

# Strategies and technologies for sustainable urban waste management

## Research consortium proposal submitted to EPSRC Sustainable Urban Environment programme

### PART 1: RESEARCH RECORD AND SPECIFIC EXPERTISE

The named investigators and their research groups have unparalleled yet complementary expertise in engineering and scientific research related to waste management.

**William Powrie** is Head of the Department of Civil & Environmental Engineering at the University of Southampton (RAE 2001 grade 5\*). He is responsible for current research grants and contracts with a total value of nearly £2M, including an EPSRC Platform grant for gas and liquid flow processes in wastes (GR/R04232/01) and a Network grant on sustainable waste management (GR/R08759/01). Other recent projects have focussed on landfill process modelling (GR/M87023), settlements (GR/R03518/01) and leachate control (GR/M34256). He is or has been a member of the IWM Sustainable Landfill Working Group, the Environmental Services Association Research Trust Board, and Research Advisory Panels for Onyx Environmental Trust and the Government's Waste Resource Action Plan (WRAP). Recent prizes include the Telford Medal (2001) and the John Henry Garrood King Medal (2002) of the Institution of Civil Engineers, and the Giovanni Bossini Award for the best technical paper at the Sardinia 2001 International Waste Management Symposium. **Charles Banks** is Reader in Environmental Engineering, with extensive interests in biotechnological process optimisation. He is responsible for current UK and EU research grants and contracts worth over £1M. Recent EPSRC grants include GR/N30651/01 (MTP: MSc in sustainable waste management) and GR/L31289/01 (Accelerated aerobic hydrolysis and acidification of biodegradable substrates). Southampton's **Waste Management Research Group** focuses primarily on microbial treatment and degradation processes, including landfill engineering, anaerobic digestion, composting, leachate management, and mechanical/biological treatment. Links with the Centre for Environmental Sciences and the **Transportation Research Group** (TRG) bring expertise in collection logistics and policy/societal issues such as improving participation in household waste separation schemes. **Tom Cherrett** is a lecturer in freight and logistics within TRG, and carries out research on sustainable distribution strategies and incident detection using urban traffic control infrastructure. He has worked on EPSRC grants GR/J97724 and GR/L43602, estimating journey times on urban road networks, and is currently researching the scheduling of core deliveries and service visits to city centre businesses. He is secretary of the ITS UK 'Freight Interest Group'.

**Jim Swithenbank (FEng)** is Director of Sheffield University Waste Incineration Centre (SUWIC) and Research Professor in the Department of Chemical Engineering. Internationally pre-eminent for research on combustion, energy from waste and pollution control, and holder of more than 20 patents, he has served as government advisor to the Select Committees of both Houses of Parliament and DTI. He was technical architect of the Sheffield waste-to-energy CHP scheme that currently provides heat to over 5000 city-centre residential, commercial and public buildings. He has published over 300 papers and has run major EPSRC projects on energy from waste, pollution control, instrumentation, waste management (eg. Platform grant GR/NO7707, GR/M/90481B, GR/M47720, GR/J10006, GR/K36645, GR/L74460, GR/L60593, GR/L22539, GR/K89481) as well as other European and industrial projects. **Vida Nasserzadeh Sharifi** is Deputy Director of SUWIC and a Reader in Chemical Engineering. She has produced more than 100 papers and been in charge of major industrial and EPSRC projects on thermal treatment technologies, pollution control and recycling/re-use of residuals (GR/M47348, GR/M17082, GR/M73743, GR/M72456, GR/M12759). She leads the steering committee of the EPSRC Dioxin Research Network and with Jim Swithenbank chairs and organises international symposia on incineration. **SUWIC** is the leading international research centre for the thermal treatment of wastes, with a worldwide reputation for innovative investigations into combustion, gasification and pyrolysis and the associated electrical power generation systems. The Centre specialises in waste management, flue gas clean-up, recycle/re-use of ash residuals and sludge disposal. In the field of urban waste and energy management, SUWIC played a key role in developing one of the UK's first and still the largest district heating system, operated by Sheffield Heat & Power, with 150MW<sub>n</sub> currently connected.

