固废处理
中欧生态城意见书

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Solid Waste Management
EC-Link Position Paper – January 2018

Authored by:
Michael Boldt, Sweco (Formerly Grontmij)
With Annabelle Cleeve (Mott MacDonald)

What is EC-Link?

Europe-China Eco cities link project (EC-LINK,) is a European Union founded project, a key element of the EU-China Partnership on Sustainable Urbanisation, which was signed by the European Commission and the Chinese government in May 2012.

It aims to assist Chinese cities in implementing energy and resource-efficient measures by sharing European cities’ experiences in sustainable urbanisation. Meanwhile, EC-Link has created a platform of experience for easy accessible exchange between Chinese and European cities on low carbon/eco city development issues.

Enhancing communication and providing training to Chinese related organizations and its’ staff on policy making, giving technical advices on specific sustainable urban development projects will contribute a lot to China sustainable urbanization.

EC-Link has produced Eco city toolboxes, a Knowledge platform and is organising city-to-city cooperation in the frame of City Network Units’ activities (CNUs). CNUs activities are focussed on pilot actions implementation based on the joint work of Chinese and EU experts for a common objective, chosen in the frame of sustainable urbanisation issues.

Our aim is to increase learning curve from European cities’ good examples & techniques, strategy and methods. These activities enhanced the communication between Chinese cities and European cities, which formed a solid base for the further cooperation. http://eclink.org/en/
PREFACE

China’s Commitment to Mitigate Climate Change

In 2015, China was one of the first Asian countries – besides Japan and South Korea – to come out strongly with a commitment to combat climate change, and to adapt to eventual future impacts.

Context. With its population of about 1,300 million people, China is one of the world’s major emitters of greenhouse gases (GHG), and at the same time it is also one of the most vulnerable countries to the negative impacts of climate change.

Commitment. In preparation for the 2015 United Nations Climate Change Meeting (COP21) in Paris, the government of China has announced that its GHG emissions will peak in 2030. Equally, it is committed to reduce by 2030 by 60-65% the intensity of its carbon usage in relationship to its gross domestic product (GDP), compared to 2005 levels. It will take on the responsibility to increase substantially its forest cover, and will ensure that by 2030 some 20% of its energy requirements will be covered by renewable energy.

Actions. The country’s measures will include mitigation of its contributions to GHG emissions, and it will introduce adaptations measures to cope with negative impacts of climate change in food production, protection of its population, and in climate-proof infrastructure. China aims at biding climate change agreements under the COP21. The international community sees the proposed measures as ambitious but achievable. Since several years, China has started with low-carbon development. Today it is working towards a full-fledged program of green development of its economy.

Eco-Cities and Climate Change

China’s activities to create eco-cities must be seen as part of its contributions to low-carbon development with aim to mitigate climate change. Among the various support mechanisms which exist, to support low-carbon development, the Ministry of Housing, and Urban-Rural Development (MoHURD), is being supported by the European Union (EU) through the Europe-China Eco-Cities Link Project (EC Link).

Background. The main objective of the EC Link project is to serve as a support mechanism to the Ministry of Housing and Urban-Rural Development to implement its sustainable low-carbon urbanisation agenda. The project will support the Ministry in 4 strategic areas:

1) Demonstrate best approaches to implement low carbon solutions by introducing appropriate urban planning tools. Best practice low carbon planning will be identified in both Europe and China and made available nation-wide to municipal governments. Advanced planning tools will be deployed at the local level with the support of the project, with a view to refining proposed low-carbon planning models and to scaling them up across Chinese provinces.
2) Serve as testing ground for innovations in specific low-carbon policies (e.g. energy performance labelling for buildings, intelligent transport systems, smart cities, GIS planning tools, eco city labelling schemes) and technologies (in the 9 sectors selected by the project: compact urban development, clean energy, green buildings, green transportation, water management, solid waste treatment, urban renewal and revitalization, municipal financing, green industries).

3) Improve Chinese Municipalities' potential to finance low carbon solutions and notably their ability to attract private sector financing in the form of public private partnerships. The EC Link will support MoHURD to define innovative financial schemes, support feasibility studies and the formulation of finance and investment proposals, better coordinate and leverage investments undertaken by EU Member States, or to link projects to European financing institutions (e.g. European Investment Bank) and to European companies.

4) Establish knowledge networks and test the functionality of the support mechanism by leveraging, scaling up, and integrating transformative actions supported by the policy and technology tools developed under the project. The Knowledge Platform will demonstrate how strategic objectives have been translated at local level and how results have been integrated at national level for the definition of long-term best practices. Results will be shared via training and capacity building at local level, and via the knowledge platform set-up by the project at national and international level.

The EC Link Position Papers. MoHURD and the EC Link Technical Assistance Team (TAT) have identified 9 specific sectors for the deployment of technology based tool boxes. In all of these, Europe has a lot of knowledge and best practice to contribute to support the deployment of these solutions in China. These 9 sectors include:

- compact urban development,
- clean energy,
- green buildings,
- green transportation,
- water management,
- solid waste treatment,
- urban renewal and revitalization,
- municipal financing,
- green industries.

MoHURD’s Department of Science and Technology, EC Link’s direct counterpart, has issued targeted objectives for the deployment of policy, research and development and engineering agendas.

Users and Target Groups of Position Papers. The EC Link Position Papers will be utilized by personnel of the cities which are covered by MoHURD’s eco-city programme. This covers technical and managerial staff of these cities. Additionally, at central government level, MoHURD and other ministries may also make use of these position papers for the purpose of staff training and briefing.
Since these position papers are also going to be published in the EC Link website (www.eclink.org), also the general public is invited to make use of these position papers.

**Content of Position Papers**

**Sector overview:** The EC-Link position papers provide an overview of each thematic sector (compact urban development, clean energy, green buildings, green transportation, water management, solid waste treatment, urban renewal and revitalization, municipal financing, green industries). It begins with a state-of-the-art review of the sector, and presents sector challenges as development objectives.

**Sector policy analysis:** As part of the sector overview, the EC-Link position papers provide sector policy analysis, and a comparison of EU and Chinese sector policies.

**Comparison of European and Chinese experiences:** The comparison of real-life EU and Chinese project experiences are used to illustrate innovations and progress in the respective sector. Both for EU and Chinese cases, there is an overview of good practices, technologies and products, performance indicators, technical standards, verification methods, and lessons learnt from best eco-city practices.

**Tools:** This position paper contains four primary tools. Throughout the text of this position paper there are flags provided to point out these primary tools (Tool SWM 1, Tool SWM 2, Tool SWM 3, Tool SWM 4). At the end of the position paper there is an Annex with short summary descriptions of these primary tools.

The primary tools for Solid Waste Management (SWM) are:

- Tool SWM 2: 3-R Tools.
- Tool SWM 3: Management of Closure of Sanitary Landfills.

It is understood that these primary tools, do contain numerous secondary tools which cannot be elaborated in the context of this position paper.

**Position Paper - a living document:** This position paper will be updated based on city-level real-life project experiences in the EC-Link pilot cities.

**Possible misconceptions:** These position papers shall not be mistaken for ‘cook books’, or ‘how to do’-manuals like we know them from other subject fields (car repair, computer servicing, etc.). Urban development is too complex for such an approach.
Upon request of MoHURD these position papers are addressing good practices and seek to provide tools for complex issues of green urban development.

DISCLAIMER

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## Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>3R</td>
<td>Reduce, Reuse, and Recycle</td>
</tr>
<tr>
<td>AAR</td>
<td>After Action Review</td>
</tr>
<tr>
<td>AMM</td>
<td>Asset Management and Monitoring System</td>
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<td>BAU</td>
<td>Business-as-Usual</td>
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<td>BMW</td>
<td>Biodegradable Municipal Waste</td>
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<tr>
<td>BOT</td>
<td>Build, Operate and Transfer</td>
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<td>BSC</td>
<td>Balanced Scorecard</td>
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<td>CBA</td>
<td>Cost Benefits Analysis</td>
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<td>CCS</td>
<td>Carbon Capture and Storage</td>
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<tr>
<td>CD</td>
<td>Council Decision (EU)</td>
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<tr>
<td>CDM</td>
<td>Clean Development Mechanism</td>
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<td>CDW (C&amp;D)</td>
<td>Construction and Demolition Waste</td>
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<tr>
<td>CFC</td>
<td>Chlorofluorocarbon</td>
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<tr>
<td>CO$_{2}$e</td>
<td>Carbon Dioxide Equivalent</td>
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<tr>
<td>CoP</td>
<td>Conference of Parties</td>
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<tr>
<td>CRM</td>
<td>Customer Relations Management System</td>
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<td>CSR</td>
<td>Corporate Social Responsibility</td>
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<tr>
<td>DFC</td>
<td>Dedicated Freight Corridor</td>
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<td>EBRD</td>
<td>European Bank of Reconstruction</td>
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<td>EIA</td>
<td>Environmental Impact Assessment</td>
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<td>EIB</td>
<td>European Investment Bank</td>
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<tr>
<td>ELT</td>
<td>End of life tyres</td>
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<td>ELV</td>
<td>End of life vehicles</td>
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<tr>
<td>EPR</td>
<td>Extended Producer Responsibility or the Polluter Pays Principle</td>
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<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>EURO</td>
<td>The official currency of the European Union</td>
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<tr>
<td>EV</td>
<td>Electric Vehicles</td>
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<tr>
<td>FIDIC</td>
<td>Fédération Internationale Des Ingénieurs-Conseils, (the International Federation of Consulting Engineers)</td>
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<tr>
<td>FS</td>
<td>Feasibility Study</td>
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<tr>
<td>GAP</td>
<td>Good Average Poor (evaluation method)</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GEA</td>
<td>Global Energy Assessment</td>
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<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>Gt</td>
<td>Giga tonne = 1,000,000,000 tonne (where 1 tonne = 1000kg)</td>
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<td>Abbr.</td>
<td>Description</td>
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<tr>
<td>GWP</td>
<td>Global Warming Potential</td>
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<td>HCRW</td>
<td>Health Care Risk Waste</td>
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<td>HCW</td>
<td>Health Care Waste</td>
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<td>HFCs</td>
<td>Hydrofluorocarbons</td>
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<tr>
<td>HHW</td>
<td>Household Hazardous Waste</td>
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<tr>
<td>HS</td>
<td>Hazardous Substances</td>
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<td>HSE</td>
<td>Health</td>
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<td>HWRC</td>
<td>household waste recycling centre</td>
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<tr>
<td>IAM</td>
<td>Integrated Assessment Models</td>
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<tr>
<td>IAS</td>
<td>International Accounting Standard</td>
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<tr>
<td>IAV</td>
<td>Impacts Adaptation and Vulnerability</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>IFI</td>
<td>International Financial Institutions</td>
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<tr>
<td>IFRS</td>
<td>International Financial Reporting Standard</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<tr>
<td>IRR</td>
<td>Internal Rate of Return (note of E = Economic, F = Financial)</td>
</tr>
<tr>
<td>ISWM</td>
<td>Integrated Solid Waste Management</td>
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<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
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<tr>
<td>LCS</td>
<td>Low Carbon Society</td>
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<td>LFA</td>
<td>Logical Framework Analysis</td>
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<tr>
<td>MBT</td>
<td>Mechanical Biological Treatment</td>
</tr>
<tr>
<td>MIS</td>
<td>Management Information System</td>
</tr>
<tr>
<td>MRF</td>
<td>Material Recover Facility</td>
</tr>
<tr>
<td>MSW</td>
<td>Municipal Solid Waste</td>
</tr>
<tr>
<td>Mt</td>
<td>Mega tonne = 1.000.000 tonne (where 1 tonne =1000kg)</td>
</tr>
<tr>
<td>MW</td>
<td>Megawatt</td>
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<tr>
<td>NGO</td>
<td>Non Governmental Organisation</td>
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<tr>
<td>NPV</td>
<td>Net Present Value (note of E = Economic, F = Financial)</td>
</tr>
<tr>
<td>O &amp; M</td>
<td>Operating and Maintenance</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>OMS</td>
<td>Operation and Maintenance Strategy</td>
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<tr>
<td>PFC</td>
<td>Perfluorinated Compounds</td>
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<tr>
<td>PPMV</td>
<td>Parts per Million Volume</td>
</tr>
<tr>
<td>PPP</td>
<td>Public Private Partnership</td>
</tr>
<tr>
<td>PPU</td>
<td>Project Preparation Unit</td>
</tr>
<tr>
<td>PRAG</td>
<td>PRActical Guide to contract procedures for EC external actions</td>
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<tr>
<td>RCP</td>
<td>Representative Concentration Pathways</td>
</tr>
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</table>
RCV  Refuse Collection Vehicle
RDF  Refuse Derived Fuel
SIA  Social Impact Assessment
SPM  Summary for Policy makers
SPV  Special Purpose or Project Vehicle
SSP  Shared Socioeconomic Pathways
SWM  Solid Waste Management
SWOT Strengths, Weaknesses, Opportunities, and Threats (evaluation method)
TA  Technical Assistance
ToC  Table of Contents
ToR  Terms of Reference
tpd  tonne per day (where 1 tonne =1000kg)
TS  Transfer Station
UNEP United Nations Environment Programme
UNFCCC United Nations Framework Convention on Climate Change
VAT  Value Added Tax
VfM  Value for Money
WB  World Bank
WEEE  Waste Electrical and Electronic Equipment
WM  Waste Management
WMP  Waste Management Plan
WTE (W2E)  Waste to Energy
WTP  Willingness to Pay
WWTP  Waste Water Treatment Plant
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# Glossary of Terms

<table>
<thead>
<tr>
<th>Types of Waste</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste</td>
<td>Any substance or object, which the Holder discards, or intends, or is required to discard.</td>
</tr>
<tr>
<td>Animal waste</td>
<td>Animal by-products not intended for human consumption, whole bodies or parts of bodies from animals.</td>
</tr>
<tr>
<td>Biodegradable waste</td>
<td>Any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.</td>
</tr>
<tr>
<td>Bio-waste</td>
<td>Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.</td>
</tr>
<tr>
<td>Construction and demolition waste</td>
<td>Waste resulting from construction or dismantling of buildings, roads and other structures of civil or industrial, which is not classified as hazardous waste.</td>
</tr>
<tr>
<td>Green Waste</td>
<td>Waste from plants.</td>
</tr>
<tr>
<td>Household waste</td>
<td>Waste from domestic activities and take part in classes 15.01 and 20 of the European Waste List.</td>
</tr>
<tr>
<td>Hazardous waste</td>
<td>Generic name for waste which fall in the categories of waste defined as hazardous and/or have at least one constituent or a property which they are dangerous.</td>
</tr>
<tr>
<td>Household Hazardous waste</td>
<td>Waste from households which is hazardous.</td>
</tr>
<tr>
<td>Inert waste</td>
<td>Waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the eco-toxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater;</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>Waste from households, as well as other waste which, because of its nature or composition, is similar to waste from households.</td>
</tr>
<tr>
<td>Packaging waste</td>
<td>Any packaging or packaging materials that meet the definition of waste.</td>
</tr>
<tr>
<td>Recyclable waste</td>
<td>Waste that may be material in a production process for obtaining the original or for other purposes.</td>
</tr>
<tr>
<td>Similar Waste</td>
<td>Originates from industry, trade, business or public administration, whose composition and properties are similar to household waste, it is collected, transported, processed and stored together with household waste.</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>Components from domestic or industrial activities, which have no value for use or do not use the user and are pre collected to be handed to the sanitation service operator.</td>
</tr>
</tbody>
</table>

---

1 It is worthwhile to note that biodegradable waste is wider than the bio-waste of the WFD. It further includes paper, cardboard, wood, textiles, etc.
Special waste: waste, whose handling, collection, transport and storage are subject to a regime governed by legal acts in order to avoid adverse effects on human health, property and the environment.

Street waste: waste specific public traffic routes, from the daily activity of the population of green spaces, from animals, from the filing of solids from the atmosphere.

WEEE: Waste Electrical and Electronic Equipment.

Products Compost: the product resulting from the fermentation and aerobic / anaerobic or by microbial decomposition of organic component of waste subject composting.

Waste Management and Waste Operators

<table>
<thead>
<tr>
<th>Public sanitation system</th>
<th>all the technological facilities, equipment and facilities specific function, construction and related land through which the service sanitation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste management</td>
<td>the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker.</td>
</tr>
<tr>
<td>Broker</td>
<td>any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste.</td>
</tr>
<tr>
<td>Dealer</td>
<td>any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste.</td>
</tr>
<tr>
<td>Holder</td>
<td>the producer of the waste, or the natural, or legal person who is in possession of it</td>
</tr>
<tr>
<td>Operator</td>
<td>the natural or legal person responsible for a landfill in accordance with the internal legislation of the Member State where the landfill is located; this person may change from the preparation to the after-care phase.</td>
</tr>
<tr>
<td>Producer of waste</td>
<td>anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.</td>
</tr>
</tbody>
</table>

Performance of Service

<table>
<thead>
<tr>
<th>Performance indicators</th>
<th>parameters of sanitation service operations, which set minimum levels of quality and which track operator performance to license conditions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service level;</td>
<td>the waste must meet the level of users, the performance indicators approved by the local councils or, where appropriate, community development associations, based on performance indicators of the framework Regulation.</td>
</tr>
</tbody>
</table>

Facilities

<table>
<thead>
<tr>
<th>Landfill</th>
<th>final disposal site for waste storage on the ground or underground.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer station</td>
<td>space specially arranged for temporary storage of waste collected from the same locality or in different localities in order to transport them to a central MRF, Pre-treatment facility, Incinerator, or a sanitary landfill.</td>
</tr>
<tr>
<td>Green Collection Points / Green Disposal Point</td>
<td>a bring to point space specially arranged for the temporary storage of waste fractions collected from households of in order to transport them a central MRF, Incinerator, or a sanitary landfill.</td>
</tr>
<tr>
<td>A Civic Amenity Site or household waste recycling centre</td>
<td>a facility where the public can dispose of recyclable materials, hazardous waste, and bulky waste. Civic amenity sites are run by the local authority in a given area. Collection points for recyclable waste such as green waste, metals, glass and other waste types are available. The site is staffed with trained personnel, who can guide and monitor visitors behaviour. In Denmark, Sweden and Germany waste may be sorted into more than 20 different factions.</td>
</tr>
</tbody>
</table>

### Activities

| Collection | the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility. |
| Separate collection | the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment. |
| Recovery | any waste management operation that diverts a waste material from the waste stream and which results in a certain product with a potential economic or ecological benefit. Recovery mainly refers to the following operations: Material recovery, i.e. recycling, Energy recovery, i.e. re-use a fuel, Biological recovery, e.g. composting, Re-use. |
| Disposal | any waste management operation serving or carrying out the final treatment and disposal of waste |
| Final treatment | Incineration, Biological, physical, chemical treatment resulting in products or residues that are discarded, i.e. going to final disposal. |
| Final disposal | Deposit into or onto land (e.g. Landfill), including specially engineered landfill, Deep injection, Surface impoundment, Release into water bodies, Permanent storage. |
1. THEMATIC BACKGROUND

1.1 Solid Waste Management

Solid Waste Management is a set of characteristic activities that include the following:

- Collection, transport, treatment and disposal of waste;
- Control, monitoring and regulation of the production, collection, transport, treatment and disposal of waste; and
- Prevention of waste generation through in-process modification, reuse and recycling.

The various waste flows for the different sources and the options for waste processing, treatment and disposal after collection need to be integrated into the solid waste management system to be employed in a Green City (or Eco-City). The system is consistent with the solid waste management hierarchy, which gives precedence to the 3Rs (reduce – recycle – reuse) and less preference to direct treatment or disposal where practicable. The directly reusable segregated waste from residences, institutions, commercial establishments, industrial facilities and construction and demolition activities goes back to these sources.

Solid waste management, or preferably Integrated Solid Waste Management (ISWM), is a comprehensive waste prevention, recycling, composting, and disposal program. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills. Each of these activities requires careful planning, financing, collection, and transport.

RESILIENCE TO CLIMATE CHANGE IMPACTS describes the impacts caused by climate changes on the waste management activities. The impact, both short-term and long-term, from higher temperature and greater rainfall leading to possible rodent infestations, disease outbreak, and groundwater contamination is discussed.

Adaptation actions can be integrated into the upfront design, construction, operation, and maintenance of solid waste management systems. Integrating adaptation can prevent maladaptive decisions that increase the vulnerability of the infrastructure and people they are trying to serve.

Best Practices – Perspectives from Europe is the main position paper section, where the important elements of Solid waste management are described. The chapter is not only discussing technical issues with focus on equipment and technologies, but tries to give the reader a broader perspective into the organisational and financial part of municipal solid waste management.

Europe consists of 47 countries (Number of member states in Council of Europe) of which 28 countries are members of EU, 5 are candidates to EU, and 4 are Free Trade Association countries. The presentation of the political structure and procedures in this “position paper” is limited to best practices inside EU, since the EU is the leading decision maker and sets the minimum standards for its member, candidate, and associated countries.
Forbidden City, Beijing –

Solid Waste Management is required even in the most prominent locations

The term of solid waste management (SWM) usually relates to all kinds of waste, whether generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, or other human activities, including municipal (residential, institutional, commercial), agricultural, and special (health care, household hazardous wastes, sewage sludge). Waste management is intended to reduce the effect of waste on health, the environment or aesthetics.

It has to be mentioned that the last bullet point - Prevention of waste generation… - is not an activity, which is directly linked to the waste handling and treatment activities, and therefore not a usual part of a municipal waste management service. In a private enterprise prevention of waste generation is driven by simple economic forces that generation of waste is not a profitable business – on the contrary – Generation of waste costs money because resources cost money and disposal of waste costs money, and there are no incomes.

Where the European municipalities (or waste handling companies) really can make a difference is when it comes to guiding the companies to segregate their waste and recyclable materials in order to minimise their costs, especially when it comes to handling of waste and recyclable materials at demolition and construction sites.

Asian cities employ a variety of waste management systems based on available technical and financial resources, and the current level of environmental awareness. This is consistent with a city’s transition from basic to the low-carbon city. Eco-Cities solid waste management adopts the 3R approach (Reduce, Reuse, and Recycle), which can be further reflected in the waste hierarchy.

The adoption of these principles will occur in varying degrees at all stages of city development and status within the assessment framework (basic – eco – carbon positive).
Cities with low institutionally and financial capacity may only employ management techniques such as partial collection, open dumping, and reliance on the informal sector for collection and any reuse practices. The role of the informal sector, i.e., sorting and recovering recyclables, is often significant when cities are only able to adopt moderately low levels of solid waste management practices. As cities develop and when resources allow, waste collection coverage will increase, disposal of waste via sanitary landfills development of composting facilities, increased recovery of recyclables (including mechanization) and development and operation of waste-to-energy (WTE) plants are some initiatives that can be implemented.

Poor waste management practices have negative impacts on human health and the environment. Waste dumped in or near watercourses contaminates the water, restricts the water flow, and leads to a degraded aquatic environment; inappropriate treatment of industrial and medical waste poses great risks to human health and the natural environment, poor practices increase vermin in urban areas, and overall poor waste management practices are a visual blight.

Forward planning that considers waste management within the context of continued urbanization and population gain also needs to consider the spatial extent of the city, the appropriate sites for waste management facilities, and the potential for cross-boundary collaboration. Consideration to the ability for expansion as well as transition from lower technology to higher technology solutions is also required.

