water runoff attenuation (eg porous landscaping, balance pond)	Yes
On-site treatment of contaminated surface water	Yes

7 Cost and quality

Indicator		BedZED performance	
Build cost – residential	£ total	6 920 000	Includes non-CHP infrastructure, landscaping and external works
	£ per m^2	1100/m^2	
Build cost – work and commercial space	£ total	2 090 000	
	£ per m^2	752/m^2 workspace	
		636/m^2 commercial	
CHP	£ total	640 000	
	£ per m^2	61/m^2	
Other (eg fees/S106)		2 140 000	
Development cost	£ total	11 790 000	
	average £/m^2 floor area	1135/m^2	
Durability – target design life of structure		75 years minimum	
Maintenance – average maintenance cost per m^2 per year		To be confirmed after five-year monitoring	

APPENDIX 2 – PARTNERS

PEABODY TRUST

The Peabody Trust is London's largest and longest-established housing association. It owns or manages over 17 000 homes, and has a commercial portfolio that provides income for its charitable work. It has a long tradition of innovation, both in social and community initiatives and in housing construction.

Peabody's view is that the poor suffer soonest and most seriously from environmental destruction, so its aim of relieving poverty in London demands a long-term sustainability perspective as well as immediate social and economic action. Peabody's interest in the ZED scheme relates to several specific areas:

- reducing fuel bills and addressing fuel poverty, while reducing global warming emissions
- mixed-use development, to build communities and support local employment
- maximising green space to improve quality of life in high-density urban developments
- supporting regional economies by using locally sourced materials
- low levels of car ownership, and alternatives to fossil-fuel-powered private cars.

BIOREGIONAL DEVELOPMENT GROUP

Established in 1994, BioRegional Development Group is an environmental organisation that aims 'to bring local sustainability into the mainstream'. It is founded on the green ideals of local production for local needs, and use of sustainable resources. The Group takes a market-led approach, taking account of economy, lifestyles and affordability.

Projects include local wood products supplied to national retailers, processing tree surgery waste, and developing the concept of BioRegional Networks to supply local food to national retailers. The BedZED project furthers BioRegional's aims to promote local sustainability.

BILL DUNSTER ARCHITECTS

Bill Dunster Architects (BDA) is committed to creating buildings and communities that reduce consumption of natural resources at the same time as improving our collective quality of life.

The eight-strong practice has a wide range of experience of working on low environmental impact projects, including design, masterplanning, risk management and developing and funding innovative environmental technologies – including the use of planning gain to fund carbon-neutral development. BDA is particularly interested in showing how green issues suggest both new and traditional construction techniques and a fresh new aesthetic.

Bill Dunster ended a 14-year association with Michael Hopkins and Partners as the project associate responsible for the Nottingham University Jubilee Campus. BDA is currently completing a new conference centre and visitor centre at the Earth Centre Doncaster, and currently works from a prototype solar live-work unit near Hampton Court.

For examples of BDA's work and published material, please see the website: **www.zedfactory.com** or contact **billdunster@zedfactory.com**

OVE ARUP & PARTNERS – BUILDING PHYSICS ENGINEERS, BUILDING SERVICES ENGINEERS

Arup, founded in 1946, provides consulting engineering, management and planning services through 76 established offices in 31 countries, with over 6000 employees. Each group within the firm has particular specialist skills and is responsible for its own projects and to its own clients. From this wide and diverse global resource, skills developed over many years are readily available for most aspects of sustainability.

Arup's design approach for sustainability is based on the tripartite balance between social progress, environmental impact and economic growth. BedZED is the result of the application of a range of engineering techniques and specialist skills. Increasingly this form of technology transfer and holistic design approach is seen as the future for solving sustainability issues. The aim is to give the stakeholder more value with the use of less resource, and it illustrates how engineering is a key constituent for society's sustainable future.

APPENDIX 2 – PARTNERS

GARDINER & THEOBALD

Gardiner & Theobald offers a comprehensive worldwide service of construction consultancy in conjunction with its global alliance partners – Levett & Bailey and Rider Hunt (Asia Pacific).

On BedZED, Gardiner & Theobald is committed to sustainable development and is playing a key role in its achievement. It is doing this by challenging existing design briefs and specifications, aiming for standardisation of components, as well as consulting and co-ordinating with the project team. It is Gardiner & Theobald's role, in conjunction with the project team, to obtain optimum, or best, value by providing the necessary functions at the lowest cost.

Gardiner & Theobald's financial knowledge with regard to sustainable development is now highly developed thanks to the growing success of BedZED and other environmentally aware schemes. It can now reasonably ascertain the overall costs of equivalent schemes, because of its experience and close working relationships with the project team, specialist contractors and suppliers.

ZEDTEAM

Zedteam is a consultancy of BedZED's partners that make the expertise and experience of design, construction and operation of sustainable developments and communities more widely available.

ELLIS AND MOORE

Ellis and Moore provides structural and civil engineering design services for a broad range of buildings. In recent years, the practice has specialised in the development of brownfield sites for new-build housing projects, refurbishment of listed buildings, estate regeneration and research into the use of lime in new-build projects. The practice philosophy is to produce technically competent solutions that are economic and practical to build, whilst being sensitive to environmental issues.

On BedZED, Ellis and Moore is responsible for the design of the building structures, site decontamination, roads, underground drainage and waste water treatment.

APPENDIX 3 – SHORT ROTATION COPPICE REQUIREMENTS

BedZED requires the following woodchip inputs per year:

- 0% moisture content – 700 tonnes/year
- 50% moisture content – 1400 tonnes/year
- 30% moisture content – 850 tonnes/year.

This would require a three-year, short-rotation coppice woodland of around 70 ha, with around 24 ha of coppice being cut to meet the community's fuel demand each year.
(Source: B9 Biomass Energy.)

CHP gasifier

BWV chipstore

REFERENCES

[1] Energy – The Changing Climate, Royal Commission on Environmental Pollution, (The Stationery Office, 2000)

[2] Urban White Paper (DETR, 2000)

[3] Derived from UK Energy and the Environment (Cambridge Econometrics, 1999) and Energy – The Changing Climate, Royal Commission on Environmental Pollution (The Stationery Office, 2000)

[4] General Information Report 53. Building a Sustainable Future. EEBPp, London, 1998

[5] Calculations by Ove Arup and Partners

[6] Ford THINK electric car (two-seater) launched 2001 in London – consumption 0.185 kWh/km. Peugeot 106 electric launched 1996 – consumption 0.27 kWh/km.

[7] BioRegional Development Group: BedZED Total Energy Strategy and Green Transport Plan, 2000

[8] Transport in the Urban Environment, Institute of Highways and Transport, 1997

[9] London Borough of Sutton Sustainable Transport Strategy, 1998

[10] Anglian Water, 1992

[11] Rethinking Construction: The Construction Task Force, 1998

[12] Davies, Desai Feasibility of Local Sustainable Food Sourcing by Supermarkets, BioRegional Development Group, 2000

This Report is based on material drafted by Bill Dunster Architects under contract to BRECSU for the Energy Efficiency Best Practice programme

The Government's Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

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Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting, etc.

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