**Matthew Leach** is Deputy Director of the Environmental Policy & Management Group (EPMG) in the Department of Environmental Science & Technology at Imperial College, where he focuses on systems

modelling of resource management. He is responsible for research grants and contracts with a total value over £1.3M, including an EPSRC Platform grant on decentralised energy (GR/R09282/01). He has contributed to systems modelling for sustainability assessment of urban material and energy flows and waste management (GR/K59637), water/wastewater (GR/M15545), and environmental footprints (overall winner of the 2001 Biffaward awards for environmental projects). Relevant current research includes two DTI studies of biomass fuel production and a study of urban hydrogen infrastructures (GR/R50790). He is a member of the Future Network Technologies Consortium of the EPSRC SUPERGEN programme, investigating the effects of reducing scales of power generation, including biomass/waste sources; and is a participant in the recently-funded Faraday Partnership on Waste Minimisation.

**Catherine Alexander** of the Department of Social Anthropology at Goldsmiths College, has worked as a consultant for fifteen British and Turkish government ministries and agencies, including MAFF, DTi, DES and the Scottish Office, advising on implementation of EU policies, introduction of internal markets, optimisation of new policy programmes, rationalisation of logistical systems, shifts in government long-term accounting systems and the implications of long-term service outsourcing to the private sector. As an anthropologist she works on bureaucratic operations, privatisation, interfaces between public and private sectors, social geographies of the household and workplaces, and urban economies. She is currently coinvestigator on a Leverhulme Trust funded project on urban transformations (F/532/B) and holds a MacArthur Foundation grant to investigate contemporary urban migration.

**Stefaan Simons** is Professor of Chemical Engineering in the Centre for CO<sub>2</sub> Technology at University College London, a multi-disciplinary research centre focussing on development of innovative technologies and methodologies for reduction and sequestration of carbon dioxide emissions, based in the Chemical Engineering Department (RAE 2001 grade 5\*). He has particular expertise in interfacial phenomena, particle technology and process imaging. Since 1993 he has attracted over £1M in research funding from EPSRC and industry. **Paola Lettieri** is a Royal Academy of Engineering Research Fellow, appointed in January 2001. Her research programme is focussed on the production of energy from waste with reduced air pollution and improved energy recovery. She has already received significant financial and equipment support from both the EPSRC (GR/R64896: Fluidisation for sustainable development) and industry, in particular BP Chemicals.

**Tim Jackson** is Professor of Sustainable Development at the Centre for Environmental Strategy (CES) in the University of Surrey (RAE 2001 grade 5). He is also an Associate of the New Economics Foundation, awarded the title 'Think-Tank of the Year' for 2002/3. Professor Jackson holds a fellowship in 'sustainable consumption' at the University of Surrey, supported by the ESRC's Sustainable Technology Programme. He has provided advice to a wide range of governmental departments including the Royal Commission on Environmental Pollution (on renewable energy), the Environment Agency (on waste policy), the Cabinet Office (on resource productivity), and DEFRA (on consumer behaviour). **Adisa Azapagic** is a Reader in Environmental Systems Engineering at CES whose current research interests include System Modelling and Optimisation, Waste Minimisation and Management, Life Cycle Assessment, Industrial Ecology, Environmental Decision-making and Corporate Sustainability.

Our industry collaborators include leading UK local authorities and waste management companies with extensive interests in Europe and elsewhere and a strong record of supporting research and technical innovation. They will help guide the research to ensure its relevance to society's needs; provide information and facilities in connection with individual projects; and ensure that the results are disseminated rapidly to influence practice within the industry.

### **Contribution to UK competitiveness and Quality of Life**

The contribution to UK competitiveness and quality of life of research carried out by the investigators is demonstrated by

- publication of the results in leading academic and professional journals (see Appendix A)
- direct uptake of the research results by collaborating and funding industry partners
- incorporation of research results into professional reports and guidance, through co-authorship
- influence of research results on local, national and international government policy through representation on advisory and review panels and published technical papers
- subsequent employment of trained researchers in industry, government and regulatory bodies.