As the world’s population continues to grow at a rapid pace, so does the problem of solid waste management. This reality, along with the consequent negative environmental impacts is never more apparent than in Asian cities. These urban centres are expected to be occupied by about 2.7 billion people by 2030\(^2\). At a conservative average per capita waste generation of 1.5 kilograms, about four (4) billion tons of waste per day can be produced, enough to build a 2-meter high wall of waste equivalent to the length of the Great Wall of China.

Asian cities generally employ a variety of waste management systems based on available technical and financial resources and level of environmental awareness. The system employed by the lower income urban centres cover mainly partial collection, open dumping, partial recovery of recyclables by the informal sector, limited composting and some landfilling. Cities of developing and developed countries have greater collection coverage, utilize landfills for disposal, operate waste to energy plants and employ mechanized recovery of recyclables and composting.

Overall, the systems are still anchored on waste collection and disposal to handle the bulk of generated waste. Composting and recovery of recyclables through mechanized or manual means have not reached significant proportions relative to the overall waste generation of these cities. Open dumping is prevalent while development of sanitary landfills is constrained by limited community acceptance to these engineered disposal facilities. The limited space in most cities likewise prevents the development of more landfills as the current set of disposal facilities gets filled up.

---

Table 1: Components of Solid Waste Management Systems in Key Asian Cities

<table>
<thead>
<tr>
<th>Reference Year</th>
<th>Cities</th>
<th>Waste Generation (tpd)</th>
<th>Collection (tpd)</th>
<th>Recycling (tpd)</th>
<th>Composting (tpd)</th>
<th>Incineration (tpd)</th>
<th>Disposal (tpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>Bangkok</td>
<td>9,400</td>
<td>7,500</td>
<td>No data</td>
<td>280</td>
<td>20^</td>
<td>~7,275</td>
</tr>
<tr>
<td>2004</td>
<td>Jakarta</td>
<td>8,562</td>
<td>6,850</td>
<td>No Data</td>
<td>7</td>
<td>22</td>
<td>6,000^</td>
</tr>
<tr>
<td>2005</td>
<td>Dhaka</td>
<td>4,634</td>
<td>1,946</td>
<td>475</td>
<td>15</td>
<td>None</td>
<td>1,946</td>
</tr>
<tr>
<td>2006</td>
<td>Beijing</td>
<td>16,000</td>
<td>13,615</td>
<td>3,918</td>
<td>740</td>
<td>30</td>
<td>12,845</td>
</tr>
<tr>
<td>2007</td>
<td>Calcutta</td>
<td>3,000</td>
<td>1,800</td>
<td>300</td>
<td>700</td>
<td>None</td>
<td>1,800</td>
</tr>
<tr>
<td>2009</td>
<td>Shanghai</td>
<td>19,233</td>
<td>19,233</td>
<td>No data</td>
<td>1,923</td>
<td>3,077</td>
<td>10,193</td>
</tr>
<tr>
<td>2009</td>
<td>Singapore</td>
<td>16,751</td>
<td>16,751</td>
<td>9,548</td>
<td>No data</td>
<td>6,795</td>
<td>408</td>
</tr>
<tr>
<td>2010</td>
<td>Hongkong</td>
<td>23,680</td>
<td>23,680</td>
<td>9,863</td>
<td>No data</td>
<td>None</td>
<td>13,817</td>
</tr>
</tbody>
</table>


Incineration is used in highly developed cities like Singapore and large cities in China. High cost\(^{15}\) and perceived negative impacts on the air environment and loss of resources serve as steep barriers for the use of this technology by less developed cities. Industrial waste is generally managed along with the ordinary municipal solid waste and as such is usually disposed in open dumps and landfills.\(^{16}\)

Evidently, the current methods for managing the bulk of the waste generated in Asian cities would not be enough as the volume grows in response to population growth and economic development.

The key to the sustainable management of solid waste in cities lies in the practical operationalization of the principles of reduce, reuse and recycle (the 3Rs) and the application

---


\(^4\) Recycling practiced by informal sector has no recorded data.

\(^5\) Hospital waste is incinerated in the facility.


\(^7\) Estimate only, about 1,700 ton per day unaccounted for and inferred to go to vacant lots, waterways or burned


\(^12\) Yoshiro H., Y. Friedrich, 2009. Municipal Solid Waste Management System----- A case study in Shanghai, Lu Keyu, University of TSUKUBA.


of the appropriate technologies in the different stages of waste flow to attain acceptable sanitation conditions and facilitate recovery and use of materials. This is what is envisioned for the Green City of the future. The following sections present the preferred flow of waste from the different generators and common methods and technologies which are consistent with Green City environmental standards as implemented in some Asian cities. The succeeding sections also highlight the features which must be present to sustain operation.

1.2 Solid Waste Flow in Green Cities

Solid waste management in Green Cities is anchored on avoidance and 3Rs (reduce, reuse and recycle practices) which occupy the upper tiers of the solid waste management hierarchy. The hierarchy serves as the general guide in the waste flow adopted at various levels of activities. It is based on the composition of the waste from various generators and the availability of conventional or available new technologies where practicable.

Figure 1: Solid Waste Management Hierarchy

The classified composition of waste from the different generators is presented in Table 2, below. The percentages of the different components vary with the level of economic development attained in cities or countries. In low income and developing countries, the bulk of the waste generated corresponds to food and other biodegradable materials. Organic matter makes up over 50% of the solid waste of the ASEAN cities of Manila, Bangkok, Kuala Lumpur and Jakarta. The high income or industrialized countries have relatively higher non-biodegradable components. For each city, an updated waste characterization data is a must as this will serve as the basis for the development of the appropriate solid waste management system. WEEE has been included in all the sources as the generation of these materials has increased with the manufacturing activities associated with economic growth.

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18 This chapter is an adaptation of Rollan, R. R. Green City Solid Waste Management, in: Lindfield, M. and Steinberg, F. (eds.), 2012. *Green Cities*. Manila: Asian Development Bank. Urban Development Series. Manila. For other references, please see the same publication. In order to ease the reading of this chapter is all other references deleted.
### Table 2: Sources and Types of Solid Wastes

<table>
<thead>
<tr>
<th>Source</th>
<th>Typical waste generators</th>
<th>Biodegradable Component</th>
<th>Non-Biodegradable Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Single and multifamily dwellings</td>
<td>Food waste, paper, cardboard, textiles, leather, yard wastes, wood,</td>
<td>Glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, appliances, batteries, oil, tires), and household hazardous wastes).plastics, WEEE</td>
</tr>
<tr>
<td>Industrial</td>
<td>Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.</td>
<td>Food waste</td>
<td>Housekeeping wastes, packaging, hazardous wastes, special wastes, WEEE, ashes,</td>
</tr>
<tr>
<td>Commercial</td>
<td>Stores, hotels, restaurants, markets, etc.</td>
<td>Paper, cardboard, plastics, wood, food wastes (unused and leftovers, expired food packages),</td>
<td>Glass, metals, special wastes, hazardous waste, WEEE</td>
</tr>
<tr>
<td>Institutional</td>
<td>Schools, hospitals, prisons, government centers, banks, offices</td>
<td>Paper, cardboard, plastics, wood, food waste</td>
<td>Glass, metals, special wastes, hazardous waste, WEEE</td>
</tr>
<tr>
<td>Construction and Demolition</td>
<td>New construction sites, road repair, renovation sites, demolition of buildings</td>
<td>Wood</td>
<td>Steel, concrete, dirt, wrapping and packaging materials</td>
</tr>
<tr>
<td>City services</td>
<td>Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.</td>
<td>Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas;</td>
<td>Sludge. WEEE</td>
</tr>
</tbody>
</table>

Green City Solid Waste Management as modified from What a Waste: Solid Waste Management in Asia, 1999

Depending on the waste composition and generator, various components follow a path, which takes these materials to various methods of segregation at source for possible reuse, collection, processing and treatment, and final disposal. The material look shows a material process from generation to recycling. Small material loops prevail at source due to the reuse of recyclable components while bigger material loops exist upon the processing and recycling of collected waste which facilitates their use by the various generators. The recycling of waste materials and subsequent reuse in various forms may not necessarily be undertaken within the same city. The indicated waste flow for the various waste sources show the preferred route that will be taken by the different segregated components in a solid waste management system of an Eco-City.
Figure 2: Generic Waste and Material Flow in a Green City


Comment to Figure: By “Segregated Collection” is understood: collection of segregated materials.

1.2.1 Residential Sector

At residential areas, the dominant waste fractions include food/other biodegradable materials and dry potentially recyclable materials which can be segregated up to five categories prior to collection. Most solid waste management systems require the basic segregation into biodegradable and non-biodegradable components.

Figure 3: Waste Flow for Residential Areas


Comment to Figure: E-Waste is the same as WEEE. “Hazardous Waste” Needs to be sorted/segregated further since this fraction contains hazardous parts which are not allowed to be incinerated. Treatment is therefore either a pre-treatment for neutralisation, Incineration (incineration temperature depends on the hazards), or disposal at sanitary landfill category A or B.
The recovery and reuse of the dry potentially recyclable materials such as paper, plastics, glass bottles and tin including old appliances and electronic equipment take place at source at residential areas. Recovery of similar materials takes place during the collection process even before the waste reaches the transfer stations, Materials Recovery Facilities (MRFs) and disposal sites. These practices are undertaken mostly by the informal sector in cities in the least developed, low income and medium countries. The sustained operations of community-managed MRFs depend largely on the amount of recyclables left after segregation at the households and collection vehicles, and buy-back strategies which may be employed to attract the sale of the previously recovered valuable materials.

1.2.2 Industrial Sector

The industrial sector generates mainly special and hazardous waste which are collected and brought to one of the following facilities: treatment facilities, waste to energy plants or sanitary landfills for final disposal. The packaging materials and some housekeeping waste can be reused directly at the source. The rest, including WEEE, is collected and brought to MRFs for final segregation before being sold to recycling facilities. Segregated food waste can be brought to either composting plants or facilities which will process these materials to become animal feed (As a minimum food waste should be autoclaved at high temperature). As in residential waste, ash from incineration plants and residuals from MRFs can be used as construction aggregates or as ingredient ceramic production.

Figure 4: Waste Flow for Industrial Waste


Comment to Figure: E-Waste is the same as WEEE- “Hazardous Waste” Needs to be sorted/segregated further since this fraction contains hazardous parts which are not allowed to be incinerated. Treatment is therefore either a pre-treatment for neutralisation, Incineration (incineration temperature depends on the hazards), or disposal at sanitary landfill category A or B.
1.2.3 Commercial Sector

Commercial establishments like restaurants, groceries, hotels and markets primarily generate food waste which can be processed into animal feed or processed in composting plants. However, also paper, cardboard, Packaging materials, glass, PET, and metal may also be reused or recycled. The remaining dry recyclables and special waste including WEEE undergo final sorting and segregation for sale to recycling facilities. Residual materials from MRFs and hazardous materials can undergo treatment and be used as Refuse Derived Fuel (RDF) for to power plants, disposed in sanitary landfills or even be used as construction aggregate.

Figure 5: Waste Flow for Commercial Establishments


Comment to Figure: E-Waste is the same as WEEE: “Hazardous Waste” needs to be sorted/segregated further since this fraction contains hazardous parts which are not allowed to be incinerated. Treatment is therefore either a pre-treatment for neutralisation, incineration (incineration temperature depends on the hazards), or disposal at sanitary landfill category A or B.

1.2.4 Institutional Sector

Waste generated at institutions consists mainly of paper products which are used for office operations. Current practice involves the use of the blank pages for printing draft reports and as note pads. The paper materials which get collected are eventually recycled and subsequently reused. The rest of the waste from institutions follow the usual waste flow to composting plants in the case of biodegradable materials, animal feed processors in the case of food waste, materials recovery facilities and recycling plants in the case of the dry recyclables and WEEE and treatment or disposal in the case of hazardous materials.
Figure 6: Waste Flow for Institutions in a Green City


Comment to Figure: E-Waste is the same as WEEE- “Hazardous Waste” Needs to be sorted/segregated further since this fraction contains hazardous parts which are not allowed to be incinerated. Treatment is therefore either a pre-treatment for neutralisation, incineration (incineration temperature depends on the hazards), or disposal at sanitary landfill category A or B.

1.2.5 Construction Sector

The construction and demolitions (C&D) materials could be used for filling up low areas or as aggregates subject to passing basic suitability tests. Residual materials from the reuse of C & D materials and from its processing in MRFs can still be used as feed for waste to energy plants or as fuel for cement plants. Wood and related products can be used as temporary sheds or formworks at construction sites. The usual practice of disposing C & D materials to sanitary landfills is to be avoided.

Figure 7: Waste Flow for Construction and Demolition Sources


Comment to Figure: The figure is not complete. Insulation materials, wrapping and packaging materials, paint and bitumen product are definitely something that as a minimum should be
taken care of in the construction sector. In the European Waste Catalogue C&D waste is divided into 8 main fractions or 38 sub-fractions where 19 can be recycled.19

1.2.6 General Services Sector

Trimmings from parks and trees along roadways which make up the bulk of the waste collected by city services can be composted to produce soil conditioners using the windrows method. Street sweepings which include various types of biodegradable and non-biodegradable materials can be directed to MRFs for recovery of recyclable materials. The residual materials along with the sludge are then brought for disposal to a landfill or to a waste to energy facility.

Figure 8: Waste Flow for Waste Services


Comment to Figure: Street sweepings are considered very toxic! Exhaust particles from vehicles and other fumes together typical litter like cigarette butts ends up in the sweepings and may therefore contaminate in, for instance, compost facilities. Collection frequency depends on the season.

1.2.7 Integrated Waste Management

The various waste flows for the different sources and the options for waste processing, treatment and disposal after collection need to be integrated into the solid waste management system to be employed in a Green City. The system is consistent with the solid waste management hierarchy (see Figure 1), which gives precedence to the 3Rs and less preference to direct treatment or disposal where practicable. The directly reusable segregated waste from residences, institutions, commercial establishments, industrial facilities and construction and demolition activities goes back to these sources. The bulk of the segregated waste is collected and transported directly to MRFs or composting plants or optionally to transfer stations for cities where the processing facilities are located at large distances from the centre of waste generation. The outputs of the MRFs are directed to recycling plants within or outside the city which will subsequently turn out products which can be used for manufacturing processes. In the case of least developed, low income and middle income cities, the recyclable materials will

likely pass through junkshops thence directly to recycling plants or go through MRFs via a buy back scheme.

The compost can be used as soil conditioners for farms and gardens. It is expected that the quality of the compost will improve to saleable standards with time as proficiency in the chosen technology is attained. Residuals left out of the composting plants and MRFs are fed into waste to energy plants where available or disposed into sanitary landfills. The ash from these plants can be disposed to sanitary landfills or used as aggregate for concrete. Once the level of segregation and waste processing is able to process the bulk of the generated waste, the viability of operating WTE plants or incinerators or even landfills need to be evaluated.

**Figure 9: Integrated Waste Flow Options**


### 1.2.8 Features of Green City Waste Management

The various features of Green City waste management can be classified in terms of legal aspects, practices, system employed, funding, and facilities used. It shows the progression from manual to mechanical, community based to private, and use of technology with the level of economic development.

**Table 3: Green City Solid Waste Management Features**

<table>
<thead>
<tr>
<th>SOLID WASTE MANAGEMENT COMPONENTS</th>
<th>Least Developed Countries</th>
<th>Low Income Countries</th>
<th>Middle Income Countries</th>
<th>High Income Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWM ORDINANCES/REGULATIONS/ACTS/PROGRAMS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3R Strategy Programs</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Garbage Collection Fees</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Penalties for non-segregation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Ban on open dumping, littering, waste burning</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Extended producer responsibility</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>PRACTICES AT SOURCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Waste Avoidance/Minimization</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Segregation at Source</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Food waste as animal feed</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reuse of dry recyclables and paper</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Reuse of construction and demolition waste</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Segregated Collection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>No segregation - no collection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FUNDING</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidy from government</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private sector initiative</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EQUIPMENT AND FACILITIES</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Various waste bins (metal, plastic, concrete)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDPE waste bins</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Waste collection vehicles</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Transfer Stations</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Food waste processing plants</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Community managed composting plants</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Privately managed composting plants</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Community managed MRFs</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Privately managed MRFs</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Privately Managed Recycling Facilities</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sanitary Landfills</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>LFG Power plants</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Waste to Energy Plants</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.2.9 Development objectives

What is a Green City? A Green City is a community of residents, neighbours, workers, and visitors who strive together to balance ecological, economic, and social needs to ensure a clean, healthy and safe environment for all members of society and for generations to come.

To have economic growth in a Green City is not contradictory. A Green city concept will attract new activities and businesses not only in the public sector but also in the private sector as well.

Why become a Green City? To ensure a viable future, the Green City must take a leadership role and address the impacts placed on the environment by urbanization and a growing population. These impacts include air, and water pollution, climate change, and habitat loss, as well as land and landscape protection.

How does Solid Waste Management work in a Green City? Today we do not only talk about Solid Waste Management but Integrated Solid Waste Management.

Integrated Solid Waste Management. Integrated Solid Waste Management (ISWM) is a comprehensive waste prevention, recycling, composting, and disposal program. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills. Each of these activities requires careful planning, financing, collection, and transport.

ISWM is the key to a Green City. Developing a Plan for Integrated Solid Waste Management Planning is the first step in designing or improving a waste management system. Waste management planners should, for example, take into consideration institutional, social, financial, economic, technical, and environmental factors.

Based on these factors, each community has the challenge of selecting the combination of waste management activities that best suits its needs. Because integrated solid waste management involves both short- and long-term choices, it is critical to set achievable goals.
### 2. KEY ISSUES – KEY CONCEPTS

<table>
<thead>
<tr>
<th>Key issues to be addressed</th>
<th>Key concepts recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial and institutional capacity</td>
<td>3-R concept (Reduce Reuse Recycle)</td>
</tr>
<tr>
<td>Revenue collection</td>
<td>Separation of waste at source</td>
</tr>
<tr>
<td>Pollution affecting water resources, soils and the air</td>
<td>Sustainable waste collection and treatment</td>
</tr>
<tr>
<td>Uncontrolled greenhouse gas emissions</td>
<td>Treatment technologies suitable for different types of waste</td>
</tr>
<tr>
<td>Indiscriminate disposal of solid waste on municipal waste sites</td>
<td>Waste-to-Energy (WTE)</td>
</tr>
<tr>
<td>Land availability for solid waste management</td>
<td>Mechanization in the waste management process</td>
</tr>
<tr>
<td>Future capacity of waste disposal sites</td>
<td>Awareness building and community participation</td>
</tr>
<tr>
<td>Closure of waste disposal sites</td>
<td>Circular economy</td>
</tr>
<tr>
<td>Rehabilitation of brownfields</td>
<td></td>
</tr>
</tbody>
</table>
3. RESILIENCE TO CLIMATE CHANGE IMPACTS

Climate resilience can be generally defined as the capacity for a socio-ecological system to:

- Absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and
- Adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts.

With the rising awareness of climate change impacts by both national and international bodies, building climate resilience has become a major goal for these institutions. The key focus of climate resilience efforts is to address the vulnerability that communities, states, and countries currently have with regards to the environmental consequences of climate change. Currently, climate resilience efforts encompass social, economic, technological, and political strategies that are being implemented at all scales of society.

Resilience to impact from climate changes in the waste management sector.

Image 1: Leachate running from a break in a landfill wall after a heavy rainstorm

Climate change will have an impact on solid waste management infrastructures and the surrounding environment. The impact may be temporary or long-lasting. If management of the Waste facilities are poor or not existing, the affect from the climate changes will lead to an even bigger impact with rodent infestations, disease outbreak, and groundwater contamination.

Solid waste collection, processing, and disposal is critical for development of practical priorities in the environment and health sector, including maintaining clean air, soil, and water, particularly in urban settings.

Waste collection is important for maintaining sanitary conditions, particularly in residential and business areas where food debris can attract rodents and insects while decaying organic matter can cause unpleasant odours. It is critical that all new and existing solid waste management systems are designed and maintained to be resilient to climate change.

Climate stressors can impact solid waste facilities both directly and indirectly. For example, while higher temperatures may directly alter decomposition rates, climate change may also
affect access to roads, ports, and energy, indirectly limiting the collection of waste and operation of waste management sites.

Flooding poses the biggest threat to solid waste infrastructure. Without proper water catchment systems around a landfill, heavy rain events can degrade the landfill, causing breaks in the containment structure, allowing debris and leachate to escape from the landfill and contaminate local resources. Flooding from extreme storms may undermine landfill foundations, releasing leachate into groundwater or block collection routes, sweep waste into waterways, and cause waste to clog other infrastructure. Landfills near the coast or in low-lying areas are vulnerable to sea level rise and storm surge. Water infiltration of the pit can lead to an overflow of waste from the landfill. Saltwater infiltration from below can deteriorate the impermeable lining of the sanitary landfill facilities.

Temperature increases may necessitate more frequent waste collection schedules and rigorous landfill management practices, as odours will be stronger. Higher temperatures and drought may also increase the risks of fire at waste facilities.

These and other climate change risks vary in relative importance, with a range of cost implications, compounding effects, and impacts on development objectives. Table 4 gives examples of Potential Climate Change Impacts on Solid Waste Management Infrastructure and Services.

### Table 4: Examples of Potential Climate Change Impacts on Solid Waste Management Infrastructure and Services

<table>
<thead>
<tr>
<th>Temperature Change</th>
<th>Collection</th>
<th>Processing</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased odour and pest activity requiring more frequent waste collection</td>
<td>Overheating of sorting equipment</td>
<td>Altered decomposition rates</td>
</tr>
<tr>
<td></td>
<td>Overheating of collection vehicles requiring additional cooling capacity, including to extend engine life</td>
<td></td>
<td>Increased maintenance and construction costs due to thawing permafrost</td>
</tr>
<tr>
<td></td>
<td>Greater exposure of workers to flies, which are a major cause of infectious diseases (flies breed more quickly in warm temperatures and are attracted to organic waste)</td>
<td></td>
<td>Increased risk of fire at disposal sites</td>
</tr>
<tr>
<td>Precipitation Change</td>
<td>Flooding of collection routes and landfill access roads, making them inaccessible</td>
<td>Increased need for enclosed or covered sorting facilities</td>
<td>Increased flooding in/around sites</td>
</tr>
<tr>
<td></td>
<td>Increased stress on collection vehicles and workers from waterlogged waste</td>
<td></td>
<td>Increased leachate that needs to be collected and treated</td>
</tr>
<tr>
<td></td>
<td>Potential increased waste in a concentrated area as people crowd into higher</td>
<td>Damage to low-lying processing facilities</td>
<td>Potential risk of fire if conditions become too dry and hot</td>
</tr>
<tr>
<td>Sea Level Rise</td>
<td>Narrowed collection routes</td>
<td>Increased need for sorting and recycling</td>
<td>Deterioration of impermeable lining</td>
</tr>
<tr>
<td></td>
<td>Potentially increased waste in a concentrated area as people crowd into higher</td>
<td></td>
<td>Water infiltration of pit leading to possible overflow of waste</td>
</tr>
<tr>
<td>Storm Surge</td>
<td>Elevations within an urban area to minimize waste storage needs</td>
<td>Permanent inundation of collection, processing, and disposal infrastructure</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------</td>
<td>-------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temporary flooding of and diminished access to roadways, rails, and ports for waste collection, sorting, and disposal</td>
<td>Closure of facilities due to infrastructure damage</td>
<td></td>
</tr>
<tr>
<td>Extreme Wind</td>
<td>Dispersal of waste from collection sites, collection vehicles, processing sites, and landfills</td>
<td>Reduced access to collection and landfill access routes due to damage and debris</td>
<td></td>
</tr>
</tbody>
</table>

Source: Addressing climate change impacts on infrastructure: preparing for change  

Waste collection and disposal facilities are critical for protection of human health and local resources (particularly water and soil resources). Regularly collection reduces exposure to contaminated waste and disease-carrying rodents and insects. Properly sited, constructed, and maintained waste treatment facilities is the only way to minimize the risk of contamination of water, soil and air from the consequences of climate change impacts.

Reducing the amount of solid waste deposited in landfills is one of the easiest ways to reduce their vulnerability. Proper location of landfills is another low-cost adaptation option. Landfills should be sited in areas where there is reliable access to the site but away from bodies of water and areas with high water tables.

Through a screening process, action priorities for adaptation of climate changes can be selected based upon the following four key factors:

a) Criticality – How important is the infrastructure to the community or region? How large is the population served by the waste management system? Are backup services available?

b) Likelihood – Given climate projections, what is the probability that the collection, processing, or disposal infrastructure will be affected?

c) Consequences – How significant is the impact? Will the impacts complicate solid waste management? Will the impacts have health implications?

d) Resources available – Can changes be made to collection, processing, or disposal using a reallocation of existing time and resources? Are additional resources, such as additional workers, required?

By understanding the answers to these questions, adaptation actions can be integrated into the upfront design, construction, operation, and maintenance of solid waste management systems. Integrating adaptation can prevent maladaptive decisions that increase the vulnerability of the infrastructure and people they are trying to serve. Table 5 illustrates this approach.
### Table 5: Examples of Solid Waste Management - Related Actions by Project Cycle Stage

<table>
<thead>
<tr>
<th>Project Cycle Stage</th>
<th>Project Cycle Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scope</strong></td>
<td>Identify solid waste-related development goals important to the country, community, or sector you are working with Identify inputs and enabling conditions necessary to achieving those goals Consider the impacts of climate and non-climate stressors on those inputs</td>
</tr>
<tr>
<td><strong>Assess</strong></td>
<td>Assess climate threats, vulnerabilities, and impacts to solid waste collection, processing, and storage to understand adaptation needs Evaluate climate-related risks in light of all existing risks to solid waste</td>
</tr>
<tr>
<td><strong>Planning Policy Changes</strong></td>
<td><strong>Project Development</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Adaptation Options (Examples)</strong></td>
</tr>
<tr>
<td></td>
<td>ACCOMMODATE / MANAGE</td>
</tr>
<tr>
<td></td>
<td>Properly site landfills away from floodplains, wetlands, or areas with high water tables Site landfills away from drinking water supplies Develop sites large enough to accommodate projected population growth and corresponding waste generation Design sites with sorting, recycling, and composting facilities to reduce waste storage needs</td>
</tr>
<tr>
<td><strong>Construction Operation Maintenance Program Activities</strong></td>
<td>ACCOMMODATE /MANAGE</td>
</tr>
<tr>
<td>Evaluate and adjust</td>
<td>Increase financial and technical resources for more frequent maintenance and repairs Train waste sorters and educate the public about separating recyclable and compostable material from other waste Maintain collection vehicles to minimize disruptions due to mechanical failures</td>
</tr>
<tr>
<td></td>
<td>Regularly inspect the integrity of water catchment systems and containment walls, particularly following extreme rain or storm events</td>
</tr>
<tr>
<td>Continue to monitor landfills for groundwater contamination and cover erosion</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>

4. PERSPECTIVES FROM EUROPE

This chapter gives an overview of the European best practice regarding solid waste management. The chapter is written following the waste flow from organisation, planning, and financing, to the single activities of disposal, collection and transportation, and the treatment of the various waste fractions.

4.1 Introduction

4.1.1 Policy Analysis

Europe is composed of 47 countries (Number of member states in Council of Europe) of which 28 countries are members of EU, 5 are candidates to EU, and 4 are Free Trade Association countries. The presentation of the political structure and procedures in this “position paper” is limited to best practices inside EU, since the EU is the leading decision maker and sets the minimum standards for its member, candidate, and associated countries.

This section discusses:

Organisation of the Waste Management Sector by looking into:

- EU Directives and overall policy on waste management;
- Municipal tasks and responsibilities;
- Ownership;
- the Polluter Pays Principle; Private Public Partnership;
- Financing of the activities; and
- Community participation.
- Green Companies and Certified Procedures.
- Corporate Social Responsibility
- EMAS or ISO Certified Activities

The above listed topics are all topics which are being discussed today when describing the organisation of municipal solid waste management in Europe.

Note: EU Directives must be seen as minimum requirements. Every member-country is obliged to implement the EU Directives in their national law.

An EU Regulation is a legal act of the European Union that becomes immediately enforceable as law in all member states simultaneously. Regulations can be distinguished from Directives which need to be transposed into national law.
Figure 10: Overview of the EU Waste Directives

Source: EUROMETREC, the European Metal Trade and Recycling Federation

4.1.2 Standards

A Standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose.

International Standards ensure that products and services are safe, reliable and of good quality. A standard may also be strategic tools that reduce costs by minimizing waste and errors, and increasing productivity.

This position paper focuses on the strategic/administrative tools in the chapter 0 Green Companies and Certified Procedures, where ISO 9000 – ISO 14000 is discussed and compared with EU-EMAS system.

Note: In the EU definition of waste, processes, and procedures are not named Standards, but described in the Directives. For instance: Waste is categorised according to the EU Framework Directive (See: Chapter 0 The European List of Waste). Other European definitions are listed in the beginning of this position paper. (See: Definitions)

Standards for technical purposes

The main idea of the norms/standards is to have a common reference so, for instance, the vehicles and the containers fit when doing the work. The norms give of course also a
methodology on how to comply with traffic regulation, occupational health, and operation efficiency.

International Standards like ISO, DIN, EN, BS, or DS are organised by private business organisations and therefore not something you must comply with. However, it is a good idea to follow them, but still not a must. Although you may find a certain piece of equipment described in an international standard, but national laws are prevailing and may overrule the use. For example, there exists a 1.1 m$^3$ wheeled container – called Euro-bin – described in Standard EN 840 and very popular southern part of Europe, but prohibited in Denmark.

The table below lists the relevant international standards that are used for waste collection equipment.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Title</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 1501</td>
<td>Refuse collection vehicles and associated lifting devices – General Requirement and safety Requirements part 1: rear loaded refuse collection vehicles part 2: side loaded refuse collection vehicles part 3: front loaded refuse collection vehicles part 4: noise test code for refuse collection vehicles part 5: lifting devices for refuse collection vehicles</td>
<td>This standard is use for all vehicles which is use in ordinary waste collection. The vehicles defined under this Standard is able to empty containers defined under standard EN 840 This standard covers wheeled containers.</td>
</tr>
<tr>
<td>EN 840-1</td>
<td>Mobile waste and recycling containers part 1: containers with 2 wheels with a capacity up to 400 l for comb lifting devices part 2: containers with 4 wheels with a capacity up to 1300 l with flat lid(s) part 3: containers with 4 wheels with a capacity up to 1300 l with dome lid(s) part 4: containers with 4 wheels with a capacity up to 1 700 l with flat lid(s) part 5: performance requirements and test methods part 6: safety and health requirements</td>
<td>Containers for multi-bucket system vehicles part 1: containers with a nominal volume up to 10 m$^3$ part 2: containers with a nominal volume of 15 m$^3$ and 20 m$^3$</td>
</tr>
<tr>
<td>DIN 30720</td>
<td>Roller contact tipper vehicles, roller containers part 1: roller contact tipper vehicles up to 26t, roller containers type 1570 made from steel part 2: roller contact tipper vehicles up to 32t; roller containers type 1570 made from steel</td>
<td>This standard defines both requirements to the vehicle and the container. The container system is named hook-lift container or ro-ro container.</td>
</tr>
</tbody>
</table>

Note: There are a number of other Standards which may be interesting for construction of waste management equipment, which will be beyond the scope of this position paper to list. (Standards about: steel welding, coating and paint, testing, etc.). There are no specific standards for construction of incinerators, compost plants, or other treatment facilities in Europe, but the constructions have to follow national laws and requirements as well as the EU Directives on waste treatment operations, mentioned in Figure 10: Overview of the EU Waste Directives.
4.1.3 Indicators

The European Union's approach to waste management is based on the "waste hierarchy" (see Figure 1: Solid Waste Management Hierarchy) which sets the following priority order when shaping waste policy and managing waste at the operational level: prevention, (preparing for) reuse, recycling, recovery and, as the least preferred option, disposal.

In line with this the 7th Environment Action Programme sets the following priority objectives for waste policy in the EU:

- To reduce the amount of waste generated;
- To maximise recycling and re-use;
- To limit incineration to non-recyclable materials;
- To phase out landfilling to non-recyclable and non-recoverable waste;
- To ensure full implementation of the waste policy targets in all Member States.

The development and implementation of EU waste policy and legislation takes place within the context of a number of wider EU policies and programmes including 7th Environment Action Programme\textsuperscript{20}, the Resource Efficiency Roadmap\textsuperscript{21} and the Raw Materials Initiative\textsuperscript{22}.

The 7th Environment Action Programme (EAP) will be guiding European environment policy until 2020. In order to give more long-term direction it sets out a vision beyond that, of where it wants the Union to be by 2050. The European Union does not quantify its strategy. It is the task of the member states to establish country targets.

Focussing on Resources in Danish Waste Management describes how the Danish Government adapts the EU strategy by establishing its own strategy. The case also illustrates the expected result of the strategy in some quantified numbers. For instance: Recycling of organic waste, paper, cardboard, glass, wood, plastic and metal waste from Households must reach minimum 50% by 2022. (Today 25% is recycled and 75% is incinerated.) See Table 7.

As a consequence of the strategy the Danish Government will issue new initiatives - or regulations that introduces new tax, higher tax, or penalties - which will provoke the public to change behaviour and the municipalities (responsible for the waste handling) to introduce new separate collection and treatment methodologies.

\textsuperscript{20} 7th Environment Action Programme, \url{http://ec.europa.eu/environment/action-programme/} (Retrieved 29 sept. 2015)
\textsuperscript{21} Resource Efficiency Roadmap, \url{http://ec.europa.eu/environment/resource_efficiency/} (Retrieved 29 sept. 2015)
\textsuperscript{22} Raw Materials Initiative, \url{http://ec.europa.eu/enterprise/policies/raw-materials/index_en.htm} (Retrieved 29 sept. 2015)
### Table 7: Expected effects of the Danish Resource Strategy

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>EXPECTED EFFECTS</th>
<th>THE CURRENT SITUATION (2011 FIGURES)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Material type (fraction)</td>
<td>2018</td>
</tr>
<tr>
<td></td>
<td>Min %</td>
<td>Min %</td>
</tr>
<tr>
<td>Households *</td>
<td>Recycling of organic waste, paper, cardboard, glass, wood, plastic and metal waste*</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Collection of waste electronic equipment</td>
<td>75</td>
</tr>
<tr>
<td>The service sector</td>
<td>Recycling of paper, cardboard, glass, metal and plastic packaging</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Recycling of organic waste</td>
<td>60</td>
</tr>
<tr>
<td>All</td>
<td>Energy recovery from garden waste *</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Collection of waste electronic equipment</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Collection of batteries</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Recovery of shredder waste</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Recycling of phosphorus in sewage sludge</td>
<td>80</td>
</tr>
</tbody>
</table>

* A smaller volume for temporary storage and special treatment is not shown in this table. Therefore the sum of the three treatment options shown is not 100%.

** Average of amount placed on the market in the past 3 years.

See also Case 1: Focussing on Resources in Danish Waste Management.

In Denmark, the National Environmental Protection Agency (EPA) is responsible for collecting all data related to waste management.

**Note:** All mentioned national indicators are in %. It is not possible to have indicators in kg because we want to collect all waste generated. (As indicated on Figure 12: Municipal Waste – Treated kg/person (Eurostat 2013), page 54, the amount of household waste varies from country to country and those countries with the highest GDP also have the highest waste volume per capita.)

On one hand, it is the responsibility of the municipality to perform waste collection; on the other hand, the municipality will contract the waste collection activities to private operators in order to have an efficient operation. The municipality will therefore add performance indicators in their system to monitor the private operation.
In the following chapter some indicators are listed which are recorded by the municipality, treatment fallibilities. It describes how they are measured and what the purpose for registration is.

### 4.1.4 Verification Methods

It is the waste collection companies and waste treatment facility, which is recording and reporting activities to the authority above. And it is the responsibility of the authorities to supervise the activities of collection companies and treatment facilities, including their reporting.

The Table 8 below illustrates how it is possible to verify several performance indicators by a few simple records.

**Table 8: Performance Indicators and Verification Methods**

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>Verification method</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Containers emptied on time</td>
<td>Visual supervision in accordance with provided collection plan</td>
<td>• Including random checks in the collection district.</td>
</tr>
<tr>
<td></td>
<td>Collection Team report</td>
<td>• In case of sudden changes due to road blocks, traffic accidents, or other incidents the collection team is obliged to report back.</td>
</tr>
<tr>
<td></td>
<td>Citizen complains</td>
<td>• An independent phone service recording all complains from citizens gives an indication of delays, missing activities, and professional behaviour.</td>
</tr>
</tbody>
</table>

<p>| Waste transported to the correct treatment facility. | All vehicles have to be recorded at the entrance of the treatment facility, by passing a weighbridge. Minimum to be recorded: time of arrival, vehicle number, amount of waste, classification of waste, collection district | • Only measurement of the waste in kg or tonne on a weighbridge is a correct measurement. |
|                                                      | | • Time of arrival will be verified against the collection plan to verify that the other recorded measures are correct. |
|                                                      | | • By measuring these data it is possible to compare the efficiency of each collection team and each collection district. |
|                                                      | | • By using this record as the proof of performance by the contractor possible cheating – illegal dumping of waste, waste from other districts or businesses transported – can be avoided. |</p>
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Performance Indicator</th>
<th>Verification method</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incoming and outgoing waste and materials</td>
<td>All vehicles have to be recorded at the entrance or exit of the treatment facility, by passing a weighbridge. Minimum to be recorded: time of arrival, vehicle number, weight, classification of cargo</td>
<td>The data is an indication of the activity at all time. The quality of the collection system may also be verified. For instance when receiving paper for sorting and recycling: if the amount of waste not to be recycled is high too many people are using the containers in a wrong way.</td>
</tr>
<tr>
<td></td>
<td>Consumables</td>
<td>measure of consumables used, like: lime, water, electricity, etc.</td>
<td>For instance: An incinerator has an automatic system for flue-gas cleaning. The consumption of lime added to neutralise acids is an indicator of how much PVC, heavy metals, and other hazardous waste there is inside the ordinary waste. And this is an indirect indicator of how effective the separate collection and treatment of Hazardous waste, batteries and other chemicals are.</td>
</tr>
<tr>
<td>Overall performance</td>
<td>Waste per capita Recycling rate Landfilling rate</td>
<td>All vehicles have to be recorded at the entrance or exit of the treatment facility.</td>
<td>It is a simple spread-sheet calculation exercise, once the entire weighbridge data mentioned above is received.</td>
</tr>
</tbody>
</table>
4.1.5 Technologies

This position paper is presenting the technologies that are used across the waste management system in Europe.

Following technologies are presented:

- Collection and Transport of Waste and Recyclable Materials
- Underground Containers
- Special containers for recyclable materials
- Vacuum system transporting waste to a central collection facility
- Transport equipment
- Transfer Stations
- Sorting/Recycling of Waste
- Manual sorting
- Fully automated sorting
- Mechanical Biological Treatment facilities
- Organic Waste Treatment
- Home composting technology
- Simple compost facilities – Windrow composting
- Tunnel reactor technology
- Using Enzymes for decomposing organic waste
- Waste to Energy
- Biogas technology
- Incineration of Waste
- Disposal of Waste – Engineered Landfills
- Construction and Demolition Waste
- Recycling of Waste Electrical and Electronic Equipment
- Sludge from Municipal Waste Water Treatment Plants

4.2 Sector Overview and Policy Analysis

4.2.1 EU Waste Framework Directive

Waste Framework Directive – EU Directive 2008/98/EC\(^\text{23}\) sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery for the EU Members States. It explains when waste is considered to be waste and when it becomes a secondary raw material, and how to distinguish between waste and by-products.

The Directive lays down some basic waste management principles: it requires that waste be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours, and without adversely affecting the countryside or places of special interest. Waste legislation and policy of the EU Member States shall apply as a priority order the waste management hierarchy (similar to the one described in Figure 1).

\(^{23}\) European commission Directive 2008/98/EC on waste
The present Directive, which replaces EU Directive 2006/12/EC on waste and Directives 75/439/EEC and 91/689/EEC regarding waste oils and hazardous waste, respectively, introduces the "polluter pays principle" and the "extended producer responsibility and includes two new recycling and recovery targets to be achieved by 2020: 50% preparing for re-use and recycling of certain waste materials from households and other origins similar to households, and 70% preparing for re-use, recycling and other recovery of construction and demolition waste.

The Directive is, as it is stated, a Framework Directive that compile all activities and other Directives. Table 9, below lists some of the most important Directives under the Waste Framework.

**Table 9: List of EU Directives under the Waste Framework Directive**

<table>
<thead>
<tr>
<th>List of EU Directives under the Waste Framework Directive (not complete)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEEE</td>
</tr>
<tr>
<td>Directive on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability</td>
</tr>
</tbody>
</table>


The European Commission has also published “Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste”. This guidance document is intended to assist both national authorities and economic operators with the aforementioned legislation, which includes some guidelines in implementing the Directive on national level24.

**The European List of Waste**

Included as annex to the Framework Directive is “The European List of Waste” (See table 10). In general, all types of waste may be identified in this List of Waste.

---

### Table 10: The European List of Waste

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Wastes resulting from exploration, mining, quarrying, physical and chemical treatment of minerals</td>
</tr>
<tr>
<td>02</td>
<td>Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing</td>
</tr>
<tr>
<td>03</td>
<td>Wastes from wood processing and the production of panels and furniture, pulp, paper and cardboard</td>
</tr>
<tr>
<td>04</td>
<td>Wastes from the leather, fur and textile industries</td>
</tr>
<tr>
<td>05</td>
<td>Wastes from petroleum refining, natural gas purification and pyrolytic treatment of coal</td>
</tr>
<tr>
<td>06</td>
<td>Wastes from inorganic chemical processes</td>
</tr>
<tr>
<td>07</td>
<td>Wastes from organic chemical processes</td>
</tr>
<tr>
<td>08</td>
<td>Wastes from the manufacture, formulation, supply and use (MFSU) of coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks</td>
</tr>
<tr>
<td>09</td>
<td>Wastes from the photographic industry</td>
</tr>
<tr>
<td>10</td>
<td>Wastes from thermal processes</td>
</tr>
<tr>
<td>11</td>
<td>Wastes from chemical surface treatment and coating of metals and other materials; non-ferrous hydro-metallurgy</td>
</tr>
<tr>
<td>12</td>
<td>Wastes from shaping and physical and mechanical surface treatment of metals and plastics</td>
</tr>
<tr>
<td>13</td>
<td>Oil wastes and wastes of liquid fuels (except edible oils, 05 and 12)</td>
</tr>
<tr>
<td>14</td>
<td>Waste organic solvents, refrigerants and propellants (except 07 and 08)</td>
</tr>
<tr>
<td>15</td>
<td>Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified</td>
</tr>
<tr>
<td>16</td>
<td>Wastes not otherwise specified in the list</td>
</tr>
<tr>
<td>17</td>
<td>Construction and demolition wastes (including excavated soil from contaminated sites)</td>
</tr>
<tr>
<td>18</td>
<td>Wastes from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)</td>
</tr>
<tr>
<td>19</td>
<td>Wastes from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use</td>
</tr>
<tr>
<td>20</td>
<td>Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions</td>
</tr>
</tbody>
</table>


For the purpose of this position paper and the discussion of Municipal Solid Waste, only waste listed in chapter 17, 18, 19, and 20 are relevant. Chapter 20 - Municipal Wastes – consists of 40 waste fractions and is listed in...
Table 11.
### Table 11: The European List of Waste Chapter 20 - Municipal Wastes

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELY COLLECTED FRACTIONS</td>
</tr>
<tr>
<td>20 01</td>
<td>separately collected fractions</td>
</tr>
<tr>
<td>20 01 01</td>
<td>paper and cardboard</td>
</tr>
<tr>
<td>20 01 02</td>
<td>glass</td>
</tr>
<tr>
<td>20 01 08</td>
<td>biodegradable kitchen and canteen waste</td>
</tr>
<tr>
<td>20 01 10</td>
<td>clothes</td>
</tr>
<tr>
<td>20 01 11</td>
<td>textiles</td>
</tr>
<tr>
<td>20 01 13*</td>
<td>solvents</td>
</tr>
<tr>
<td>20 01 14*</td>
<td>acids</td>
</tr>
<tr>
<td>20 01 15*</td>
<td>alkalines</td>
</tr>
<tr>
<td>20 01 17*</td>
<td>photochemicals</td>
</tr>
<tr>
<td>20 01 19*</td>
<td>pesticides</td>
</tr>
<tr>
<td>20 01 21*</td>
<td>fluorescent tubes and other mercury-containing waste</td>
</tr>
<tr>
<td>20 01 23*</td>
<td>discarded equipment containing chlorofluorocarbons</td>
</tr>
<tr>
<td>20 01 25</td>
<td>edible oil and fat</td>
</tr>
<tr>
<td>20 01 26*</td>
<td>oil and fat other than those mentioned in 20 01 25</td>
</tr>
<tr>
<td>20 01 27*</td>
<td>paint, inks, adhesives and resins containing dangerous substances</td>
</tr>
<tr>
<td>20 01 28</td>
<td>paint, inks, adhesives and resins other than those mentioned in 20 01 27</td>
</tr>
<tr>
<td>20 01 29*</td>
<td>detergents containing dangerous substances</td>
</tr>
<tr>
<td>20 01 30</td>
<td>detergents other than those mentioned in 20 01 29</td>
</tr>
<tr>
<td>20 01 31*</td>
<td>cytotoxic and cytostatic medicines</td>
</tr>
<tr>
<td>20 01 32</td>
<td>medicines other than those mentioned in 20 01 31</td>
</tr>
<tr>
<td>20 01 33*</td>
<td>batteries and accumulators included in 16 06 01, 16 06 02 or 16 06 03 and unsorted batteries and accumulators containing these batteries</td>
</tr>
<tr>
<td>20 01 34</td>
<td>batteries and accumulators other than those mentioned in 20 01 33</td>
</tr>
<tr>
<td>20 01 35*</td>
<td>discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components (6)</td>
</tr>
<tr>
<td>20 01 36</td>
<td>discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35</td>
</tr>
<tr>
<td>20 01 37*</td>
<td>wood containing dangerous substances</td>
</tr>
<tr>
<td>20 01 38</td>
<td>wood other than that mentioned in 20 01 37</td>
</tr>
<tr>
<td>20 01 39</td>
<td>plastics</td>
</tr>
<tr>
<td>20 01 40</td>
<td>metals</td>
</tr>
<tr>
<td>20 01 41</td>
<td>wastes from chimney sweeping</td>
</tr>
<tr>
<td>20 01 99</td>
<td>other fractions not otherwise specified</td>
</tr>
<tr>
<td>20 02</td>
<td>garden and park wastes (including cemetery waste)</td>
</tr>
<tr>
<td>20 02 01</td>
<td>biodegradable waste</td>
</tr>
<tr>
<td>20 02 02</td>
<td>soil and stones</td>
</tr>
<tr>
<td>20 02 03</td>
<td>other non-biodegradable wastes</td>
</tr>
<tr>
<td>20 03</td>
<td>other municipal wastes</td>
</tr>
<tr>
<td>20 03 01</td>
<td>mixed municipal waste</td>
</tr>
<tr>
<td>20 03 02</td>
<td>waste from markets</td>
</tr>
<tr>
<td>20 03 03</td>
<td>street-cleaning residues</td>
</tr>
<tr>
<td>20 03 04</td>
<td>septic tank sludge</td>
</tr>
<tr>
<td>20 03 06</td>
<td>waste from sewage cleaning</td>
</tr>
<tr>
<td>20 03 07</td>
<td>bulky waste</td>
</tr>
<tr>
<td>20 03 99</td>
<td>municipal wastes not otherwise specified</td>
</tr>
</tbody>
</table>

* Any waste marked with an asterisk (*) is considered as a hazardous waste pursuant to Directive 91/689/EEC on hazardous waste, and subject to the provisions of that Directive unless Article 1(5) of that Directive applies.
End-of-waste criteria

End-of-waste criteria specify when certain waste ceases to be waste and obtains a status of a product (or a secondary raw material).