## PART 2: DESCRIPTION OF THE PROPOSED RESEARCH AND ITS CONTEXT

### Background

In the developed world, 75% of the population live in urban areas - a figure projected on medium estimates to rise to nearly 83% by 2030 (United Nations, 2002). In the developing world, the rate of urbanisation is even faster and in total, it is expected that by 2030 some 60% of the world's population, or about 5 billion people, will live in urban areas. At the same time, there is a growing acceptance that many of the world's resources are being more used more quickly than they can be regenerated, and must be managed much more carefully than in the past if the quality of life enjoyed by most people in developed countries is to extend to an increasing proportion of the world's population. This is especially important because development and urbanisation are inextricably linked to increased consumption of resource (United Nations, 2001). In the UK and Europe, increasing public awareness of and political emphasis on the need for better management of resources currently treated as waste is evidenced by the recent and impending legislation summarised in Table 1.

Title	Implementation date in the UK	Impact on urban waste management
EU Packaging Waste directive	March 1997	Requires systems to be established for return, collection and recovery of packaging wastes
EU Regulation on Ozone-Depleting Substances	January 2002	Requires ODS to be removed from fridges and freezers for disposal
EU End-of-Life Vehicles directive	April 2002	Requires collection systems for ELVs and parts
EU Landfill directive	June 2002	Reduction of biodegradable waste to landfill; banning liquid and other waste types; only pretreated waste to be landfilled
EU Animal By-Products regulation	August 2002	Requires treatment of catering and domestic wastes
EU waste incineration directive	December 2002	More stringent requirements on emissions
EU Waste Electrical and Electronic Equipment directive	2004	Separate collection and recycling schemes for WEEE
Draft EU Biowaste directive	2004	Separate collection and utilisation for all organic wastes

**Table 1: Recent and impending EU waste management legislation as it affects the UK**

Although undoubtedly well-intentioned, there is no guarantee that the legislation summarised in Table 1 will have the desired effects of improving resource utilisation and reducing waste and uncontrolled emissions of greenhouse gases and other pollutants. This is because waste management is an immature yet complex application area, requiring input from and interaction between a number of core disciplines including engineering, science social science and economics. As a result, there is considerable scope for the development and improvement of (a) process and treatment technologies, (b) waste management strategies that exploit the particular attributes of the urban environment such as transportation networks and residential/commercial infrastructure, and (c) our understanding of the full environmental, economic and societal impacts of these technologies and waste management strategies.

### Aim and objectives

The **aim** of this proposal is to bring together a number of leading UK university groups, local authorities, waste management companies and other industry bodies to create a strong interdisciplinary research consortium. The Consortium will draw on the strengths of the partner organisations in terms of practical experience and research expertise, to focus particularly on the challenges, constraints and opportunities for waste management presented by the urban environment.

The **objectives** of the Consortium are to

- build on the underpinning scientific expertise of individual partners to carry out research that will
  - in the short to medium term, contribute towards meeting impending legislative requirements without making an inappropriate and irrevocable commitment to any particular type of treatment technology
  - in the medium to long term, contribute to the development of waste management strategies that are optimal in environmental, societal, technological and economic terms,
 in both cases with a particular emphasis on the constraints and opportunities of urban environments
- engage with local authorities, regulatory bodies and the waste management industry in defining research needs and priorities, carrying out projects, and implementing research results
- develop a profile and reputation for high-quality research that will allow us to challenge current policy and influence future policy in urban waste management, both nationally and internationally.

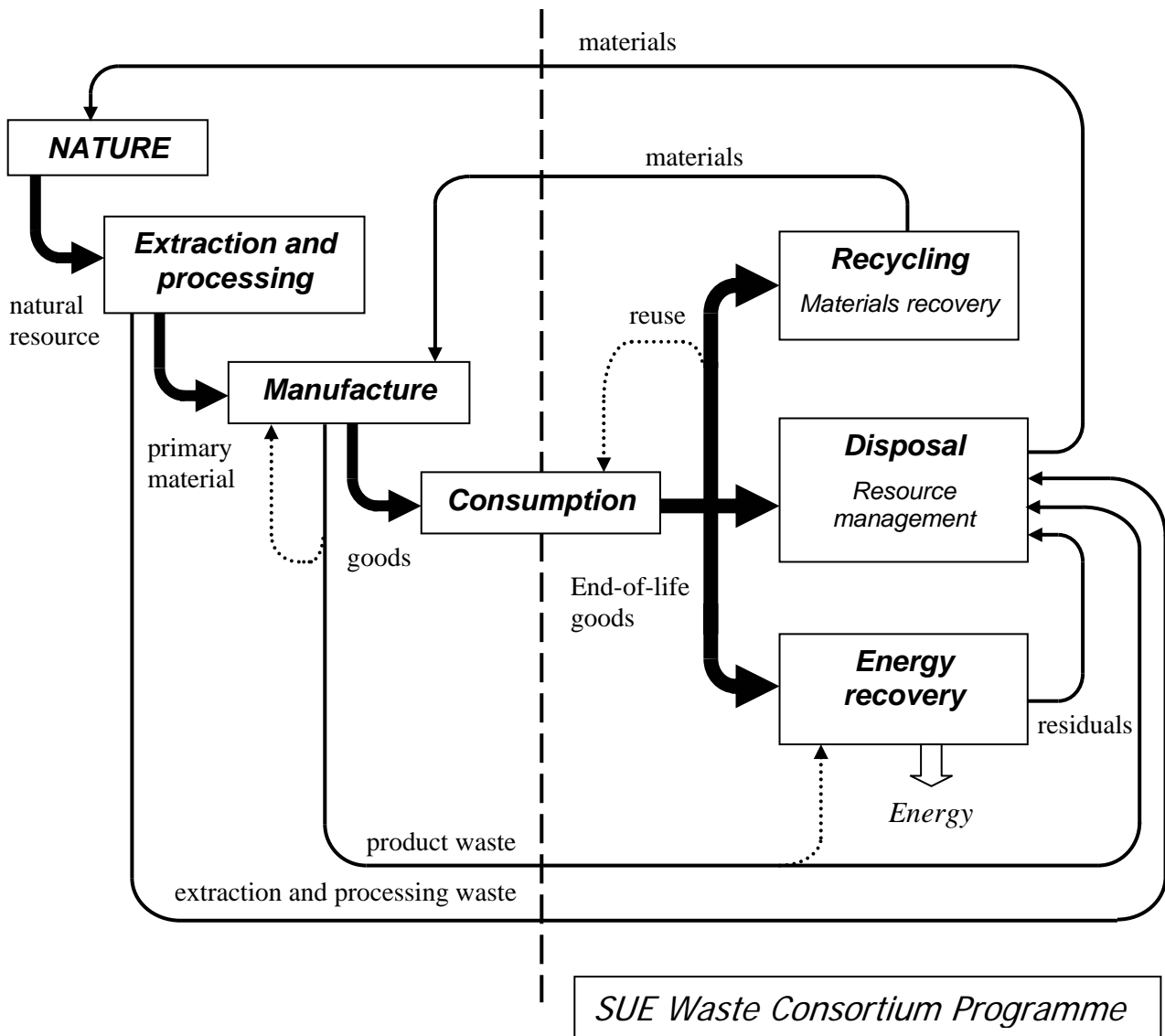


Figure 1: Schematic representation of resource cycle. The area to be addressed by the Consortium is to the right of the vertical dashed line

### Strategy and programme

The resource cycle comprises a number of processes, each of which has inputs (materials and energy) and outputs (products, energy and waste). Waste outputs from one process may be used as resource inputs to another or even the same process (Figure 1). Closure of the cycle, ie. return of waste or used resources to

the environment in a way that enables them to be extracted and used again, rarely happens except in a haphazard way and on a geological timescale. The volumes of virgin or waste resource input, product and waste output from each process depend on a complex interaction of technological, economic and societal factors. Minimisation of environmental impacts is becoming more important as a driver, but historically this has not generally been the case.