To define End-of-waste criteria is important for introducing a circular economy. According to Article 6 (1) and (2) of the Waste Framework Directive 2008/98/EC, certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions, in particular:

- the substance or object is commonly used for specific purposes;
- there is an existing market or demand for the substance or object;
- the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products);
- the use will not lead to overall adverse environmental or human health impacts.

Such criteria should be set for specific materials by the Commission using the procedure described in Article 39(2) of the Waste Framework Directive (so called "comitology"). A mandate to set end-of-waste criteria was introduced to provide a high level of environmental protection and an environmental and economic benefit. They aim to further encourage recycling in the EU by creating legal certainty and a level playing field as well as removing unnecessary administrative burden.

A methodology to develop the criteria has been elaborated by the Joint Research Centre.\(^\text{25}\) After having agreed this methodology with the Member States, the Commission is now preparing a set of end-of-waste criteria for priority waste streams. So far, the criteria have been laid down for:

- iron, steel and aluminium scrap (see Council Regulation (EU) No 333/2011)\(^\text{26}\)
- glass cullet (see Commission Regulation (EU) N° 1179/2012)\(^\text{27}\)
- copper scrap (see Commission Regulation (EU) N° 715/2013)\(^\text{28}\)

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### 4.2.2 Municipal Waste Collection and Treatment in Europe

In 2013, the total waste generation in the EU amounted to 2.5 billion tons. From this total only a limited (but increasing) share (36%) was recycled, while the remaining was incinerated or landfilled, of which some 600 million tons could be recycled or reused. Just in terms of household waste alone, each person in Europe is currently generating, on average, half of a tonne of such waste. 43% of it is reused, recycled, or composted, but in some countries more than 90% still goes to landfill.

Figure 12 and Figure 13 illustrates how amounts of Municipal Solid Waste vary and how waste is treated across Europe. It is visual that countries with lower economy generates less waste and has simpler waste treatment possibilities. It has to be noted that the definition of Municipal Solid Waste varies from country to country, and that Eurostat do not provide own statistical material but is collecting data from national statistical agencies only.
Figure 12: Municipal Waste – Treated kg/person (Eurostat 2013)

Source: Adapted from Eurostat newsrelease 54/2015 - 26 March 2015

Figure 13: Municipal Waste – Treatment options (Eurostat 2013)

Source: Adapted from Eurostat newsrelease 54/2015 - 26 March 2015
Figure 14 shows the composition of MSW, which indicates that a much higher amount of the waste actually could be recycled or reused.

Turning waste into a resource is one key to a circular economy. The objectives and targets set in European legislation have been key drivers to improve waste management, stimulate innovation in recycling, limit the use of landflling, and create incentives to change consumer behaviour. If re-manufacture, reuse and recycle is thought into the processes, and if one industry's waste becomes another's raw material, then it is possible to move to a more circular economy where waste is eliminated and resources are used in an efficient and sustainable way.

Integrated solid waste management helps to reduce health and environmental problems, reduces greenhouse gas emissions - directly by cutting emissions from landfills and indirectly by recycling materials, which reduce the extraction and consumption of new materials. Integrated solid waste management are limiting negative impacts at local level, for instance: on landscape deterioration due to landflling, on local water – river, lakes and ground-water, and limiting air pollution, as well as littering.

The development and implementation of EU waste policy and legislation takes place within the context of a number of wider EU policies and programmes including 7th Environment Action Programme\(^29\), the Resource Efficiency Roadmap \(^30\) and the Raw Materials Initiative\(^31\). EU sets in line with the Environment Action Programme, the following priority objectives for waste policy:

- To reduce the amount of waste generated;
- To maximise recycling and re-use;
- To limit incineration to non-recyclable materials;
- To phase out landflling to non-recyclable and non-energy-recoverable waste;
- To ensure full implementation of the waste policy targets in all Member States.

\(^29\) [http://ec.europa.eu/environment/newprg/](http://ec.europa.eu/environment/newprg/)


Case 1 Denmark: Focusing on Resources in Danish Waste Management

<table>
<thead>
<tr>
<th>Denmark without waste - Strategy &amp; resource plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>The municipalities in Denmark has every 4 years since 1986 been preparing Municipal Solid Waste Management Plans as a part of the national waste management strategy. In 2013 the Danish Government Introduced a new Strategy: &quot;Denmark without waste&quot; and is now implemented in Resource Plan for Waste Management.</td>
</tr>
<tr>
<td>&quot;Denmark without waste&quot; aims to give impetus to a movement from &quot;consumption and combustion&quot; towards a society in which the materials are used again and again. It is about seeing our waste resources and make sure that valuable materials are not lost.</td>
</tr>
<tr>
<td>The Resources Strategy “Denmark without waste” from 2013, together with the municipal resource plan for 2013-2018 is the management framework for waste management in Denmark.</td>
</tr>
<tr>
<td>&quot;Denmark without waste&quot; sets ambitious targets for recycling. Among other things, we want to recycle 50% of waste from households in 2022. This is more than twice as much as in 2011. Municipalities must contribute to achieve the goal, but it is up to each municipality to find the best solution to their local conditions.</td>
</tr>
<tr>
<td>As part of the resource strategy, the government will take the initiative to come up with examples of simple and workable solutions that municipalities may be inspired by.</td>
</tr>
<tr>
<td>In &quot;Denmark without waste&quot; are the municipalities a crucial partner in the realization of the Government's waste policy. There is an agreement between the municipalities and the Ministry of the Environment on a number of initiatives for the realization of “Denmark without waste”.</td>
</tr>
<tr>
<td>At the same time there is a need for modernization of the waste-to-energy sector. As stated in the agreement on local finances for 2015 the government and the municipalities agreed on the objective of improving the efficiency of waste incineration with 200 million kr. (=27 Million Euro) until 2020 to the benefit of businesses and consumers.</td>
</tr>
</tbody>
</table>

**New opportunities for businesses**

The Danish companies may be affected very differently by "Denmark without waste". In some sectors - like building and construction – the Resource Strategy initiatives will mean more new jobs. In agriculture, it means better opportunities for biogasification of manure, which will reduce the impact from Methane and CO₂. For the many companies working with technology and recycling strategy will mean new business opportunities.

<table>
<thead>
<tr>
<th>Overall, the strategy will entail:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased recycling of materials from households and service sectors;</td>
</tr>
<tr>
<td>Increased recycling of materials from WEEE;</td>
</tr>
<tr>
<td>Increased quality in the recycling of construction and demolition waste; and</td>
</tr>
<tr>
<td>Better utilization of nutrients in organic waste.</td>
</tr>
</tbody>
</table>

Denmark does not operate with waste strategies and waste management plans in traditional way anymore. The idea behind this change is that implementation of various treatment facilities are done, maintenance of the investments is on the track, and the Danish municipalities know what to do with the waste. Instead the new strategy forces everyone to (re-) think in resources and recycling.
The resource strategy is now implemented into Resource Management Plans period working until 2018, giving the municipalities 2 planning periods to implement and correct plans to reach the ambition of 2022.

### The expected effects of the Resources Strategy

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>EXPECTED EFFECTS</th>
<th>THE CURRENT SITUATION (2011 FIGURES)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Material (fraction)</td>
<td>2018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min %</td>
</tr>
<tr>
<td>Households*</td>
<td>Recycling of organic waste, paper, cardboard, glass, wood, plastic and metal waste*</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Collection of waste electronic equipment</td>
<td>75</td>
</tr>
<tr>
<td>The service sector</td>
<td>Recycling of paper, cardboard, glass, metal and plastic packaging</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Recycling of organic waste</td>
<td>60</td>
</tr>
<tr>
<td>All</td>
<td>Energy recovery from garden waste*</td>
<td>25</td>
</tr>
<tr>
<td></td>
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<td>Collection of batteries</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Recovery of shredder waste</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Recycling of phosphorus in sewage sludge</td>
<td>80</td>
</tr>
</tbody>
</table>

* A smaller volume for temporary storage and special treatment is not shown in this table. Therefore the sum of the three treatment options shown is not 100%.

** Average of amount placed on the market in the past 3 years.


Today’s waste management have 3 main focal points:

- **How do we increase the amount of waste to be recycled instead of incinerated or landfilled?** By increasing the amount of secondary raw materials in the production less virgin materials may be needed.

- **How do we collect and transport the segregated waste fractions?** The cheapest collection and transport option is having 1 fraction emptying one type of containers. The more fractions waste is separated into, the more complicated the transport will become. On the other hand, when the waste generator is segregating their own waste in to various fractions the material will be cleaner and the value higher.
• How do we secure the capacity for pre-treatment of the various fractions and that there is a market for the second-hand materials? Today the actual collection of materials for recycling is higher than the capacity for pre-treatment and the demand of materials from the production. This is indicated by the price for acceptance of secondary raw material.

Image 2: illustration from EU framework programme webpage: Horizon 2020

4.3 Organisation of the Waste Management Sector

Handling of Municipal Solid Waste in Europe is organised on a local / municipal level. While handling of waste from business entities is the responsibility of the entity itself although, the legal framework, operational permit, environmental permit, etc. will define minimum requirement for disposal of special waste fraction.

It is not possible for a state, or local authority in EU to dictate, which collection system or treatment facility business entity shall use for its handling of their waste, because this will be seen as a barrier for competition. The authorities may instead order office paper to be shredded and sent to an appropriate facility for recycling, or food waste to be collected and sent for either bio-gasification, or composting. It is up to the business entities to comply with the regulations and organise the collection, transport and treatment, and pay for the service.

In the following Municipal Waste is defined as waste and recyclable materials from Households and household like waste from business entities.

4.3.1 Municipal Waste Collection

When looking at the management of waste generated by households, the picture is more simple and clear although, even this system may vary across Europe.

A municipality in EU is responsible for the handling of the waste generated by the households. The municipality can issue local directives, which defines the level of service, how the household shall sort and store waste before collection, and how the household shall pay for the service.

According to EU is a municipality allowed to collect the household waste using their own vehicles and workers, if the vehicles and workers are organised as a department in the municipality, but if the work is organised in a municipal enterprise, the work shall be open for competition.

Almost every municipality have today contracted their waste collection activities to private operators. The reason for doing so is, that the municipalities cannot afford to have municipal funds tied up in waste collection vehicles and containers, when the local investment budget also have to provide for schools, elderly care taking, etc. On the bottom line is the annual operation costs the same whether the task is organised by the municipality or tendered to a private operator when including financial costs like interests and depreciation.

Waste Collection in the UK:

In the UK, Waste Disposal authorities, controlled by local Unitary and County Councils, are responsible for ensuring that appropriate waste management facilities for waste disposal are in place, and for providing local household waste recycling centres to enable homeowners to dispose of their own waste. The way that waste is collected varies in different parts of the country. Generally each street or apartment block is allocated a collection day, which is normally once a week, or once every two weeks, or in some cases once every three weeks.
Image 3: Street-side Household collection in Europe

Source: https://commons.wikimedia.org/wiki/File:Bin_day,_Cranmore_Avenue,_Belfast_-_geograph.org.uk_-_715856.jpg (retrieved 23/10/2017)

Image 4: Waste collection and segregation at apartment blocks in Europe
Case 2 UK: Waste management data collection - WasteDataFlow

WasteDataFlow (WDF) is the UK’s recognised web-based data collection system for local authority collected municipal waste. It has undergone continuous refinement since it became operational in April 2004, to serve as a comprehensive data reporting system for local authorities as well as a user-friendly data management tool for many public and private sector organisations.

**Background**

In 2002, a steering group comprising government and industry representatives decided that a web-based quarterly reporting system would constitute the most effective method of data collection, and thus WDF was born. The system was also intended to measure the UK’s progress with the EU Landfill Directive, as the schemes that were to deliver the Directive would be implemented on 1 April 2005.

**Data set**

WDF only reports on local authority collected municipal waste; it does not include commercial and industrial wastes or construction and demolition wastes which are not collected by local authorities. 63 questions are provided, 40 of which are applicable to all four countries (England, Wales, Northern Ireland and Scotland). The questions in WDF are divided into four main categories, namely general infrastructure, recycling waste, residual waste, and waste costs, while 62 material types are listed in WDF.

**Data uses**

WDF enables progress to be measured against national policy targets through the use of a range of indicators. It also supports evidence-based decision making in numerous areas, including options assessment, assessment of capacity needs and infrastructure requirements, benchmarking, private sector investment, research programs, and carbon impacts.

**Image 5: WasteDataFlow example**


**Roles and responsibilities.** In order to satisfy the diverse needs of its stakeholders, a formal governance structure was adopted that comprises a UK project management board, a UK operational group and a user group of local authorities in each country. The project board consists of Defra, the
devolved governments and assemblies (of Wales, Scotland and Northern Ireland) and the Chartered Institute of Wastes Management. It is tasked with financial control and overall delivery of WDF.

The operations group manages the day-to-day delivery of the WDF survey tool, while user groups hold meetings to feedback their experience, and discuss guidance and policy updates.

**System costs.** The cost for the design and delivery of WDF was estimated in 2002 to be £500,000. From 2004 to 2009 outsourced services for project management, user support, data validation services (England only), documentation, user training (England) and survey development, have cost approximately £200,000 to £350,000 per annum.

**System benefits.** The benefits that WDF provides are numerous, and include the following:

- More timely data reporting; national statistics were published 12-18 months after the end of the reporting period prior to WDF, now data is released within six months;
- More detailed dataset;
- Ensuring a single consistent data source is used by all stakeholders;
- Allows for the estimation of the quantity of biodegradable municipal waste landfilled and to demonstrate the UK’s progress in complying with the EU Landfill Directive;
- Reduced data reporting burden for local authorities;
- Cost savings linked to closer contract management;
- Easy access to detailed local authority data.

**Case 3 Denmark: R98, the Waste Collection Company owned and operated by City of Copenhagen**

In 1898 the City of Copenhagen, Denmark, decided to organise the emptying of all latrines in one municipal company called “Renholdningsselskabet af 1898” or just R98. Shortly after, also solid waste collection was included.

In 1984 the container department Renoflex was separated from R98 in order to be able to organise solutions for commercial waste outside the coverage area (City of Copenhagen).

During 1998-2002 the collection of MSW was reorganised. 2 shift operations were introduced and the mechanical workshop was set to operate 24 hours/day, 7 days/week. The organisational changes reduced the fleet from approximately 300 vehicles to 180 vehicles, but the workforce remained. The reorganisation of the activities was done in order to please the liberal parties of the City Council, to show that the municipal activities could stand competition from the private sector.

In 2005, the ties between R98 and the City of Copenhagen were declared illegal in a lawsuit and the municipality took a political decision to close the R98. The decision was also taken on background of the EU competition rules, and the wish of having a transparent and competitive market.

The public utility company R98 was – at that time – the largest waste handling companies in Denmark with:

- 600,000 citizens;
- 300,000 tonnes of waste;
- 450 employees of whom 350 were waste collectors;
and 141 garbage trucks, 150,000 wheel bins and 1200 containers.

After a tender procedure the collection activities were transferred to 4 private collection companies on 4 individual contracts. The privatisation process took place from 2008 to 2011. Necessary office and operational staff was transferred to the municipality and in May 2011 the City of Copenhagen transferred all its household waste collection activities from the public to the private operators.

Source: R98 and City of Copenhagen http://www.r98.dk/ (Retrieved 10th June 2015)

### 4.3.2 Municipal Waste Treatment

Ownership of treatment facilities is as complicated as there are different waste treatment options. Facilities may be owned and operated by one municipality or more in a joint ownership; or owned by a municipality and operated by a private contractor; or completely private owned and operated.

#### Case 4 Denmark: Inter-municipal Cooperation

Denmark is a small country with 98 municipalities and approximately 5.5 million inhabitants.

Denmark was, in the period – 1970 to 1990 – when the municipal waste management structure was established, divided into 275 municipalities. None of the municipalities where big enough to carry the economic burden of establishing waste treatment plants alone, so all of the municipalities entered 1 or more joint municipal companies (partnerships) for waste treatment. (A partnership is a business where all participants are personally liable, jointly and severally liable without limitation for the company’s obligations.)

In total 34 joint-municipal companies are established in Denmark, operating incineration plants, recycling plants, composting facilities, landfills, public amenity centres, etc.

The activities of the joint-municipal companies have become the backbone of the entire solid waste management system in Denmark. Once a household generates some waste it is the responsibility of the municipality to collect and treat this waste. The municipality is the owner of the possible recyclable materials in the waste, and may therefore decide what shall be done.

The Municipalities have guaranteed the economy in the Joint-Company by handing over all of their waste and recyclable materials to the companies, and to pay for the operation of these companies with a collected household fee and to buy the energy generated.

The municipalities shall provide waste collection and treatment services for their citizens and the citizens shall pay for this service, according to the Danish Waste Executive Order32. Under the Partnership agreement in the joint-municipal company are these obligations transferred to the company and used as guarantee for investments and operation.

Furthermore, the energy produced by incinerators is sold to the national electricity grid and the local district heating grid. (District heating in Denmark is organised in a cooperative structure, where municipalities are the main customer because of the municipal owned buildings: administration, schools, caretaking centres, social housing…)

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32 Affaldsbekendtgørelsen
Extended Producer Responsibility or Green Dot is not a financial structure for recyclable materials in Denmark. Instead direct tax on raw materials, plastic, and packaging materials is forcing the businesses and industry to integrate the use of second hand raw materials in their production. Finally, the household pays the municipality to take care of the recycling and the cost for this activity is not hidden in a product sale-price.

Beer, soft drink and wine bottles, cans and PET-bottles are recycled outside the municipal waste handling by the breweries and importers themselves. Car batteries and tires have established their own take back system. Everything else of waste and recyclables in a Danish household is taken care of by the municipal system, and the households pay directly to their municipality for handling of this.

Source: Danish Waste Association: http://danskaffaldsforening.dk
Danish District Heating Association (Dansk Fjernvarme): http://danskfjernvarme.dk
DAKOF - Waste and Resource Network Denmark (Danish organisation under IWSA): http://dakofa.dk

4.3.3 Extended Producer Responsibility or the Polluter Pays Principle

Polluter pays is also known as Extended Producer Responsibility (EPR). This is a concept that was first described by Thomas Lindhqvist for the Swedish government in 1990. EPR seeks to shift the responsibility of dealing with waste from governments (and thus, taxpayers and society at large) to the entities producing it. In effect, it internalised the cost of waste disposal into the cost of a product, theoretically meaning that the producers will improve the waste profile of their products, thus decreasing waste and increasing possibilities for reuse and recycling.

OECD defines EPR as:

“a concept where manufacturers and importers of products should bear a significant degree of responsibility for the environmental impacts of their products throughout the product life-cycle, including upstream impacts inherent in the selection of materials for the products, impacts from manufacturers’ production process itself, and downstream impacts from the use and disposal of the products. Producers accept their responsibility when designing their products to minimise life-cycle environmental impacts, and when accepting legal, physical or socio-economic responsibility for environmental impacts that cannot be eliminated by design.”


In 1991, the German government passed a packaging law (Verpackungsverordnung) that requires manufacturers to take care of the recycling or disposal of any packaging material they sell. As a result of this law, German industry set up a "dual system" of waste collection, which picks up household packaging in parallel to the existing municipal waste-collection systems. The "Dual System Germany Ltd" (DSD) only collects packaging material from manufacturers who pay a license fee to DSD. DSD license fee payers can then add the Green Dot logo to their package labelling to indicate that this package should be placed into the separate yellow bags or yellow wheelie bins that will then be collected and emptied by DSD-operated waste collection vehicles. After the introduction of Green Dot in Germany many other countries have followed with their version of a Producers Responsibility Act.
The main idea of the Green Dot system is to generate enough funds to operate the system and not rely on market price on recyclable materials, and hereby also establish a market for products that could be more difficult or not profitable to recycle.

PRO EUROPE s.p.r.l. (PACKAGING RECOVERY ORGANISATION EUROPE), founded in 1995, is the umbrella organisation for European packaging and packaging waste recovery and recycling schemes which mainly use the "Green Dot" trademark as a financing symbol. In its primary role, PRO EUROPE is the general licensor of the "Green Dot" trademark.

The "Green Dot" has evolved into a proven concept in many countries as implementation of Producer Responsibility. Industry in twenty-eight nations is now using the "Green Dot" as the financing symbol for the organisation of recovery, sorting and recycling of sales packaging. Private-sector compliance schemes working toward this objective are today in place in twenty-two EU member states, viz., Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Estonia, France, Germany, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden as well as additional countries include Norway (as an EEA member), Croatia, Turkey, Serbia, Israel and Macedonia. Moreover, PRO EUROPE has concluded co-operation agreements with similar systems in UK and Canada.

**Figure 15: Map of Countries which have implemented Green DOT**
Key facts:

- 31 member organisations active in 31 countries.
- 28 packaging recovery organisations in 28 countries are using the Green Dot as their financial symbol.
- About 170,000 companies are contributing licensees/members of PRO EUROPE member systems.
- About 300 million inhabitants have access to separate collection financed by PRO EUROPE member systems.
- About 460 billion packaging items are yearly labelled with the ‘Green Dot’, a registered trademark in more than 170 countries.

4.3.4 Private Public Partnership

Private Public Partnership (PPP) is a business relationship between a private-sector company and a public entity for the purpose of completing a project that will serve the public. PPP can be used to finance, build and operate projects such as public transportation networks, parks and convention centres. Financing of a project through a PPP can allow a project to be completed sooner or make it a possibility in the first place.

PPP’s are typically medium to long term arrangements between the public and private sectors whereby some of the service obligations of the public sector are provided by the private sector, with clear agreement on shared objectives for delivery of public infrastructure and/or public services. PPPs typically do not include service contracts or turnkey construction contracts, which are categorized as public procurement projects, or the privatization of utilities where there is a limited ongoing role for the public sector.