The main strategic features of the proposed Consortium are that it will

1. specifically address problems of waste management in urban environments, with a particular emphasis on the technical, social and economic constraints and opportunities such environments offer. It is therefore concerned with wastes arising from manufacture and consumption (Figure 1), which are likely to be generated within domestic, commercial and light industrial premises
2. focus mainly on the application of engineering science and technology to waste management in urban environments, but interact strongly with other disciplines. This is because we recognise that engineering and scientific research must both (a) be informed by social, economic and political realities (even though these may change over time) and (b) seek to challenge and influence policy
3. draw on, utilise and add value to the extensive research in a variety of relevant and related areas already being undertaken by the partners in the Consortium
4. complement, rather than duplicate, other major waste management research programmes, eg. WRAP (the Government's Waste Resource Action Plan) and the Biffaward Mass Balance projects.

All projects in the proposed research programme are focused specifically on the context of the urban environment. Overlap with other established programmes (particularly in development of new markets for recovered materials) has deliberately been avoided through a combination of topic selection, jointly-funded projects and working in areas in which we have complementary expertise.

The proposed projects focus on a cross section of problems, each associated with at least one of the following areas.

#### **A. Understanding materials and energy flows through the urban environment**

Overall assessment of the environmental, economic and social impacts of a given waste management strategy depends crucially on a sound understanding of the basic materials and energy flows. Previous work (e.g. the Biffaward projects) has generally focussed on mass balance techniques: here, we will aim to develop and apply approaches based on both the materials and energy demands and outputs associated with various processes as a basis for the comparison and selection of urban waste management options. A major difficulty with research based on real data is that the datasets needed are rarely complete: Project 1 (led by the University of Surrey) will develop methodologies and models for the reliable interpolation and extrapolation of data as a basis for an assessment of waste management strategies. This work will both draw on the findings of the other projects, and inform them by providing a coherent approach. An energy-focused assessment building on the results of mass balance and other studies will be carried out with reference to a case study of the Southampton area (Project 8, led by the University of Southampton, for which 50% funding has been obtained from Biffaward). The work in this section of the programme will provide an essential underpinning framework for the other projects in the Consortium proposal.

#### **B. Waste Streams**

We take it as a given that any future waste management strategy worthy of the name will involve different treatment technologies for different waste streams, for which separation of wastes (either following collection or at source) will be a prerequisite. The major waste streams of commercial and light industrial waste, biodegradable waste, and domestic non-degradable waste together typically account for much of the waste arising from an urban environment. A further waste stream that is often neglected, but is of interest for its re-use potential and the difficulties associated with its collection, is that of bulky items such as furniture and domestic white or brown electrical goods. We therefore have projects focussing on each of these four waste streams. Projects on biodegradable and domestic non-biodegradable waste will focus on the assessment of appropriate scales and technologies for biological and thermal treatments respectively. Project 2 (Thermal processing) will be led by Imperial College with input from the University of Sheffield and University College London, while Project 3 (Bioprocessing) will be led by the University of Southampton with input from Imperial College. Both projects will take account of relevant recent and impending legislation, and will include appropriate consideration of possible changes in the

composition of the urban waste stream including those brought about by developments in technology, legislation and/or strategy including those arising as a result of this research. Project 4 on commercial and light industrial waste, which has been submitted to Onyx Environmental Trust for additional funding, will focus on methodologies for assessing types and quantities and on identifying the infrastructure needed to optimise joint recovery with domestic waste. The project on bulky wastes (Project 6) has a rather different emphasis. It will be led by Goldsmiths College and the University of Southampton, and will focus on analysing the contribution and performance of multiple (economic, environmental, social) benefit schemes for waste avoidance and reuse, through studies of bulky waste collections, furniture recycling schemes and informal local exchange networks.

### **C. Attributes of the Urban Environment**

These projects will focus on particular attributes of the urban environment and the constraints and/or opportunities they present for sustainable waste management. Project 5 (led by Southampton TRG) will focus on the optimisation of logistics and transport requirements and identification of strategies and technologies to increase recovery rates at centralised urban collection facilities such as household waste and civic amenity sites. Project 7 (led by Goldsmiths College with input from Southampton) will aim to develop an understanding the impact of the interface between public and private space on operation and efficiency of household waste minimisation, re-use and recovery schemes. Project 6, with its consideration of the role of foreland informal local exchange networks, also falls into this category.

These eight projects put forward for EPSRC funding are summarised in the accompanying work programme. As the diagrams in appendix C indicate, they are closely interlinked, as the knowledge and expertise associated with the technological projects provides essential input to the projects concerned with the development of means of understanding the relationships between technological know-how, societal expectations and regulatory/economic drivers and the assessment of waste management options for urban environments.

### **Additional projects**

The above projects are submitted for EPSRC funding under the SUE programme, but the Consortium intends to apply for additional funding from other sources. Additional project proposals in this area which have been or are being submitted for external funding include proposals on optimal scheduling of household waste collections (submitted to SITA Environmental Trust); integrating collection and disposal of domestic refuse, recyclables and commercial waste across local authority boundaries (EPSRC responsive mode); ethnographies of sustainability (ESRC Sustainable Technologies Initiative); anaerobic digestion of kitchen wastes (SITA Environmental Trust); commercial/industrial waste audit (Onyx Environmental Trust); Efficient exploitation of energy from biomass/wastes (EPSRC responsive mode). Detailed plans for further linked applications await the resolution of the present uncertainty concerning the ending of the Landfill Tax Credit Scheme and arrangements for its successor initiatives.

### **Programme management**

The remaining element in the research programme is coordination and management of the Consortium, and expansion of its core EPSRC-funded programme by the addition of externally funded projects. This component is critical to the success of the programme, due to the highly interdependent nature of the themes addressed and the many resulting interconnections between different individual projects (see appendix C for project interrelation diagrams). It is taken as a principle that management of the projects should be closely integrated with the work being carried out and should take place as far as possible at individual project level by those directly involved. The management strategy is therefore designed to ensure effective provision of multi-directional coordination and exchanges of information (bottom-up, top-down and horizontal).

1. Individual projects will be managed on a day-to-day basis by the investigators named in the project descriptions. As indicated in the project interconnection matrix in appendix C, most of the projects involve more than one Consortium partner. There will be frequent *informal meetings* between the partners on a given project to discuss plans, progress and results.

2. The projects themselves form into subgroups or clusters of interconnected interests: one such grouping is outlined above, while others are illustrated graphically in appendix C. *Joint theme workshops* will be held periodically between partners in project clusters: the number of these will vary from theme to theme according to the participants' needs but each cluster is expected to meet at least three times in the course of the programme.
3. Representatives from all the research teams will take part in three *Project Seminars* at the beginning, middle and towards the end of the 4-year project period to allow exchange of data and ensure that new synergies between results are identified and exploited.
4. Top-down direction will be provided by an *Advisory Committee*, comprising representatives from each of the major industry collaborators and other end-user organisations together with the named investigators. The Advisory Committee will meet at approximately six-monthly intervals to consider progress with the research and discuss future directions and dissemination of the results.

Effective administration of the research is essential to the success of the Consortium, and this will be the responsibility of the Consortium Leader. Funds to support a Senior Research Fellow (University of Southampton) for eight months within the 4-year period are requested in addition to direct project costs, to ensure that administration, reporting and dissemination activities are carried out smoothly and effectively and to work on development of the broader Consortium programme.

### **Relevance to beneficiaries**

Major beneficiaries will be

- society and communities, who will benefit economically and environmentally from the development and implementation of an informed consensus on best practice in urban waste management
- companies in the UK waste management sector, who will benefit from the development of innovative approaches and best practice expertise in urban waste management that can be exported around the world
- national, regional and local government, who will be able to set and to meet appropriate targets for sustainable urban waste management to the environmental, economic and social benefit of the communities they serve.