PPPs has been used, for instance in Germany, where construction and operation of sanitary landfills have been organised as 50/50 companies where the municipality provides land and the company design, build, operate, and close the site. Once the landfill is closed and temporarily sealed, the site is given back to the municipality and the partnership company is dissolved.

Construction of companies with 50/50 ownership between a private and a public partner is a delicate balance: on one side the private partner is bringing capital and know-how, and the public partner a need and a market. However, if the public partner is expecting any profit it could be seen as illegal tax collection or re-distribution of public funds.

Another example of private public partnership is described in the Case 26.

Almost every municipality have today contracted their waste collection activities to private operators. The reason for doing so is, that the municipalities cannot afford to have municipal funds tied up in waste collection vehicles and containers, when the local investment budget also have to provide for schools, elderly care taking, etc. On the bottom line is the annual operation costs the same whether the task is organised by the municipality or tendered to a private operator when including financial costs like interests, and depreciation.

Although, contracting of activities like collection of waste and recyclable materials or operating treatment plants is not considered PPP but simple contracting of activities, are these contracts in Europe often called PPP.

33 Permanent seal of a landfill takes 10 to 20 years after that the landfill needs to be closed. Monitoring of the site may in principle take forever.
4.3.5 Financing

When talking about Waste: Investment is never a problem - if you know how to finance the operation. (Where operation is defined as both direct costs: fuel, salary, and maintenance; – and indirect costs: re-investments, depreciation, and interest.)

The financing structure in the waste management sector is different compared to all other public infrastructural activities because; the upkeep costs are relatively high compared to the investment.

Invest in a waste collection vehicle and some containers and you have to add staff costs, fuel, insurance, and maintenance in order to be able to collect waste.

Looking at the annual turnover as a percentage of the investment in illustrates how waste management differs. Case 5: Bosnia & Herzegovina, Example of Investment and Annual operation costs for waste collection only”, and Case 29 Denmark: Waste to Energy Plant - I/S Reno Nord (incinerator line 4), are showing annual turnovers of 28% and 70%. Average for an entire waste management system is approximately 40%. (Compared to water management or road management, which have annual turnovers of less than 5 %.)

**Case 5: Bosnia & Herzegovina, Example of Investment and Annual operation costs for waste collection only**

This example illustrates the impact from a small investment in a municipal waste collection system in Bosnia & Herzegovina (BiH). The figures are estimated by a municipality under the Municipal waste management programme in BiH funded by SIDA.

BiH is a former Yugoslavian republic.

The investment described is what is needed in order to collect approximately 10 tons of MSW per day using 1.1 m³ containers and a truck with a capacity of 10 ton.

The cost is only illustrating the simple direct cost of operating and maintaining the equipment. Gate fee at the landfill or treatment facility is not included.

In the investment table below is included asset life. Asset life is used to calculate depreciation cost.

<table>
<thead>
<tr>
<th>Investment</th>
<th>units</th>
<th>unit price</th>
<th>Investment total</th>
<th>asset life</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Euro</td>
<td>Euro</td>
<td>years</td>
</tr>
<tr>
<td>Vehicle</td>
<td>1</td>
<td>100.000</td>
<td>100.000</td>
<td>10</td>
</tr>
<tr>
<td>Containers</td>
<td>200</td>
<td>300</td>
<td>60.000</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>160.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the table below is listed the operation costs in a simplified version.

Please note that the interest on the investment should not be included if the equipment is donated.

Money is a commodity.

The interest rate depends on how the investment is financed. If the investment is done using borrowed money, the interest rate should be the rate from the financing institute. If
the money is the company’s own funds an interest rate illustrating possible returns of other investment /deposit rate.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Unit</th>
<th>Unit cost</th>
<th>total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest of total investment</td>
<td>5%</td>
<td>8.000</td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>Vehicle</td>
<td>10,0%</td>
<td>10.000</td>
</tr>
<tr>
<td></td>
<td>Containers</td>
<td>16,7%</td>
<td>10.000</td>
</tr>
<tr>
<td></td>
<td>20.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>Vehicle</td>
<td>2%</td>
<td>2.000</td>
</tr>
<tr>
<td></td>
<td>Containers</td>
<td>10%</td>
<td>6.000</td>
</tr>
<tr>
<td></td>
<td>8.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salary, driver</td>
<td>1</td>
<td>18000</td>
<td>18.000</td>
</tr>
<tr>
<td>Salary, assistance</td>
<td>3</td>
<td>12000</td>
<td>36.000</td>
</tr>
<tr>
<td>Insurance</td>
<td>1</td>
<td>1000</td>
<td>1.000</td>
</tr>
<tr>
<td>Fuel litre /year</td>
<td>12000</td>
<td>1,50</td>
<td>18.000</td>
</tr>
<tr>
<td>Administration cost</td>
<td>5% of</td>
<td>73.000</td>
<td>3.650</td>
</tr>
<tr>
<td>Total</td>
<td>112.650</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The annual turnover is 70% of the investment. If this was a normal business in middle- or high-income country.

But, BiH is a poor country living on donations and the mercy of the World bank. The municipality do not get the necessary income to operate waste collection as a business so: no interest, no depreciation, no maintenance, only repair of the vehicle and a hope to receive another donation to replace the old vehicle donated after the war in 1995.


**Household Fees**

Introduction of household fees was done in EU-countries because the municipalities could not afford to pay for the waste management service from their general budget. The higher demands like: separate collection of recyclable materials, the ban on disposal of un-treated waste at landfills, and the introduction integrated solutions have forced the municipalities to introduce household fees for waste collection.

UN and the World Bank have estimated that a household can afford to spend 1-2% of their income on waste collection.

Europe may be divided into 3 different income categories, where 14 countries may be considered to be high-income countries, 12 middle-income countries, and 10 low-income countries (5 of the low-income countries are a member of EU).34

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The author of this paper presume, that all EU member states have introduced a multiple financing structure for their waste management system like household fees and an Extended Producer Responsibility or a Tax system to co-finance their activities.

There is no available statistic for Europe on actual household fees for solid waste management service.

Case 6: Pay-As-You-Throw and waste incentive schemes in Europe

PAYT case study: County of Aschaffenburg, Germany

The “pay-as-you-throw” (PAYT) scheme is looked at through the best practice example of the German County of Aschaffenburg (the County), spanning close to 20 years of implementation across 32 municipalities with 173,000 inhabitants. PAYT is an economic tool and application of the “polluter pays” principle that charges residents depending on the quantities of waste that they send off for third-party waste management. The technical application of the PAYT scheme is based on a three-pronged approach: identification of the waste producer, determination of the quantities of waste sent for treatment, and unit pricing.

Background

Until the early 1990s, untreated waste in the County was landfilled. Public pressure led to the County switching to a waste management system focussed on preventing and recycling waste. A PAYT system was introduced in 1997 and has led to the County having one of the highest rates of recycling and lowest rates of residual waste generation per capita. The success of the system has led to it being replicated in other German counties, in Italy and Belgium.

Previous studies have demonstrated the good performance of pre-paid sack schemes (whereby sacks are set out for collection) in terms of residual waste prevention and recycling, and the comparatively poor performance of volume-based schemes that use varying bin sizes. The best performance, however, has been recorded with weight-based systems that are supported by well-developed infrastructure and waste-aware citizens, such as in the case of Aschaffenburg.

Implementation of the system

The County adopted a weight-based collection of residual, organic and bulky waste, in addition to the separate collection of paper from all households. The introduction of such a system for residual and organic waste was driven by the need to develop a fair system for domestic users, the introduction of centralized billing in the County in 1994, excessive incineration costs, limited composting capacity for organic waste, as well as ecological factors.

Bins and containers are equipped with chips that can be read by a transponder, while waste collection vehicles are equipped with a reading device and weighing device, the latter of which requires regular calibration and maintenance due to the vibrations arising during vehicle movements. Data is sent via telemetry in real time to a central processing facility, which processes the data and allows for accounting and billing of domestic users.
Image 6: Waste collection truck equipped with a waste identification system

Figure 16: Data collection and processing scheme

Outcome

The success of a PAYT system is reliant on well-developed infrastructure, the provision of convenient collection centres that accept other waste streams and the environmental awareness of inhabitants. The system in place in Aschaffenburg ticked all these boxes, and resulted in an overall collection rate of recyclables of up to 86%, which compares very favourably to other PAYT systems, with recycling rates typically approaching 70%. In 2013, the quantity of residual waste arising in the County was 55kg per capita per year, compared with 165kg in 1995 and 220kg per capita per year in Germany.

Other types of waste collection systems have not been able to produce the same results in relation to landfill diversion and recycling. For instance, in Germany residual waste generation has been very steady over the last ten years. Though the implementation of the PAYT scheme...
was the primary reason for these excellent results, awareness raising and the development of better waste infrastructure for sorting and recycling also played a part.

Taking into account numerous factors, GHG emissions savings were conservatively estimated to be 91kg of CO₂ per capita per year, therefore equating to 15,716 tonnes of CO₂ per year in the whole County.

There has been a steady decrease in the total annual waste management fee since 2000. The fee in 2013 was lower than that before 1997, despite the additional costs incurred due to PAYT implementation (including the construction of waste infrastructure, separate collection of different waste fractions, weighing and reading equipment etc). Unrecovered costs were €44.5 per capita per year in 2013, a relatively low figure relative to other cities and municipalities, demonstrating that great environmental performance is not necessarily tied to high unrecovered costs.

However, despite the significant results that the PAYT scheme brought to the County, it is notable that this did not significantly impact the total quantity of waste generated. This has also been apparent for PAYT schemes in other countries, and reinforces the notion that for substantial waste prevention to be achieved with a PAYT system, this must be accompanied by other policies at the national and regional level (e.g. product policies, waste prevention plans, and tax regulations) in addition to targeted local initiatives such as awareness raising campaigns, reuse schemes, second-hand markets, repair stores etc.

**PAYT systems in other European countries**

A pre-paid sack PAYT system was adopted in Flanders and helped to increase the recycling rate to 71% while decreasing residual waste generation to 149kg per capita per year. These systems deliver good results, though do not achieve the landfill diversion and recycling rates that weight-based PAYT systems are capable of achieving. In Italy, PAYT systems implemented in Treviso region and the municipality of Trento helped to achieve residual waste quantities of 55kg and 102kg per capita per year respectively.

It should be noted that geographical considerations may impact PAYT application; for instance, organic waste would need to be collected more regularly in hotter countries due to the hygiene implications which could lead to increased collection costs. However, this could be counterbalanced by the fact that increased organic waste collection would likely result in reduced collection frequency for residual waste.

**Waste incentives in other European countries**

In the UK, the legislative framework is not compatible with PAYT schemes. Recycling incentive schemes avoid legal barriers associated with the implementation of PAYT schemes and thus are more commonplace. In order to encourage recycling, these incentive schemes grant users payment or rewards, usually in the form of vouchers, or by refunding waste management fees. The difference in the behavioural aspect is notable when comparing the two schemes, as recycling incentive schemes appear to be more impactful on users with a high level of awareness, while PAYT addresses individuals with varying degrees of waste-awareness. For example, a recent incentive scheme in Bracknell Forest has increased the quantity of recyclables collected by 91kg per capita per year, increasing popularity among citizens as well as their perceptions of recycling. Best practice examples have also been observed in the Netherlands, where recycling incentive schemes have helped lower residual waste generation by 37%.
4.4 Relationship between Authorities, Enterprises, and Citizens

Solid Waste Management differs from other public services by the way users of the waste system should observe the many and often complex rules in order to have a well-functioned and well-organized system: There are rules on how to sort the waste in order to maximize the utilization of the recyclable materials or in order to minimize the environmental impact from the treatment; and there are different rules and timeframes to observe when the various waste fractions have to be disposed at various disposal points, etc.

Figure 17: Stakeholders in Solid Waste Management

Source: Mikael Boldt

4.4.1 European Waste Prevention and Recycling Initiatives

Case 7: Waste prevention measures in Germany

Having conducted an in-depth cost-benefit analysis on the subject, the German government recommends promoting waste prevention through the implementation of the following measures:
**General measures. Research and development:** The development and/or optimization of waste-preventing technologies is a focal point, and includes the extension of technical products' life spans. The government seeks to improve life cycle assessment tools to analyse the environmental benefits of different waste prevention measures, in addition to developing indicators and methods on which the award of eco-labels to waste-saving materials and products could be based.

**Information and sensitisation:** More practical and user-friendly information on waste prevention measures should be provided and targeted to different segments (manufacturers, consumers, companies etc). Awareness raising about waste prevention measures should be conducted through campaigns and schemes. The European Week for Waste Reduction is the primary event at the European level, and provides the institutional framework for such campaigns and projects in the Member States, showcasing best practice examples in the field.

**Product design.** The government is conducting research to develop criteria for measuring resource use in product design, which will help identify products for which waste-preventing criteria could be incorporated in the EU Ecodesign Directive.

**Reuse of products.** The public sector should be made aware, through advertising or educational measures, of the crucial role that reuse of products plays in waste prevention. Support should be provided at all levels for the development of quality standards for reusable goods such as furniture, electrical appliances etc.

At the local level, structures should be established that will facilitate the reuse of materials, whether on an institutional or individual level, while networks should be created that focus on the repair or reconditioning of used products.

“Rent rather than buy” schemes should be promoted in addition to other services that encourage waste prevention.

Regular examination and ecological assessment of the material streams in relation to manufacture, use and disposal throughout a product’s lifecycle is required in many areas, and will facilitate practical enforcement of waste prevention in product development as well as enabling further improvement to existing policy tools.

**Waste prevention measures in companies.** Encouraging companies to use environmental management systems (EMS) that comprise waste prevention measures is pivotal. EMS’ such as EMAS or ISO 14001 generally require companies to document their waste volumes, while the former also states that a compulsory continuous improvement in environmental performance (including the waste sector) should be specified.

Waste prevention incentives should also be made available to small and medium-sized enterprises (SMEs) that implement simpler EMS’. “Ökoprofit” or “Qualitätsverbund umweltbewusster Betriebe” (QuB) constitute two such systems, and should incorporate appropriate waste prevention guidelines.

Support should be provided for regional and local training and advisory programmes for companies looking to implement waste prevention measures. Campaigns should be launched emphasizing the importance of such measures and agreement between public institutions and companies encouraged to decrease food waste throughout the entire value chain.
**Waste prevention measures among consumers.** The government strongly supports the use of product service systems, whereby certain goods are shared with other individuals or temporarily rented. This can take the form of car sharing or the shared use of lawnmowers, road sweepers etc. Such systems allow the capacity use of a product to be maximised, and should be reinforced by appropriate legal and political framework conditions as well as promoted by the public sector as a form of waste prevention. For example, as a means of easing traffic in urban areas, governmental organisational assistance could be provided to support car sharing schemes, by providing adequate parking spaces or making public land available.

Campaigns that emphasize cleaner purchasing behaviours (quantities, size of packaging, best-before/use-by dates, reuse) can play a key role in educating the public. A sound example of this with regards to food waste is the “Zu gut für die Tonne” programme (“Too Good for the Bin”) launched by the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV).

**Waste prevention in the public procurement sector.** The Centre of Excellence for Sustainable Procurement at the BMI Procurement Agency is developing practical guidance documents for public-sector awarding authorities to ensure greater incorporation of resource efficiency aspects, including waste prevention.

**Waste prevention through polluter-pays concepts.** Polluter-pays schemes incentivise the prevention of waste, though they need to be supplemented by specific waste advice, the development of suitable waste management infrastructure and awareness-raising of citizens to maximise their potential benefits. Private disposal companies set disposal prices, while public disposal agencies are responsible for establishing waste fee systems. The setting of a reasonable price is important to prevent waste producers from resorting to fly-tipping.

**Eco-label.** Consumers can be encouraged to select cleaner products by awarding “Blue Angel” eco-labels to product groups for which waste-minimising manufacturing techniques were utilised.

Source: Waste Prevention Programme of the German Government with the Involvement of the Federal Länder

**Case 8: The European Recycling Company**

The European Recycling Company assists people all over the UK to provide a new lease of life to their unwanted shoes and clothes. Every day in the UK approximately 2,000 tonnes of clothing and shoes are sent to landfill. The European recycling company has worked in coordination with local authorities, waste companies and clothing retailers for over 20 years, helping to eliminate landfill. The ERC is part of the SOEX International Group of Companies, employing over 3,500 staff around the world. From the UK, collections are shipped to the SOEX recycling plant in Germany, and clothing is sorted into 400 different grades. The unit produces materials for the manufacturing industry, to suit exact needs and specifications. Products include woolens, fibres, cottons, and acrylics.

Pulled fibres can be supplemented by new fibres, resulting in mixtures, custom tailored for manufacturing. Nothing is wasted in the recycling process, so that tons of zips, buttons, and
rivets are extracted and recycled. Even the plastic bags the clothing is collected in are sent for reprocessing. As an aside it currently requires between 10,000 and 30,000 litres of water to produce a single cotton t-shirt, producing between 1.5-3.6 kgs of CO2. Using recycled fibres and material can reduce these numbers by up to 95%.

**Image 7: European Recycling Company**

![Image of recycling](Image)

Source: European Recycling Company

**Case 9 EU: European Week for Waste Reduction**

The European Week for Waste Reduction (EWWR), is an initiative that aims to promote the implementation of awareness-raising actions about sustainable resource and waste management during a single week. It encourages a wide range of audiences such as public authorities, private companies and citizens to get involved. It normally takes place during November. For 2017 the thematic focus is “Reuse and Repair: Give it a new life!” They state that behind this topic there is a need to shift society away from its throw away attitude, towards a better appreciation for products and the resources that are used.
A European Week for Waste Reduction


Case 10 UK: WRAP – Waste and Resources Action Programme

The Waste and Resources Action Programme (WRAP) works with governments, businesses and communities to deliver solutions to improve resource efficiency, including redefining what is possible through re-use and recycling. Amongst other things, they run consumer campaigns to empower individuals to take action.

Their publications include “Barriers to Recycling at Home”, which has helped local authorities build coherent strategies to engage communities in recycling.

They divide the barriers into four different types.
- Situational
- Behavioural
- Knowledge and understanding barriers; and
- Attitude and motivational barriers

For situational barriers, current recyclers say they would recycle a little or a lot more, if they had
- Collections of a wider range of materials
- Bigger containers
- More containers
More space to store their container
- More frequent collections
- Containers were easier to move

For behavioural barriers current recyclers still sometimes or often:
- Bin things because they are not sure if they can be recycled
- Throw recyclable bathroom wastes in the residual waste bin
- Put things in the recycling even if they are not sure they can be recycled
- Forget to put out the recycling because they are not sure of the collection day
- Bin things because their recycling container is full
- Bin things rather than clean them for recycling
- Fear of identity theft

For knowledge and understanding barriers less than half of their survey sample understood “very well” what they were supposed to do, and about a third said they would increase their recycling if they had better information about services. For attitudes and motivators 90% of recyclers said they were happy to be doing their bit for the environment, but would still be encouraged to recycle more by
- seeing the practical impact of recycling in their local area;
- receiving an incentive for recycling;
- or if they were fined for not recycling.

For declared “non-recyclers”, the main reasons for not recycling were because it was easier to throw everything away in one bin; they had not seen any information about recycling; they didn’t know what could or could not be recycled, and or had nowhere to store recyclables.

Research has shown the need for customization and targeting of recycling messages so that they link better to the different barriers faced by different segments of the population. Promotional communications initiatives can address behavioural, knowledge and attitude barriers, but should not be applied in isolation from steps to reduce the situational barriers.

4.4.2 Community Participation

Community Participation as we know from for instance in Republic of South Africa where NGO’s organises their own waste collection, in order to keep their township clean and lower the cost for waste collection for their low-income community is not known, in Europe.

Community Participation in Europe is only known during campaigns as described in
Case 11 below.
Case 11 EU: European Clean-Up Day

Every year, millions of tonnes of litter end up in oceans, beaches, forests and elsewhere in nature. The primary causes are our societies' unsustainable production and consumption patterns, poor waste management strategies and the lack of awareness of the population. In order to reduce littering in nature and to give visibility to the issue, the EWWR (European Week for Waste Reduction) coordinates a Europe-wide annual clean-up day.

Several clean-up campaigns have been implemented in Europe over the past years to tackle the litter problem. The European Clean-Up Day, “Let’s Clean Up Europe!” intends to bring these initiatives together to have a Europe-wide clean-up event that takes place on the same day all over the continent; involving and reaching as many citizens as possible. The European Clean-Up Day takes place in beginning of May every year.


Case 12 Estonia: Let’s do it! World

Let’s Do It! World is a global civic movement that started from Estonia, asking people all over the world to join a series of local, national and regional clean-up events.

The Let’s Do It! movement was first conceived in Estonia in year 2008, where a country clean-up action called Let’s do it! Estonia in 2008 (in Estonian: “Teeme Ära!”) cleaned up 10,000 tons of illegal waste by more than 50,000 volunteers in one day. Following Estonia’s lead many countries also started their own country clean-up events.

In 2011 a new initiative called Let's do it! World was started with the aim of promoting massive clean-ups from 24 March 2012 till 15 September 2012.

Today, the movement has grown into a network of 112 countries. Altogether, 11 million participants have been engaged in movement’s activities.

Let’s Do It! World is an accredited member of the United Nations Environment Programme (UNEP).

4.5 Green Companies and Certified Procedures

In Europe working in the waste handling sector is no longer a “dirty” business for unskilled labour; today Waste management is considered working for the environment to the benefit for all of us, and on every level from the lowest ranked street sweeper to the highest administrator training, awareness, and public relations have become a part of the work.

The face of a waste collection company is the collection vehicle and its collection team. Dirty vehicles and disorganised workers give an image of a poor organisation, while workers in uniforms, who are able to communicate with the clients (citizens) gives an image of well organised activities, with a clear focus and perspective.

4.5.1 Corporate Social Responsibility

Both private and public enterprises have in Europe found a way to identify themselves and their care for the environment, through public statements also identified as their Vision, Mission, and Values.

Especially within the Environmental sector and among Waste Handling Enterprises are corporate statements a method to get public acceptance of the activities. Case 13 below is an example on "clean CSR activities" in the sense that everything the company provide is clean water on their customers’ CSR mill.

Management of waste will always be closely linked to social responsibility. Everyone handling waste, delivers clean energy, and produces environmentally sound products, takes a greater social responsibility than the average.

Case 13 Denmark: Extended Corporate Statement – NORD

![Image of NORD's Sustainability Key]

How the Company NORD describes themselves

a) Responsibility
NORD is an environmental company and thus has a responsibility to ensure that our operations are conducted with a high level of safety in relation to the environment as well as to our employees. We do our utmost to always meet our responsibility.

Environment and safety has top priority

NORD handles hazardous waste with consideration for the environment – an attitude which is deeply rooted in our everyday life. It takes considerable expertise to handle hazardous waste in an environmentally responsible and safe way.

We have been certified according to ISO 14001 and EMAS III, and every year we issue an environmental report which also contains a greenhouse gas protocol.

It is essential for our employees to have a safe working environment when we carry out our activities. Within the working environment area we have been certified according to OHSAS 18001.

NORD’s environmental and safety management system is one of the means to meeting the certification demands year after year.

b) With a focus on society

NORD strives to be a socially responsible company that contributes to reducing the environmental impacts from hazardous waste.

This is reflected in our daily work where we remove the poisonous substances from the waste to avoid impacting the environment unnecessarily and also in the way we run the company through cooperation and management.

c) Respecting the environment

NORD handles hazardous waste in consideration of the environment - an attitude which is deeply rooted in our everyday life. It takes considerable expertise to handle hazardous waste in an environmentally responsible and safe way.

d) Working environment through reflection

A good working environment is one of NORD’s absolute core values and we are aware of our responsibility to create a healthy, physical and mental environment for our employees.

Only a very few near-miss incidents in NORD are associated with the handling of hazardous waste. The vast majority have the same character as in any other large company.

We work continuously to prevent accidents through a targeted security program and the campaign Working environment through reflection, to identify safe/unsafe situations.

Our security program includes:

- Risk assessments
- Cause Analyses
- Security patrols across the departments
- Registration and follow-up of near-miss incidents

For NORD it is very important to involve employees and use their core competencies in the effort for a good working environment. Along with a dedicated working environment organization, it helps NORD to keep a high level within the working environment.

NORD’s goal is zero accidents!

About NORD
The Company was previously known as Kommunekemi, a company established by all municipalities in Denmark being the only company treating all chemical wastes and toxic wastes in Denmark using the most advanced treatment procedures known.

NORD is a specialist within sustainable Total Hazardous Waste Management. As one of Europe’s leading incineration facilities, and offers end-to-end solutions for all types of hazardous waste.

The company is working to minimize the risks for the industry, use B.A.T. classified Waste-to-Energy techniques, recover oil, iron and metals and deliver full traceability throughout the process.

NORD treats approximately 250,000 tonnes of hazardous waste and oily water per year. The customer portfolio contains manufacturers, processing companies, maritime industry (harbours and offshore), universities, hospitals, waste collectors, and workshops.

NORD is owned by Ekokem Group. Ekokem Group is a provider of comprehensive environmental management services. Ekokem was established in 1979 and is owned by the Finnish state, municipalities and companies.

The Group’s purpose is to enhance customers’ material- and energy efficiency as well as offer solutions for recycling, resource use and energy production.

Ekokem Group is focusing on circular economy.


4.5.2 EMAS or ISO Certified Activities

The European Commissioner for the Environment from 1999-2004, Margot Wallström, already said: ‘we will not solve environmental problems by simply adding a few new directives, especially if we discover later on that these directives are not always implemented by the Member States. We need a broader range of instruments to tackle ever more diffuse sources of environmental pressures. We need instruments which:

Promote information, awareness and commitment with citizens and in the business community;

Give the right incentives for environmental improvements in the market place; and

Ensure the integration of the environment into other policies.’

Environmental Management Systems (EMS) are the instruments that meet these requirements. An EMS is a tool that provides organisations with a method to systematically manage and improve the environmental aspects of their production processes. It helps organisations to achieve their environmental obligations and performance goals.

An EMS can be implemented in many different ways depending on the precise sector or activity and the needs perceived by management, but several common operating principles should be present. These operating principles of an EMS follow a ‘Plan-Do-Check-Act Cycle’ (PDCA Cycle):

- **Plan**: Establish an environmental policy including objectives and targets.
- **Do**: Implement organisational structure, allocate resources and assign responsibilities to achieve set objectives and targets. Also, establish training and communication procedures to implement set objectives and targets successfully.
• Check: Collect, analyse, monitor and measure retrieved information and results (against planned objectives and targets). Check results through audits.

• Act: Review and evaluate environmental performance and correct and/or improve environmental policy including objectives and targets, as well as organisational structure, procedures and processes in order to continuously improve environmental performance.

**Figure 18: Plan-Do-Check-Act – the PDCA Cycle**

![PDCA Cycle Diagram](http://ec.europa.eu/environment/emas/)

Source: The European Commission for the Environment

The International Standards Organisation (ISO)\(^{35}\) defines an EMS as ‘the part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy’. ISO is one of biggest for worldwide certification of procedures and has developed a series of standards suitable for the environment sector:

- ISO 9001: Quality Management System;
- ISO 14001: Environmental Management; and
- ISO 18001: Health and Safety.

The idea behind these standards is to guide the companies and institutions in to a clear and well-defined management routine. To have an ISO certified procedure doesn’t mean that the procedures in every ISO-certified entity are identical. To have an ISO certified procedure means the management of the company has been able to argue why the organisation is doing what it is doing down though the organisation.

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The European Commission has also recognised that the interest in the environmental performance of organisations is continually increasing. Operating without taking into account the environmental consequences of their actions becomes almost impossible for organisations. So because of that the European Commission has launched an Eco-management and audit system called EMAS 36.

EMAS is a voluntary tool available for any kind of organisation aiming to:

- Improve its environmental and financial performance;
- Communicate its environmental achievements to stakeholders and society in general.

EMAS’ distinctive key elements are performance, credibility and transparency:

**PERFORMANCE:** EMAS is a voluntary environmental management instrument based on a harmonised scheme throughout the EU. Its objective is to improve the environmental performance of organisations by having them commit to both evaluating and reducing their environmental impact, and continuously improving their environmental performance.

**CREDIBILITY:** The external and independent nature of the EMAS registration process (Competent Bodies, Accreditation/Licensing Bodies and environmental verifiers under the control of the EU Member States) ensures the credibility and reliability of the scheme. This includes both the actions taken by an organisation to continuously improve its environmental performance, and the organisation’s disclosure of information to the public through the environmental statement.

**TRANSPARENCY:** Providing publicly available information on an organisation’s environmental performance is an important aspect of the scheme’s objective. It is achieved externally through the environmental statement and within the organisation through the active involvement of employees in the implementation of the scheme. The EMAS logo, which can be displayed on (inter alia) letterheads, adverts for products, activities, and services, is an attractive visual tool which demonstrates an organisation’s commitment to improving its environmental performance and indicates the reliability of the information provided.

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4.6 Collection and Transport of Waste and Recyclable Materials

Collection and Transport is the most expensive activities of all activities in solid waste management, and with more focus on recycling and reuse, collection and transport of segregated materials becomes more and more.

In some areas waste is separated at source by the householder into very general categories of recyclable and non-recyclable materials, and in other areas many different dustbins or collection bags are required for individual separation between, glass, plastic, paper, PET etc.

In Europe, a huge effort is put in to simplify and lower the collection and transport costs. Of course by making collection and transport more efficient it would be seen as the number
employees in the sector are decreasing. But in reality the opposite is happening. By segregating waste into several fractions more transport and collection service is needed. By introducing more advanced technologies, more skilled labour in the collection and transport sector is needed. And the result is that working in the waste management sector has become more acceptable. You are no longer just a waste collector; you are working for a better environment.

The following chapter will focus on presentation of the latest inventions and developments within Collection and transport of waste and recyclable materials in order to give an indication of, in which direction the collection and transport of waste is moving.

**Tool SWM 2**

### Organic waste could provide the building materials of the future

Cities could tackle the global problem of rising levels of waste and depleted resources by using organic waste, such as bananas, potatoes and maize as building materials, Arup predicts.

Globally the construction industry is one of the largest users of raw materials; in the UK alone it accounts for 60 per cent of all raw materials consumed. Capturing organic waste streams from cities and the countryside could provide the industry with lower-cost, lower-CO2 building materials such as bricks, insulation and partition boards. The report envisions a completely circular system with building waste fed back into the biological cycle at the end of its service life with nutrients returned to the soil.

The potential for the bio-economy is huge. Over 40 million tonnes of dried organic waste from agriculture and forestry was produced in Europe in 2014 alone and the amount is growing year on year. A kilogram of waste incinerated for energy recovery has a value of approximately 0.85 Euros but the same material used for interior cladding could sell for up to six Euros per kilogram.

The report also points to advances in the development of alternative organic materials, including mushroom bricks grown in five days and waste potatoes used as insulation and acoustic absorbers. Arup has created the SolarLeaf, the first façade system in the world cultivating micro-algae to generate heat and biomass and BioBuild, the first self-supporting façade panel made out of bio-composite materials.

Innovative manufacturing processes are a significant enabler, with 3D printing of bio-polymers becoming increasingly widespread. The report highlights the following organic matter products already available:

- **Peanuts**: shells are being used to produce low-cost materials, such as partition boards that are resistant to moisture and flame retardant.
- **Rice**: rice husk ash can be mixed with cement to reduce the need for fillers. Rice can also be used as a raw material for the production of boards.
- **Banana**: banana fruit and leaves are being used to make rugged textiles. Bananas contain high strength fibre and have good acoustic absorption and durability.
- **Potato**: the peel from potatoes can be cleaned, pressed and dried to create a low-weight, fire resistant, water repellent, insulating material and acoustic absorber."

As one of the world’s largest users of resources we need to move away from our ‘take, use, dispose’ mentality. There are already pockets of activity, with some producers making lower-CO2 building products from organic materials. What we need now is for the industry to come together to scale up this activity so that it enters the mainstream. An important first step is
to work with government to rethink construction codes and regulations to consider waste as a resource, opening up the opportunity to repurpose it on an industrial-scale.”

Arup is working on opportunities to embed circular economy principles in the built environment, working alongside the Ellen McArthur Foundation as a Knowledge Partner. In 2016 Arup installed the Circular Building, a building designed and constructed out of fully re-usable components to demonstrate how circular economy thinking can be applied to the built environment.


### 4.6.1 Smart City Management

Modern technology, smart phones, tablet computers, mobile data transmission, and sensor technology, together with more data and more sophisticated computer processing algorithms has become important tools for development of Smart City management tools.

Logistic planning, information, and supervision of the activity as well as local authorities’ inspection and control of the activities have become an important issue for the Solid Waste Management sector.

With the new demands on having separate collection of several segregated waste fractions, the demand for the operator of the waste collection is to be more efficient.

When looking at the entire chain of waste handling activities, collection and transport is the single largest activity for example: In Denmark with a high sophisticated and differentiated solid waste management system, collection and transport of municipal solid waste is more than 60% of the total cost for a household.

The following section describes smart management system developed by Enevo. Enevo was founded in 2010 and is a provider of smart logistics optimizations solutions for the waste management and recycling industry, helping both commercial waste management companies and public organizations to operate more resource efficiently.

**Tool SWM 2**

Collection of waste and recyclable materials using Smart City Management Tools
Case 14 Finland: Waste collection using Smart City Management Tools

Until now collecting waste has been done using static routes and schedules where containers are collected every day or every week regardless if they are full or not. It is now possible to change this by using smart wireless sensors to gather fill-level data from waste containers directly. Based upon the data send from the individual waste container, the system can automatically generate collection schedules and optimise routes based several parameters (future fill-level projections, truck availability, traffic information, road restrictions etc.).

Collection based this type of smart planning tools can significantly reduce costs, emissions, road wear, vehicle wear, noise pollution and work hours.

How does it work?

a) **Fill level measurement**

A small battery powered wireless sensor in each container, monitors fill level in real time.

The sensors are firmly attached and hidden away out of sight inside the container.

Waste monitoring works with any type of container and any type of waste (mixed, paper, glass, bio, metals and fluids such as oils and waste water etc.).
b) Analysis and modelling

The data from each container are sent over wireless cellular networks to the server for analysis and immediately is following displayed:

- Real time fill level status
- Alerts for abnormal events (such as high temperature and movement)
- Predicted fill-up dates
- Statistics


c) Forward to route planning

You can automatically provide a list of containers, schedules and routes to your drivers through your existing fleet management system.

Source: Enevo Oy, Finland
Benefits

<table>
<thead>
<tr>
<th>Lower costs</th>
<th>Better environmental efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Money Icon] Fewer collections</td>
<td>![Tree Icon] Less CO$_2$ and other emissions</td>
</tr>
<tr>
<td>![Money Icon] Fewer trucks needed</td>
<td>![Tree Icon] No overfull containers</td>
</tr>
<tr>
<td>![Money Icon] Less fuel needed</td>
<td>![Tree Icon] Less scattered waste</td>
</tr>
<tr>
<td>![Money Icon] Less time used (labour cost)</td>
<td>![Tree Icon] Better hygiene</td>
</tr>
<tr>
<td>![Money Icon] Lower servicing costs</td>
<td></td>
</tr>
<tr>
<td>![Money Icon] Lower cleanup costs</td>
<td></td>
</tr>
</tbody>
</table>


Furthermore, it is possible also for the municipal supervisors to monitor the activities of the Contractors for waste Collection.

Drawbacks

These kinds of systems are only sufficient in bigger collection district where the collection is organised with several vehicles inside the same organisation. (Several means: The activity involves so many vehicles that the collection company has a logistic department.)

The electronic sensor in each container has to be maintained. (Batteries must be changed, sensors tested, etc.)

Risk of theft of the electronic sensor for other purposes. (The first traffic speed cameras in Europe contained a cell phone circuit board with a SIM card used for transmitting the pictures to the traffic control centre. By stealing these SIM cards it was possible to make private calls for free – until the system was changed.)

4.6.2 Containers and Drop off Points

Collection and transport of waste and recyclable material is a costly business and many new systems have been developed in order to lower the operation costs. One way of lowering the cost is by establishing drop off points as an alternative to door-to-door collection but, as illustrated in Figure 20 the quantity and quality of the recyclable materials becomes less and poorer.
Households, who do not sort their waste, are also the ones least likely to bring their waste to anywhere but to the nearest container. It is therefore important to underline that the collection system for residual mixed waste must be better than the collection of recyclable materials and special waste, otherwise the recycle waste will be contaminated. (By easier to use is meant: a waste collection system with easier access, with containers closer to the point of generation, with a higher collection frequency, and with sufficient container-volume...)

Another issue is also how to establish enough space for the containers for the various materials. The more fractions we want the public to sort their waste into, the more bins do we need. And if we want to make savings on the collection cost larger volume is required.

Case 15 UK: London Borough of Richmond

The London Borough of Richmond encourages residents to recycle using containers provided by the council. Black boxes are provided for plastic bottles, pots, tubs, trays, tins, unbroken glass and aerosols. Blue boxes are provided for paper and cardboard. A food waste container is provided for food waste. Householders are required to rinse food remnants from containers before recycling them. This helps to ensure that the material can be recycled and reduces the cost. Rinsing drinks containers can also help reduce street litter by discouraging scavenging animals from rummaging through recycling boxes awaiting collection.

If residents live in apartments (80% of householders live in houses in the UK), recycling wheeled bins are usually placed near the normal domestic refuse bins for the building (as arranged by the managing agent or resident's association).

Sacks are provided for a fortnightly collection of garden waste. Bulky items such as fridges, freezers or furniture and hazardous waste can be collected from householders dwellings by arrangement.

Use of collected materials

Food waste and garden waste is collected for composting.

Paper, cardboard and cartons are collected, mixed together and taken to a depot for transportation to a reprocessing mill.
Cans, foil, plastic bottles, glass bottles and jars and other mixed plastic containers are collected, mixed together and taken to the local depot before transportation to Veolia’s materials recovery facility at Rainham in East London.

Once separated the materials are sold on to reprocessors and recycled as follows:
- Glass is remelted to make new bottles, jars and aggregate
- Steel cans are recycled into new cans
- Aluminium cans are recycled into new cans
- Plastic bottles and containers are recycled into fleeces, pillows or more packaging

Separately, textiles, clothes and shoes are collected and recycled by The European Recycling Company.

Below is presented 3 case stories describing how new developed waste collection all tries in different ways to solve some main problems doing collection and transport. ➔Tool SWM 2

**Case 16 Lund, Sweden: Collecting 4 different waste fractions at once**

In a dwelling area in municipality of Lund in Southern Scania, Sweden, waste from households is collected Door-to-Door.

Every household has received two 320-litre Wheel-bins, each divided into 4 compartments: one for organic waste; one for glass, one for metal, and one for the remaining. And in the second container also packaging materials, paper and PET is included.

Every week one of the containers are emptied, which gives a collection circle for each fraction of 2 weeks.

Collection of the 4 waste fractions in one wheel-bin is performed by a collection team with a special collection vehicle, which automatically empties all 4 fractions in one rotation.

One rotation takes approximately 25 seconds per wheel-bin (or per household)
Image: Collection vehicle for collection of segregated waste - open

- Inside the collection vehicle is the waste kept in separate compartments, which can be open and unloaded individually.
- The cost for the waste collection vehicle is approximately 200 - 225.000 Euro.
- The capacity may vary. The shown vehicle has a capacity of approximately 5 ton.

(source: Field visit to Municipality of Lund, Sweden. August 2011. By Mikael Boldt)

**Case 17 Copenhagen, Denmark: Vacuum systems**

- Collection of waste from the pedestrian area Nyhavn in Copenhagen, Denmark.
- Collection of waste from new developed dwelling area in Malmö, Sweden.

**Waste Collection Nyhavn, Copenhagen**

The Pedestrian area Nyhavn in Copenhagen, is a busy tourist area with many restaurants, cafés, and bars. Because it is not possible to drive through the area with any kind of motor-driven vehicle, waste collection trucks are also prohibited to enter. In order to solve the waste collection problem, a vacuum system able to transport the waste 800 meter away from the area is established.

The system serves 120 restaurants and businesses, as well as 150 apartments.

(photo: Commercial/City of Copenhagen)
Waste Collection - Underground system

The illustration above shows how it is possible to collect different waste fractions using the same tubes, bringing the different factions to different containers

Source: City of Copenhagen

Underground Vacuum station

- The picture on the left shows the pipe-work, pump, and container in the Copenhagen system in an underground facility.

- The waste is transported to a 20m3 ro-ro container, which is replaced by a simple container truck every time the container is full (16 ton).

- The pedestrian area and restaurants generates approximately 15 ton/day during the peak of the tourist season.

- A permanent vacuum system has been chosen since there are only 2 of such systems in the City of Copenhagen.

Västra Hamnen in Malmö – Sweden, a new developed city area is equipped with a vacuum system.

Inside the new dwelling area only light traffic is allowed and in some area only bicycles are allowed.

When the area is fully developed approximately 10,000 apartments and a university for 20,000 students will be in the area.

From a point, (5 points in total) near the entrance to the area, a mobile vacuum truck can collect waste from the area.

The total investment is not known.

The collection vehicle has a capacity of 6 ton waste, and the investment cost is approximately 1.5 million Euro.

Source: Field visit to Municipality of Malmö, Sweden and City of Copenhagen. August 2011 by Author


Case 18 UK: Underground waste management vacuum systems in residential developments: Wembley City case study

Image 9: Wembley City

Source: Envac – Wembley City case study.

Quintain Estates and Development plc’s flagship Wembley City project involved the installation of the first underground waste management vacuum system in the UK, supplied by Envac. This major urban regeneration project, one of the largest in Europe, covers 85 acres of land and surrounds Wembley stadium. It was masterplanned by world-renowned architect Lord Rogers and MAKE Architects, and consists of 4,200 flats, in addition to retail, hotel and leisure facilities. 252 inlet points were installed for the collection of four separate waste streams (general waste, organic food waste, mixed recyclables with paper, card/cardboard), while a single collection station services the entire development. The inlet points are located in each apartment building in proximity to the exit area where residents dispose of their waste.

Image 10: Apartments and collection points in Wembley City


**Process**

Waste is vacuumed several times per day, or when porthole sensors indicate that waste needs to be emptied, and is automatically transported at 50mph through 2.5km of underground pipework to the collection station. The benefits of the system are substantial: it is low energy, quiet, out-of-sight, always accessible to users, has low long-term operating and maintenance costs, limits or eliminates odours and attraction of vermin, while each collection cycle lasts only a few minutes. At the collection station, the waste is separated,
compacted and sealed into containers, which, when full, are transported to a waste management facility. Dry recyclables are sent for recycling. The organic waste is sent to West London Composting and the residual fraction to the Edmonton incinerator.

**Image 11: ENVAC waste collection system**


**Outcome**

The system has displayed impressive efficiency until now, owing in large part to the system’s capability to increase vacuum pressure and prevent blockage caused by oversized bags. Brent Council’s recycling levels have surpassed 50% (twice that of the London average), regular removal of waste ensures the district is kept clean, and waste collection vehicle movements have been slashed by up to 90%. Thus, it is estimated that around 400 tons of CO₂ emissions are saved annually by using the Envac system instead of a conventional waste collection system.

The vacuum system has also enabled 1865m² of space to be saved for residential development (equivalent to 22 flats), as well as providing 62 additional car parking spaces and a further 1,106m² for other commercial uses.

The construction activities were undertaken over a period of two years, while the development costs amounted to approximately £7 million. Residents of Wembley City experienced cost savings as households are charged £60 annually by the Council for waste collection, compared to £90 per year in all other Brent areas.

The system has been introduced to 30 countries around the world by Envac, and can be retrofitted to existing housing developments as has occurred in areas of Barcelona and Vitoria in Spain, where access for waste collection vehicles is difficult.
Sources:

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   .pdf%3FMediaArchive_ForceDownload%3DTrue&usg=AOvVaw0-NMcG9ixDV69-u-oT2Vop

2. Envac - Underground vacuum systems for sustainable waste handling. Handling waste the
   http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiNrpL8
   -
   tWAhVJPFAKHZgkD1IQFgoMAA&url=http%3A%2F%2Fwww.envacgroup.com%2FMediaBi
   naryLoader.axd%3FMediaArchive_FileID%3D5ac3cd8f-292d-453f-ab33-
   aBeb138bfc8%26FileName%3DCompany-and-Products-13.pdf%26MediaArchive_ForceDownload%3Dtrue&usg=AOvVaw3G32css2_HKKEF7OT65b
   U

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   (January 2013). Wembley City case study, p24-25. 
   http://www.iswa.org/home/news/news-detail/browse/18/article/new-publication-underground-
   solutions-for-urban-waste-management-status-perspectives/109/

Case 19 EU: Bring Banks and Underground Containers

Bring Bank Containers

- Bring Bank Containers for collection of recyclable materials can be found in many shapes and sizes. Colour and opening indicate which type recyclable material the container is dedicated to.

- The shown containers have a capacity of 3 m³.

- The shown containers are made of fibre-armed poly-ethylene and the cost is approximately 1000 Euro each.
Underground containers

- In the northern part of Europe the underground container is replacing containers for recyclable material and waste.
- Below every chute (The visible part) is an integrated container of up to 5m³.
- The chutes may be coloured and with openings for the specific material or waste.
- The underground have a larger capacity and appear more uniform in the cityscape, compared to a Bring Bank Container.
- The most important part of the cost of establishing these containers is the cost of excavating, draining, and building the walls.
- Total cost is estimated to 3000-5500 Euro each.
- To establish these sites in new developed area will lower the costs significant.
- Both the bring bank containers and the underground containers are emptied, using a crane.
- Emptying a container takes approximately 3-5 minutes depending on the access, the support-leg, and the number of containers to be emptied per site.
- The system can be single man operated and the efficiency (amount of waste per worker or unit) is high.
- Image 12: Emptying container using a Crane to lift Underground containers (photograph: Geesink-Norba)

Source: European manufacturers of bring bank containers and underground containers (the list is not complete):
SULO: http://sulo.com/

European manufacturers of superstructures for waste collection vehicles (the list is not complete):
Geesinknorba: http://www.geesinknorba.com/
Civic Recycling Centres:
At recycling centres householders have the option to bring their own sorted waste for recycling. The photographs below provide examples from Fort William, Scotland. Cars queue to enter the facility, and waste is unloaded into the appropriate containers. There is a secure area to dispose of hazardous materials, such as used gas bottles or oil filters. Separate containers are provided for paper, metal, plastic, bulky white goods, and electrical goods etc.