### **Novelty and timeliness**

The proposed research is novel because it brings together for the first time researchers from a variety of disciplines both within and outside engineering, to focus specifically on the problems of sustainable waste and resource management in urban environments. It is timely because it

- builds on the unrivalled combined expertise of the members of the Consortium to develop waste resource management strategies that are environmentally benign and flexible enough to meet future needs that are likely to be different from those of today
- will help to meet the requirements of recent and impending changes in legislation and the technical, societal and economic challenges they pose
- addresses an issue that is central to the concept of a sustainable urban environment, and that we cannot afford to ignore any longer.

### **Dissemination and exploitation**

As mentioned earlier, dissemination of the research results in a way that will influence and inform policy and practice is a key component of the Consortium's work, and will be achieved in the following ways.

- Publications in leading international peer-reviewed journals (eg *Waste Management Research*, *Journal of the Chartered Institute of Waste Management*, *Environment and Waste Management*, *Journal of Material Culture*)
- Articles in specialist trade and technical press (eg *Wastes Management*, *WARMER Bulletin*, *Materials Recycling*, *Recycling International*, *Sustain*)
- Our own biennial conference: all Consortium members to attend
- Presentations and strong corporate presence at conferences eg Sardinia 2003/5, Waste 2004, International Conference on Solid Waste Technology and Management

- Academic/industry/local authority workshops and seminars: these will be run independently and also in conjunction with Project Integra dissemination activities.
- Dissemination of best practice through networks with which Consortium members are already involved (NetSWAM GR/R08759/01, Southampton; National Dioxin Network GR/M72456/01, Sheffield)
- Consortium website with links to participants' own websites
- Briefing materials to existing associations and networks eg Association of Cities and Regions for Recycling (ACRR); Association of Sustainable Use and Recovery of Resources in Europe (ASSURRE); International Solid Waste Association; Institute of Wastes Management, WasteWatch, LetsRecycle, European Recycling Network (ERnet), European Network of Social Economy Enterprises in Re-use and Recycling RREUSE, Community Recycling Network CRN, European Incineration Network PREWIN/Petten.

The link with Hampshire County Council and its Project Integra group is of particular importance: shared publicity and dissemination activities and briefing of senior figures have a major role in ensuring that research findings reach a key audience of government policy-makers, waste industry companies and local authorities involved in implementation.

In addition, we see the Advisory Committee as playing a key role in promoting the interplay between the project team members and the end users of the research, ensuring rapid dissemination of the results into practice as well as timely guidance and steering. To this end, we have invited representatives of a number of major end-user organisations (including ESART and CIWM: the Environment Agency is still to be approached) to join the Advisory Committee in addition to our industry collaborators and the named investigators.

### **Justification of resources**

The resources requested for the overall work programme and for each individual project are given in detail in appendix B. A total of £50,859 (including 8 months of a Senior Research Fellow over the 4-year period at the University of Southampton) is requested as direct funding to coordinate the research and support dissemination activities. This is matched by equivalent contributions of £54,650 from the industry partners. This activity is essential if the full potential added value of the Consortium approach is to be achieved.

### **Added value**

As well as the additional projects for which funding is being sought, the proposed research will benefit from a number of related projects already in progress in which Consortium members are participating. In addition to the grants mentioned in Part 1, these include

- *Facilitating more sustainable patterns of production and consumption in the UK.* (Imperial College. Biffaward, £360k, 2 years from June 2002): development of an easily accessible, central source of information to demonstrate the UK's progress in achieving the principles of Agenda 21, in particular in the areas of reducing solid waste generation as part of an overall move to more sustainable patterns of production and consumption.
- *Comparative evaluation of mesophilic and thermophilic biodigestion for the stabilisation and sanitation of kitchen waste.* (Southampton, Biffaward, £147k, August 2001 for 18 months).
- *'It's in the bag'.* (Southampton, Cleanaway, £250k, 2000-5): a study of the impact of education and other factors affecting public participation in a source-separated waste collection scheme.
- *Faraday Partnership on Novel Technologies & Processes for the Minimisation of Industrial Waste.* (Imperial College EPSRC, £2.2M, 5 years from April 2003).

### *References*

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