There is normally a steady stream of householders visiting the site to dispose of unwanted items, and this is a common method to remove large volumes of goods at one time.

Image 13: Fort William Recycling Centre

Source: Annabelle Cleeve, Mott MacDonald

4.6.3 Transport and Transfer of household waste

There are 3 common ways of transporting waste from a collection point to a treatment facility:

a) Direct Haul;

b) Mobile Transfer; and

c) Transfer via a transfer station.

A simple rule, which allows a first rough evaluation, when a transfer station might be viable:

“Depending on the collection vehicle, a round trip of less than one hour from the collection round makes direct transport more economical. With longer round trip times, transfer loading and bulk transport may be cheaper”
Nonetheless, transfer stations are often not conveniently located and therefore increases the travel distance of waste. Furthermore, transfer stations have important operating cost that must be overcome through any savings in transport.

**Direct Haul**

There are other factors than just the transport time when comparing Direct Haul with the use of Transfer Stations:

The condition of the roads to a waste treatment centre might give problems for heavy duty vehicles so in reality what is gained by transfer may only be 50% or less per truckload.

Transfer means additional vehicles and drivers. By considering that a vehicle is not the property of one driver and one collection team, and by employing an additional driver for a collection team / vehicle, the transport to a treatment facility may be performed as a second shift operation, which will make transfer unnecessary.

Demands like recording and weighing the incoming waste, before unloading, as a part of a supervision of the activity, has made operation of Transfer Stations more expensive.

Vehicles have, over the years, become more and more fuel-efficient performing transport.

Although the decision on doing direct haul or transfer still depends on road quality, total waste amounts to be transported, maximum payload per trip, fuel economy, salary-level, etc. the transport distance where transfer should be considered has raised from minimum 30 km in year 2000, to minimum 50 km today, according to various project scenarios, calculated by the author during the past 20 years.

**Mobile Transfer**

Mobile Transfer is when small collection vehicles are unloading into a larger collection vehicle.

*Image 14: Mobile Transfer of MSW between two vehicles*

Source: Reloading on Bornholm. 2010 – neighbourhood of the author (photograph: Mikael Boldt)
The system is common to larger, older cities, where the old city-centre does not allow heavy vehicles to enter, or the structure is not designed for large vehicles (narrow streets and passageways).

Under mobile transfer, whenever a small collection vehicle is full, the load is transferred to the larger collection vehicle. This way of organising the collection is efficient, but requires planning or a regular schedule, for the two vehicles to synchronize their meeting. Nonetheless, with GPS and mobile communication networks, synchronisation is today far easier, and a lessened issue.

**Bulky Waste Collection**

**Image 15: Bulky Waste Collection**

![Bulky Waste Collection](source: www.bassetlaw.gov.uk)

Municipal waste authorities often have arrangements in place for the collection of bulky waste from householders’ dwellings, such as waste fridges, freezers, furniture or hazardous waste.

**Transfer Stations for MSW**

A transfer station is a viable option whenever it can lower the transport costs of MSW from collection points to treatment facility vs. direct haul transport.

When designing a MSW transfer station, the following should be taken into account:

Type of transfer station:

- Capacity of the transfer station;
- Location of transfer station and possible savings in transport cost of using bigger vehicles or increasing the service time of local collection vehicles; and
- Efficiency of loading.

There are two major transport options for transfer stations:

- Transfer of MSW using containers or semi-trailers without compaction; and
- Transfer of MSW by using a compaction system.

The transfer stations can be constructed.
As stations with direct unloading into the transfer hopper or containers (usual approach in Western Europe); or
With an interim storage area, which allows buffering the waste in peak hours and which also may allow waste scavengers to pick recycling materials, if politically required (generally this requires larger volumes of waste).

The transfer stations may be:

- Open air, if the transfer site is far outside populated areas and odour problems are of no concern;
- The transfer area might be covered with a roof, to protect from rain and snow; or
- The transfer area might be fully housed, and will include ventilation and odour treatment. This third option usually is used for larger sized transfer stations, build in densely populated areas.

Often transfer stations are combined with Green Disposal Sites, including:

- Green waste collection, interim storage and shredding places;
- Acceptance points for recycling materials; or
- Domestic hazardous waste acceptance points.

Transfer without compaction

For MSW quantities of up to 150,000 t/a to 200,000 t/a (400 to 550 t/day), mostly simple transfer stations with open containers are the more economical solution. As it may be noticed in the figures below, waste is directly tipped into a container or semi-trailer and then is shipped to the treatment or disposal plant.

Figure 21: Example for an open transfer-station with transfer in open containers

Such a transfer station usually has several tipping places into several containers or semi-trailers. Often the MSW is slightly compacted by a wheeled loader, before shipping. Depending on whether the waste already was compacted in a waste collection vehicle or whether it was delivered loose on open trucks or by companies, the density in these containers can vary between 50 kg/m³ and 300 kg/m³. In the county most of the MSW will be delivered with compaction RCVs, which usually unload a MSW of a density of 200 to 300 kg/m³.

The MSW is then transported by truck-trailers, transporting 2 containers of 40 m³ each, or about 16 to 20 t in total or semi-trailers with 100 m³, transporting 18 to 22 t, depending on the MW. If the station is located close to residential areas, it needs to be housed, in order to prevent odour problems. Nonetheless, such a transfer station would require waste quantities roughly that of the entire county. The County has no need for this type of transfer station.
Transfer via compaction station

For large quantities and long transfer distances, compaction transfer stations are used. However, given that due to maximum weight conditions on road of 40 t, the maximum payload usually is in the range of 22 to 24 t, i.e. practically the same weight as used for transfer without compaction, it is not much in use for road transport. The system is mainly in use for railway transports.

Figure 22: Transfer station with compaction

To ensure continuous compaction, such transfer-stations are usually equipped with 2 compactors, should repairs or other compaction interruption be required. If the station is located close to residential areas, it needs to be housed, in order to prevent odour problems. These stations are for high volumes beyond that required for the county.

Options for Waste Transport

The following table shows a comparison of the major criteria of the two above mentioned transfer station types.

Table 12: Options for Transfer

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Mobile Transfer</th>
<th>Transfer into open containers</th>
<th>Transfer via compaction station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density of transported waste</td>
<td>Up to 400 kg/m³, Depending on the compaction vehicle.</td>
<td>150 to 300 kg/m³, average usually 200 to 250 kg/m³ since waste from compaction RCV is pre-compact</td>
<td>Up to 600 kg/m³</td>
</tr>
<tr>
<td>Average load transported on transfer vehicles (road transport)</td>
<td>9-12 t/vehicle</td>
<td>- up to 22 t/vehicle</td>
<td>- up to 22 t/vehicle</td>
</tr>
<tr>
<td>Construction</td>
<td>No construction needed</td>
<td>Simple construction; A ramp for the collection vehicle and hard surface for the containers.</td>
<td>Complicated construction; Ramp, surfaces, power supply for compactors, rail for containers, Backup system.</td>
</tr>
<tr>
<td>Criteria</td>
<td>Mobile Transfer</td>
<td>Transfer into open containers</td>
<td>Transfer via compaction station</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>Odour emissions and pest</td>
<td>Not a specific issue for this activity, as vehicles directly load into another.</td>
<td>Odour emissions and possible pest nuisances during transfer, since the station is not housed and the containers are open while loading. Recommend that at least a precipitation cover by provided.</td>
<td>Odour emissions during transfer are limited. No emissions during transport. Pest are kept under control.</td>
</tr>
<tr>
<td>Storage of containers overnight</td>
<td>Not an issue</td>
<td>Overnight storage of containers possible, but the containers should be covered.</td>
<td>Overnight storage possible, because containers are densely compacted and closed.</td>
</tr>
<tr>
<td>Flexibility at increasing quantities</td>
<td>Increasing quantities will be handled by changing the collection plan and adjust the numbers of vehicles.</td>
<td>The transfer station design can be adjusted by adding additional tipping places.</td>
<td>Inflexible, since at least two compactors should be installed, each compactor having a capacity of about 70 t/h.</td>
</tr>
<tr>
<td>Break down problems</td>
<td>Transfer or not - the usual spare vehicles are always necessary.</td>
<td>No problems with breakdown</td>
<td>If complete plant breaks down, e.g. because of electricity break down, no transfer possible. Usually a redundant compactor is provided.</td>
</tr>
<tr>
<td>Connection with other waste management activities</td>
<td>No</td>
<td>Possible in case of both types in case of the hazardous waste acceptance points and green waste collection points</td>
<td></td>
</tr>
<tr>
<td>Costs</td>
<td>Costs for transfer is 0 €/t + transportation</td>
<td>Costs for transfer in the range of 4 to 8 €/t + transportation</td>
<td>Costs for transfer in the range of 5 to 10 €/t + transportation, depending on volumes.</td>
</tr>
</tbody>
</table>

Source: Summary by Mikael Boldt.

4.7 Sorting/Recycling of Waste

Sorting of the separately collected municipal waste fractions (segregated waste) is universally applied throughout the European Union. The process proved to be the best practice to meet the targets for the recycling/recovery of packaging waste.

There are various techniques used in the sorting stations for Recyclable Materials. There is semi-automated sorting with high share of manual sorting up to the fully automated sorting. The general trend is to replace manual sorting with fully automated sorting. At present, there are only a few fully automated sorting plants under operation.

The current trend in waste sorting is to:
- Separate recyclable materials from mixed household waste at source;
• Screen the waste to improve the quality of the waste streams and separate various recoverable waste streams; and
• Automatic separation and removal of contaminants.

4.7.1 Manual sorting

The technology typically used in the manual sorting, followed by baling and transfer to the recyclers. Sorting may only be performed on segregated, dry fractions, due to the risk to the occupational health. Manual sorting centres need only simple equipment (conveyor belts, feeding chutes), a heated hangar and bins to store the sorted fractions for sale, bail pressing and weighting, as a first step. A reasonable sized facility can be built for 500.000 to 2 million Euro. 

Image 16: Example of Manual Sorting Plant

Source: Mikael Boldt

4.7.2 Fully automated sorting plants

Fully automated sorting plants are highly engineered. These plants use specialized equipment for the mechanical separation of the materials. These plants have the advantage that the quality of the mechanical separation is more consistent and for some materials, a higher sorted specification can be achieved. A good example of this is plastic bottles that can be sorted into different polymers. Usually, the higher the specification of the materials the higher the price paid by the re-processor for the materials.
Robots with superpowers to sort waste for recycling purposes

Lightning fast robots equipped with advanced sensor technology will soon start sorting through waste in order to recover raw materials. The potential is huge – in [Danish Technological Institute] (DTI)’s estimation, recoverable resources worth billions can be found by sorting through what we discard. Robots are now able to fully automatically sort garbage, in order to ensure that all recoverable materials are indeed recovered. This applies to domestic waste that has traditionally been incinerated as well as to electronic waste where high value materials, such as gold, can be extracted. Each year, valuable materials worth around five billion DKK are lost in the trash. By exploiting available technology, we will be able to extract a large part of those valuable materials, while protecting the environment and people who manually sort waste… This technology is a great opportunity for improving the work environment and increasing efficiency of the whole process – not only will we able to sort through more waste in fewer hours, we will also achieve a greater degree of purity and better quality waste resources. Together, those factors contribute to improve both the environment and the economy…


Image 17: Example of Mechanical Sorting Plant

Source: Waste and recycling company Raumarike Avfallsforedling IKS (RoAF) of Norway (municipal company) STADLER Anlagenbau GmbH http://www.w-stadler.de/ (Retrieved 7- July 2015)
Case 20: Braunschweig, Germany: MRF (Material Recovery Facility) - Sorting on segregated waste fraction principle

MRF – Shredder

Step 1: open bags and cut bigger parts

MRF – Infrared Separator

Step 2: Different type of waste reflect light differently. Separation using compressed air

MRF – Magnetic Separator

Step 3: A magnetic drum separate iron from other metals and other waste
MRF – Air Separator

Step 4: Light fractions is blown upwards heavier fractions continue downwards

MRF – Manual Control and Sorting

Step 5: Manual operation in order to reach 95% clean material.
Example:

- MRF – Braunschweig, Germany
- Receives 120,000 tons of waste, annually
- 70% is recycled
- Sorted in 13 different fractions
- Investment: minimum 25 million € (estimate)
- Depreciation: approx. 20-25 €/ton (per incoming ton)
- Operation cost: (estimate 10-15 €/ton)
- Final treatment of 36,000 ton/y: incineration 80 €/ton
- Total cost 55-60 €/ton

Income:

- Sale of material: 0 €/ton
- Refund from Grünne Punkt: approx 50 €/ton

Source: "ingeniøren" Danish Engineers Association weekly news magazine - march 2012
http://ing.dk/infografik/se-de-fire-teknoLOGier-til-affaldssortering-i-europa-127694
(Retrieved 6 July 2015)

Case 21 UK: Bywaters Materials Recovery Facility, London

The schematic below shows how different waste categories are separated at the Bywater facility in East London.

Figure 23: Materials Recovery Facility

The waste is delivered to the facility and unloaded into a hopper, from where it passes up a conveyor belt into the first cabin where people pick out anything that is dangerous. The hazardous waste, or waste that can be incinerated is then dropped down one of two chutes. Paper is picked out and dropped down a chute where people in a cabin then pick out high quality white paper from the rest. The rubbish then moves across a series of giant screws to filter out cardboard, which is separated into a big yellow labelled box. The rubbish that is not cardboard falls through the large screws onto a set of rollers. Waste that ends up on the top of the rollers is mostly
containers. A scanner detects plastic and filters them out separately into PET, HDPE and all other plastic. Magnets are used to separate magnetic metals such as steel cans. After this the conveyor belt moves really fast. Most of the rubbish sticks to it, but aluminium cans are so light that they fly off into a bin. Gradually the waste is separated into its different fractions. After the waste has been sorted into individual chutes it is stored in bins. The bins take it in turns to empty materials into the baling machine. The baler compresses the rubbish into bales and ties them up with steel rope. A forklift truck moves bales into stacks ready for collection.

Image 18: Bywaters Materials Recovery Facility

Source: Mott MacDonald

4.7.3 MBT - Mechanical Biological Treatment waste

Mechanical Biological Treatment is mentioned here because this kind of treatment facility is often referred to as a recycling plant although; the main output of the process is compost and fuel.
A mechanical biological treatment, MBT, system is a form of waste processing facility that combines a sorting facility with a form of biological treatment composting or bio-gasification. MBT plants are designed to usually process residual mixed household waste.

MBT systems and plants have evolved from earlier described bio treatment and waste separation technologies. In 2008, Germany reported some 61 plants, under the broadest definition. Of these, 10 plants produce RDF fuels (The figure has decreased since incineration plants have been introduced).

MBT covers a range of technical operations. These include:

- Shredding, crushing and milling;
- Screening and other mechanical waste classification and separation processes, such as air separators, magnet separators, etc.;
- Compacting and baling processes; and
- Biological processes, such as biological drying, composting or anaerobic digestion.

In addition to the separation of dry recyclables from the incoming waste stream (unless this is done in separate facilities), an MBT facility can be designed to produce one or more of the following outputs:

- Energy-rich RDF comprising of paper, cardboard, plastics and other combustible fractions, that can be combusted in waste-to-energy plants, industrial furnaces and cement plants; and
An organic-rich fraction that is sometimes suitable for composting; or the production of cover material for landfills. Otherwise, outlets for treated materials is limited, most of residual material is landfill disposed of (analogous to WWTP sludge disposal).

Typical material yield from MBT plants are:
- 36% for RDF;
- 62% for compost (if accepted), otherwise landfill disposal;
- 2% for recycling (mainly metals removed from the waste stream by a magnetic separator, this is when source separation is practiced); and
- Methane production, usually used internally.

The RDF fraction, as a solid fuel, has the following approximate values:
- Calorific value: 13-16 GJ/tonne (3-3.8 G Cal/tonne)
- Humidity: 20-35%
- Ash content: 10-15%
- Sulphur: 0.1-0.2%
- Chlorine: 0.3-1%

RDF fuel is generally used in cement kilns, by major industrial furnaces or in a waste incineration, depending on market conditions and market capacity to absorb RDFs.

### Table 13: MBT Summary

<table>
<thead>
<tr>
<th>Advantages</th>
<th>MBT reduce landfill volumes to less the 30%, through extensive sorting, fermentation and RDF production. MBT provides various degrees of bio diversion.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawbacks</td>
<td>Current RDF market prices are negative; i.e. cement kilns currently charge of the order of 40 €/tonne, plus transport, Compost quality is low, mostly landfill disposal (with no bio diversion credit), Bio diversion credit is unspecified.</td>
</tr>
<tr>
<td>Investment and Operating cost</td>
<td>The annual operational cost is estimated to approximately 35-45 Euro/t – excluding landfill disposal cost at approximately 15-25 Euro/t.</td>
</tr>
</tbody>
</table>

It should be understood that MBT plants are not standardized facilities: designs and costs varying based on yields, separation degree, and bio diversion quantities, and production of RDF.

MBT plants are also sensitive to laws on landfill disposal (maximum allowed biodegradable waste) and markets for Residual Derived Fuels, RDFs. Consequently, the choice of an MBT facility should be carefully studied with detailed specifications, material balances and cost developed in order to choose amongst many competing designs and options.

Still, operation of an MBT plant is considered as pre-treatment as required by the EU Landfill Directive.

### Case 22 EU: The use of waste-derived fuels in cement plants

**Background.** Waste-derived fuels are featuring more prominently in the cement industry, as the use of them is highly conducive to the cement production process, which requires temperatures of 2000°C in the primary burner. Lower fuel costs resulting from waste-derived fuels are the primary reason for this upswing in their usage, without which many cement plants in Europe could no longer remain competitive. The need to reduce the environmental footprint of cement plants has also driven the push towards waste-derived fuels.
Due to the significant capital investment required for cement plants and difficulty in obtaining the necessary permits, companies aim to operate plants for several decades as well as secure long-term agreements with suppliers of fuels and raw materials. Therefore, waste management companies or waste producers that fit this ethos are becoming more sought-after in this industry.

**Process.** Approximately 200 tonnes per hour of sintering material is transferred to the burner(s) in a typical cement kiln. The blended mixture of material, including ash produced as a result of fuel heating the kiln, is converted into a granular material called clinker, requiring temperatures high enough to partially melt the mixture and agitator to ensure the clinker’s composition is uniform. The clinker is then ground into a fine powder to produce cement. Emission limits that apply to waste-to-energy plants are also applicable to cement kilns that use waste-derived fuels. Emissions of heavy metals, dioxins and furans are not increased when using waste-derived fuels, owing to the high temperatures, long residence times, and the use of lime as a scrubber in the pre-heater.

**Hazardous waste treatment in Belgium**

The petroleum and chemical industries in Benelux (Belgium, Netherlands and Luxembourg) are significant, owing in large part to the presence of some of Europe’s biggest ports in the area, including Antwerp, Rotterdam and Amsterdam, and as such produce significant quantities of hazardous waste materials that require treatment. 

Approximately 27 years ago, a recovery plant was built to treat solid hazardous waste and generate fuel appropriate for use in the cement industry. Nowadays around 50% of all hazardous waste produced in Belgium is dealt with by two highly advanced hazardous waste treatment plants: one in Seneffe, operated by Holcim’s Geocycle, and another named Recyfuel located close to Liege and operated by a Joint Venture of Sita and Heidelberg Cement. The plants also receive considerable quantities of specific hazardous waste from neighbouring countries.

Recyfuel is a pretreatment centre that accepts a variety of industrial and special household waste, including paint/ink residues, resin, glue, sludge, tar, grease, soaps, detergents, cosmetics, filter cake, active coal and petrochemical products. It is capable of handling bulky waste, in addition to waste packed in drums, cans, plastic bottles, small containers etc. Steel is recycled as scrap, while the organic material is mixed with sawdust to produce an impregnated wood sawdust. This material is then transferred to cement kilns where it is incinerated, with the ashes resulting from the combustion process being reintroduced in to the raw material.

A crucial aspect of the operation is laboratory work; any waste supplied by a waste generator or waste management company is first analysed and undergoes rigorous acceptance criteria monitoring and testing, to ensure that it is suitable for treatment. The chemical and physical composition of the waste is the main determinant of the fee to be charged to the waste generator.
Image 19: Recyfuel Treatment Centre

Source: http://www.recyfuel.be/

Image 20: Hazardous waste pre-treatment at the Geocyle site in Seneffe

Case 23 Poland: Cement case study

The cement sector in Poland has grown considerably over the last decade in its use of alternative fuels as an energy source. Two main factors helped ease this transition, namely the willingness of Polish cement companies to lower their operating costs in recognition of the practices of international cement groups, and the enforcement of Polish regulations to adopt the relevant waste management EU acquis.

In 2005, a ban on landfilling of recyclable and organic waste was imposed in Germany, which did not have sufficient waste incineration capacity to cope with overproduction of refuse-derived fuel (RDF) and solid recovered fuel (SRF). In its transition towards alternative fuel development based on RDF, Poland imported this fuel for five years before Germany increased its waste burning capacity, after which it was replaced by locally generated RDF.

The rise of co-processing in Poland was primarily due to the following factors:

- Strong commitment of the cement industry, including through:
  - Correctly reading the alternative fuel market and taking advantage of opportunities as they arose
  - The establishment of mid- and long-term contracts with the waste management sector
  - Wise investments with regards to the handling and preparation of alternative fuels
  - Workforce skills development in operation of cement kilns to accept low-quality alternative fuels
  - Continuous enforcement of waste regulations
- Shrewd national and international investments
- Landfill taxation
- European subsidies that supported some alternative fuel opportunities

Sources:

4.8 Organic Waste Treatment

Compost facilities have over the years had their ups and downs.

In the 1970 and 80‘ies Compost plants was seen as a cheap solution on a problem with overfilled landfills in Europe. The product was seen as bringing back the soil to agriculture land. However, producing compost on mixed waste created huge problems for the agriculture sector and they refused to accept compost from mixed waste onto their land.

In the 1990‘ies new modern composting, or MBT, systems was invented based upon segregated waste and the technology was seen as a method to comply with the EU-Directive of not disposing un-treated organic waste on landfills. Especially in Germany and Austria, where incineration of waste was prohibited, became composting a popular and simple method to treat waste before landfilling.

After year 2000 when the first incinerators where built in Germany, the first compost plants stopped their production, and some of the facilities actually went bankrupt.
Today organic waste treatment has become popular again because there is a wish of bringing fertilisers, especially Phosphorous, back to agriculture.

**Case 24 UK: London Borough of Richmond – Green waste and food waste collection and treatment**

In the UK it is estimated that approximately 20% of food that is purchased is thrown away. The average family wastes about GBP60 (approximately 500rmb) a month on food that is thrown away.

The London Borough of Richmond has been collecting and composting food waste since 2011. The table below shows that although the service is well used, the quantities of waste recycled is remaining static, or even slightly decreasing in some cases. The Council launched a campaign to raise awareness about general recycling and increase the amount of food waste recycling in the worst-performing villages in the borough. It conducted two forms of research, the first of which involved a qualitative survey undertaken through the online community Talk Richmond. The second was an online quantitative survey that aimed to understand residents’ behaviours and motivations regarding food waste recycling, the barriers faced, as well as how to encourage food waste recycling, so that this may inform future communications activities in this area.

Recyclable food waste is being collected from an average of just over 40% of households in the Borough, although when the service started nearly 45% of households were using the service. The highest figure was a recycling rate of 92.6% from one village, and the lowest just 37.5%.
Table 14: Collection of Recyclable Materials in Richmond upon Thames

<table>
<thead>
<tr>
<th></th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
<th>2014/15</th>
<th>2015/16</th>
<th>2016/17 Q1</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and card</td>
<td>10087.17</td>
<td>9894.86</td>
<td>10235.28</td>
<td>9412.8</td>
<td>9169.48</td>
<td>2296.36</td>
<td>51095.95</td>
</tr>
<tr>
<td>Comingled</td>
<td>7021.3</td>
<td>7242.14</td>
<td>7112.62</td>
<td>7116.73</td>
<td>7119.89</td>
<td>1892.54</td>
<td>37505.22</td>
</tr>
<tr>
<td>Garden</td>
<td>3867.36</td>
<td>3826.1</td>
<td>4783.16</td>
<td>5430.12</td>
<td>4953.12</td>
<td>1506.44</td>
<td>24366.3</td>
</tr>
<tr>
<td>Food</td>
<td>3449.92</td>
<td>3868</td>
<td>3034.7</td>
<td>2906</td>
<td>2990.28</td>
<td>755.92</td>
<td>17004.82</td>
</tr>
<tr>
<td>Total</td>
<td>24425.75</td>
<td>24831.1</td>
<td>25165.76</td>
<td>24865.65</td>
<td>24232.77</td>
<td>6451.26</td>
<td>129972.3</td>
</tr>
</tbody>
</table>


The research was undertaken to design a targeted campaign of strategic communications and engagement with those living in the borough who currently recycle the least amount of food waste. Their specific objectives were to:

- To increase the amount of food waste recycled in the lowest four villages in the borough
- To raise awareness of general recycling across the whole of Richmond upon Thames.
- Raise the number of people in the borough who feel that recycling is one of the best services Richmond Council offers (currently 64%)*
- Reduce the number of people who disagree that the Council provides good value for money as a result of its recycling service. (8%)*

As a result of their survey, some of the barriers to recycling food waste were identified. Regarding these barriers, 31% of respondents said they did not want to keep food waste in a caddy/bucket in their kitchens; 31% said it was too messy; 27% said it was too smelly, and 28% said they lived in an apartment and therefore were unable to recycle food waste, since the Borough cannot collect food waste from estates made up of five or more units. Some householders did not recycle their food waste because they composted their waste themselves at home. Practical barriers to recycling food waste were also identified.

**Practical barriers**

- Size/shape of receptacle: not big enough for larger families, those with small kitchens do not have the space to accommodate it
- Liners used: some considered to be expensive to purchase, only available from certain locations and likely to break easily
- Waste viscosity: Food waste that is liquid can make the process seem less hygienic and unpleasant
- Collection frequency/scheduling: regular collections would be beneficial from those with larger households and to stop the receptacle smelling
- Collections damage: Collection teams can damage receptacles after emptying

**Attitudinal barriers included**

- Laziness
• Lack of information/benefits
• Faith in effectiveness or doubts about the benefits of recycling
• Unopened food: disposing of unopened food is seen as an additional burden to recycling as one also has to dispose of packaging separately

However, for those who do recycle their waste, the majority of respondents surveyed said they did it because it was good for the environment, highlighting a high awareness of waste disposal issues. 95% of householders living in houses reported that recycling food waste was easy, compared to 84% living in flats.

Richmond council asked householders what suggestions they had for increasing food recycling. The responses from those who currently do not recycle included:

- Issues in communal living/flats, including central composting
- Caddy bin liners should be provided (or continue to be provided free or at discounted rates
- Provide bins / better bins
- More information/education about benefits, tips, what can be recycled, how it is used to create energy
- Outside bin needs to be more secure against animals (mainly foxes)
- Collection more frequent, especially in summer, regular times, weekly
- Outside bin does not empty properly - sticky/smelly/unhygienic
- Should be more publicity / advertising / promotions - press, Schools

The council recommended adopting the use of the Easy, Attractive, Social and Timely (EAST) model to inspire behavioural change in residents with regards to food waste recycling.


Case 25 UK: Southwark’s Food Waste Recycling Campaign

Background
Recycle for London provided Southwark London Borough Council (the Council) with communications support for the launch of their food waste recycling service in October 2010. This was trialled on 10,000 properties in five areas of the Borough and involved the provision of a weekly commingled collection of dry recyclables, a weekly collection of food and garden waste, and a fortnightly collection of refuse. In order to interact with residents directly, the Council employed both traditional and innovative communication channels, including the use of a ‘pedal bike media’ which consisted of a mobile advertising hoarding transported to the various target locations by someone on a push bike.
Approach

A plan was developed to trial various combinations of communication techniques during ten different collection rounds carried out in the five areas. The communication methods that were experimented with are as follows:

- Community road shows, which included a survey to receive feedback from residents;
- Bin stickers that were initially aimed at 4,000 households. The success of the stickers led to a further 6,000 being delivered to the remaining properties in the trial area;
- Thank-you leaflets issued to 4,000 households, with feedback from residents obtained from an accompanying survey;
- The ‘pedal bike media’, which was pulled around on roads and streets on four of the collection rounds. Two campaigners undertook the necessary training beforehand to be able to effectively engage with the public about their recycling activities and collect feedback.

Traditional media channels such as bus shelters or local press advertising were also explored but were not as effective in targeting residents.

Monitoring of residents’ participation was conducted over three consecutive weeks, and households were deemed to have participated if they recycled on at least one of these occasions.

Outcome

The campaign demonstrated the benefits that different communication techniques can have on improving participation of residents in recycling. As a result, an additional 3.59kg per household per week of organic and dry recyclables were collected across the trial area, surpassing the initial landfill diversion target of 3.55kg per household per week.

The pedal bike media proved to be a very effective means of public engagement and outdoor advertising owing to its flexibility in manouevring around the trial area and outreach team, which was able to promptly respond to any queries regarding recycling services.

The survey element of the campaign proved to be very effective, garnering an approximate response rate of 14% from 3,891 postal surveys. 94% of the residents found the engagement with the pedal bike media team to be helpful or very helpful, while 49% stated they would
recycle more because of their interaction with the campaign team and finding out about the different material types that could be recycled through the Council’s collection service.

Collection rounds that included all four aforementioned communication techniques, demonstrated an overall participation rate increase of 18.4% for blue box recycling and 18.67% for food and organics recycling. Collection rounds that included all communication techniques except the ‘pedal bike media’ only showed an increase of 4% and 6% for blue box recycling and organics recycling respectively, thereby emphasizing the effectiveness of the pedal bike media in raising public awareness.


4.8.1 Home Composting

Individual composting is the recommended option in areas of houses with gardens. Home composting can only treat a small part of the organic waste from a household because not all garden and kitchen waste can or should be home composted:

- Tree cuttings and shrubs need to be shredded in order to be compostable, but few people possess a shredder;
- Cooked food and meat should not be placed on home-composters, since these may attract rats and other vermin/pest. In a green waste composting plant, the material is heated above 55°C and more and thus rats are not attracted. Home-composters do not reach such temperatures.

Image 22: Example of Home-composting bins


4.8.2 Simple Composting – Windrows

Compost is the aerobically decomposed remnants of organic materials (those with plant and animal origins). Compost is used in gardening and agriculture as a soil amendment, and commercially by the landscaping and nursery industry.

Simple composting can be performed in private gardens and in public parks using the “mattress” system, where the garden refuse is piled up in layers with twigs from trees and
bushes mixed into the garden waste to secure an open structure of the material enabling penetration of air (oxygen) to the pile to sustain the decomposition process. After a year the compost can be screened, un-composted twigs returned to a new mattress, while the finished product can be used.

On larger scale simple composing can be performed in windrows or trapezoid heaps. A compost turner possibly with an automatic watering system can be used to turn the compost on regular basis. Only a thermometer and a hydrometer are necessary to monitor the composting activity and determine the time of turning. A shredder for crushing of branches and a sieve for screening of the final compost product are supplementary equipment for the simple composting system.

The processing time for a simple composting process is 12-18 weeks depending on the season plus 12-15 weeks for maturation.

**Image 23: Example of Simple Composting System using Windrows**


### 4.8.3 Advanced Composting Technologies

**Tunnel Reactor**

In tunnel composting organic material is deposited in a tunnel created between the floor and two concrete walls. The automatically driven turner runs on top of the concrete walls while turning the composting material.
Image 24: Example of the Tunnel Reactor System for Composting of Waste


Case 26 Denmark: Aikan Technology

Solum Gruppen - creators of the Aikan® Technology - have more than a quarter century of experience and are Denmark’s largest supplier of compost, growth media and turf care products. Solum Gruppen creates value by integrating waste processing, biogas production and production of a wide range of soil improvement products. Aikan / Solum Gruppen is operating a production plant in Holbæk, Denmark as a Private Public Partnership. The Public partner is the Municipality of Holbæk owning the site and bringing their organic waste for treatment. The private partner is Solum Gruppen operating the plant, optimising the process, selling the final product, and exporting the concept.

Due to strict rules for utilisation of the final compost on agriculture land, is only source segregated organic waste used in the process. An Aikan plant is a hybrid solution which brings anaerobic digestion and in-vessel composting into a single production work flow and the technology is a batch processing of waste, producing both biogas and compost, without moving the solid waste fraction. The system is laid out in such a way that it physically separates hydrolysis ("leaching out") and methane generation, the two main processes that constitute what is generally known as dry anaerobic digestion.

The performance relies on the following 3 steps:
The Aikan 3-step process

**1. HYDROLYSIS**

Hydrolysis: Inside the process module fresh waste is sprayed with degasified percolate drawn from the biogas reactor. This induces bacterial hydrolysis, leaching out fatty acids. Percolate is drained from the bottom of the process module, effectively separating the waste into dry and wet fractions.

**2. METHANE PRODUCTION**

Methane production: The wet fraction (the percolate), with its content of fatty acids, is pumped back to the biogas reactor where methane production takes place, physically separated from the solid waste fraction. Steps 1 and 2 are continued as long as the percolate has potential for methane production.

**3. COMPOSTING**

Composting: When the potential for methane production has decreased, the process module switches to forced ventilation (negative aeration) of the remaining solid waste. Aeration rapidly initiates a highly effective composting process. Heat from the composting ensures complete sanitization and evaporation of excess humidity.

During all 3 steps, the process module remains closed. No solid waste is moved, with only fluids and air circulating between the process module and the gas reactor in a closed system. The system design ensures that the processes of hydrolysis, percolation, methane generation and composting are separate and occur rapidly and extremely efficiently. There is no need for inoculation using earlier processed material to start fresh batches. This insures full traceability. The process is self-sustaining and there is no need for heating to start the process.

4.8.4 Decomposing using Enzymes

Some organic matters will never or only slowly be decomposed. This is the problem with for instance: leather and bones.

By using enzymes, is it possible to break down even the most difficult organic waste fractions to something which can be further processed, for example in biogas plants.

Case 27 Copenhagen, Denmark: REnescience- a pilot project on how to decompose organic waste with enzymes

The pilot project is located in Copenhagen and will annually convert 80,000 tons of unsorted household waste to a bio-fluid that can be used to produce everything from biogas to bio-ethanol, electricity and heat.

Reception of organic waste (illustration: REnescience)

In 2010 the consortium behind REnescience received 22 million DKK (3 million Euro) from EUDP funds to design a plant on a commercial scale. The high level of organics captured in the REnescience bio-liquid and high recycling rate ensures significant value from the waste. The waste coming from the households is prepared for processing in the REnescience reactor using only heat and water. In the specially designed reactor, the waste is mixed with enzymes to ensure highly efficient sorting of the waste into various end fractions.
Treatment of organic waste with Enzymes

The bio-liquid is processed to biogas for further refining into green gas, transport fuel and recycling. DONG Energy have entered into partnerships with key players to test the technology in pilot projects and full-scale environments.

Partners: Aarhus University: Amager Ressource Center (City of Copenhagen); University of Copenhagen; Technical University of Denmark; EUDP - Energy Technology Development and Demonstration Program; REnescience is a technology owned by DONG Energy. DONG Energy is one of the leading energy groups in Northern Europe. The business is based on procuring, producing, distributing and trading in energy and related products in Northern Europe. DONG Energy has around 6,500 employees and is headquartered in Denmark.


4.8.5 Production of Biogas

Somewhere between the composting technology and advanced treatment lies anaerobic digestion or bio gasification of organic matter of biological origin (bio-waste) where, under anaerobic conditions, simultaneously are produced methane gases, and as bottoms, soil enrichment materials. Under this scheme, animal wastes (principally manure) are used to produce methane gas with the bottoms used for soil enrichment. The biogas can be used in a gas engine producing electricity and possibly heat/steam depending on local possibilities for energy usage.

It is possible to mix organic waste with the manure and thereby also generate bio-gas from organic waste.
Case 28 Tønder, Denmark: Northern Europe’s largest Biogas Plant

Northern Europe’s largest Biogas Plant is on its way near the town of Tønder in Southern Denmark.

In cooperation with an Argentinean investor, ENVO and Grontmij a/s, Biogas Tønder A/S is now a reality. The Northern Europe’s largest Biogas Plant will be situated just outside the town of Tønder in Southern Denmark. Negotiations with suppliers are well underway. Approximately 120 Farmers will be delivering manure and organic surplus/waste to the Biogas Plant. The Biogas Plant will be complete and up and running by mid 2016.

The sustainable production of electricity and heat from manure, energy crops and waste has been given a boost with plans for two huge biogas plants in southern Jutland. With a total investment of half a billion kroner (67 million Euro) the plant will become the largest in Denmark. The plant is expected to be joined by another plant with the same size in Aabenraa 40 km away. Behind the plans for the environmental and climate-friendly biogas stands firm ENVO Group and Jose Cartellone of Argentina, who is an investor in both projects. Grontmij a/s is consultant on both plants.

The farmers in the area will supply the plant with approximately 700,000 tons of manure annually. About 230,000 tons of other organic materials mainly waste from dairies, slaughterhouses and other industrial companies, as well as sewage sludge and household waste will be included in the production of biogas.

Biogas plant in Tønder

The plant in Tønder will produce almost 65 million cubic meters of biogas a year, which corresponds to the gas consumption of approximately 17,500 households in Denmark. The gas will be upgraded to natural gas quality and sold to the natural gas grid, replacing some of the fossil natural gas from the North Sea. In contrast to the natural gas is biogas CO₂ neutral.

The raw material for the plant, the organic material does not cost the system anything, since the farmers have great advantages of concluding agreements on supplies of manure and
waste. The plant borrows the manure from the farmers and delivers back a better product to the farmers when fertilizer has been degassed. The nitrogen comes back in a form that makes that it is absorbed more efficiently in the crops. 80 to 100 farmers will have contracts on delivery of the 700,000 tons of manure.

The plant will generate about 80 new jobs at the plant or derived from it. The Danish parliamentary parties signed in March 2014 an agreement on energy policy until 2020. One element of the agreement was that half of manure in Denmark in 2020 shall be used for the production of biogas. If the goal is to be achieved by 2020, Denmark must established 20 new biogas plant of the same size as in Tønder.

(A pig for slaughtering generates approx. 0.5 ton manure. A cow 21.5 ton/year including bedding.)

Source: ENVO Denmark  [http://envogroup.dk/envo-biogas-toender-as-2](http://envogroup.dk/envo-biogas-toender-as-2)

## 4.9 Waste to Energy / Incineration of Waste

Incineration of waste is a common method of waste treatment and in some countries; household waste has been incinerated for decades (for instance, in Denmark incineration with energy recovery of household waste has taken place since 1970).

EU flue gas treatment requirements (Incineration Directive$^{37}$) are mandatory and have greatly reduced emissions. For example, the Directive dictates the minimum temperature of combustion gases (850°C or 1100°C depending on the chlorine content of waste) to oxidize the waste and destroy toxic gases. Furthermore, the Incineration Directive sets as an objective that critical loads and levels of certain pollutants such as nitrogen oxides (NOx), sulphur dioxide (SO2), heavy metals and dioxins should not be exceeded, and further sets as an objective with a 90% reduction of dioxin emissions of identified sources by 2005 and at least 70 % reduction from all pathways of cadmium (Cd), mercury (Hg) and lead (Pb) emissions in 1995. All incinerators in operation have to comply with the Incineration Directive; there is no exemptions given to older incineration plants build under previous versions of the Incineration Directive.$^{38}$ Incinerators are also popular when landfill capacity is limited, as they significantly reduce waste volumes, generally by over 95 percent.

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$^{38}$ NOx and Dioxin Emissions from Waste Incineration Plants  
Incineration provides nearly 100% bio diversion credit for the incinerated biodegradable fraction of MSW, thereby meeting, and often exceeding, the Landfill Directive’s bio-diversion targets. Consequently, on a Euro per tonne of bio diversion, W2E incineration is considered more economically attractive than MBT coupled to RDF facilities, especially in northern Europe where incinerator’s enjoy an important credit for urban heating and where landfill’s accept only waste with lower than 3% TOC.

Incineration plants require little space and are often located in cities. This allows for minimum waste transport and is convenient for coupling to urban heating and electrical distribution systems. Further, energy produced is considered sustainable, and counts towards self-sustaining energy targets.

The most common form of incineration is the so called mass burn grate incineration. This concept is based on a (moving) grate on which the waste is incinerated. Waste received at the incineration plant is tipped into a bunker and partly homogenised. From the bunker, waste is further mixed and removed by an overhead crane before and during feeding of waste into the furnace’s incineration hopper. From the hopper, waste is channelled to the furnace’s’ moving grate. In the incineration chamber, combustion converts waste - typically with an average calorific value of 9-11 MJ/kg – into energy, with residue/slag dropping to the furnace’s bottom for removal, and ash, following a water quench, is caught up in the incinerator’s fly ash removal systems.

The capacity of waste incinerators varies from a capacity of 2,5 ton/h to 75 ton/h, depending on the waste amounts in the catchment area. Incinerators are in operation 24/7 and minimum 8200 h/year leaving 3 weeks for service and maintenance annually. It is possible to vary the incoming waste, but too small amounts of waste and the furnace cannot maintain the temperature without supply fuel, and too high amounts of waste and the slag will contain too
high amount of unburned part, which will not make it possible to utilise the slag and the remains have to be landfilled.

The incinerator’s combustion temperature generally ranges from 950-1,200°C. From the main combustion chamber, flue gases passes into after-combustion chamber to ensure complete flue gases combustion. Flue gasses are then cool through radiation and convection as heat is transferred to the incinerator’s steam boiler. After leaving the boiler, flue gasses pass through a flue gas cleaning system. Steam from the boiler is used to make electricity (from a steam turbine) and hot water. ➔Tool SWM 4

Table 15: Energy Balance from Mass Incineration

<table>
<thead>
<tr>
<th>Energy Input</th>
<th>Energy Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Combined Heat and Power Production (CHP)</td>
</tr>
<tr>
<td>Waste 100%</td>
<td>Heat 60-65%</td>
</tr>
<tr>
<td></td>
<td>Power 20-25%</td>
</tr>
<tr>
<td></td>
<td>Own consumption 5%</td>
</tr>
<tr>
<td></td>
<td>Process loss 10-15%</td>
</tr>
</tbody>
</table>


A modern mass Incineration Plant with combined heat and power production can utilise energy from waste up to some 90 % of the potential as indicated in the table below. Utilisation of 90% of the energy input requires that a district heating network is available to receive the heat production. Production of power only is done where such network is unavailable and the surplus heat will be cooled in a cooling tower. Thus, energy planning is an important consideration in waste incineration.

Nonetheless, waste to energy incinerators still suffer from a stronger NIMBY (“not-in-my-backyard”) syndrome than MBT plants. Consequently, localisation of new incineration plants can be time consuming and may require substantial awareness raising measures.

➔Tool SWM 4

Case 29 Denmark: Waste to Energy Plant - I/S Reno Nord (incinerator line 4)

I/S Reno Nord is treating MSW from 225,000 inhabitants from 7 municipalities in the northern part of Denmark.

I/S Reno Nord is a partnership owned by the 7 municipalities.
(A partnership is a business where all participants are personally liable, jointly and severally liable without limitation for the company's obligations.)
In October 2005 one of the most modern and efficient waste-to-energy plants in Denmark was officially opened at I/S Reno Nord in Aalborg. The new furnace line 4 replaced the two old furnace lines 1 and 2, which were supplied in 1981. The existing furnace line 3, supplied in 1991, is kept as a replacement.

The main contractor was B&W Vølund a/s. The nominal capacity of the plant is 20 t/h waste at a calorific value of 12 MJ/kg, corresponding to approx. 160,000 t/year. The boiler generates 80 t/h steam at 50 bar, 425°C. The total cost was 680 million DKK (92 million Euro). Reno Nord line 4 in Aalborg, Denmark, is a state of the art incineration plant that produces both electricity and district heating. The plant was built using today's best solutions with respect to the combustion grate, operation control, materials and boiler design, and is able to operate stably and safely with relatively high steam data of 425°C and 50 bar.

The turbine generates approx. 18 MW of electricity, which will be fed into the main grid. Furthermore, the plant will supply approx. 43 MW of heat to the district heating network in Aalborg. The efficiency is approx. 100%, and the energy produced will supply approx. 16,000 houses with electricity, and approx. 30,000 houses with district heating.
<table>
<thead>
<tr>
<th>Guarantee test</th>
<th>Design values</th>
<th>300-hour test</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process parameter</td>
<td>Waste capacity</td>
<td>20</td>
<td>21,72</td>
</tr>
<tr>
<td>Calorific value, lower</td>
<td>Steam production</td>
<td>12</td>
<td>11,28</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>Steam pressure</td>
<td>22,42</td>
<td>22,55</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>Steam temperature</td>
<td>425</td>
<td>423</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>Steam temperature</td>
<td>50</td>
<td>48,6</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>Input efficiency</td>
<td>66,66</td>
<td>67,69</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>Electricity produced</td>
<td>17,918</td>
<td>18,232</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>Thermal efficiency</td>
<td>85,56</td>
<td>87,1</td>
</tr>
<tr>
<td>Annual turnover</td>
<td>Electrical efficiency</td>
<td>26,88</td>
<td>26,93</td>
</tr>
<tr>
<td>Annual turnover</td>
<td>TOC, bottom ash</td>
<td>&lt; 20</td>
<td>&lt; 0,23</td>
</tr>
<tr>
<td>Annual turnover</td>
<td>Flue gas temperature before superheater</td>
<td>620</td>
<td>530</td>
</tr>
<tr>
<td>Annual turnover</td>
<td>Outlet temperature, boiler</td>
<td>180</td>
<td>181</td>
</tr>
</tbody>
</table>

The plant design and test values comply with the EU directive on waste incineration. One reason for this high level of efficiency is that the cycle has been optimised through preheating the condensate by flue gas cooling after the boiler. Reno Nord uses 97% of the waste’s energy, with an electrical efficiency of 27%. If, for example, sea water from the Limfjord in Denmark was used at this plant to cool the turbine’s condenser, electrical efficiency would increase to approximately 35%, but total energy use would drop to 35%, as opposed to today’s level of 97%.

On the whole, the current solution is much more efficient. How do we obtain more electricity?

There are five factors that have crucial influence on a plant’s ability to produce electricity:

- Steam temperature;
- Steam pressure;
- Temperature of the cooling agent used on the turbine’s condenser;
- An optimised cycle; and
- Stable and robust operation.

The steam temperature is primarily limited by corrosion on the superheaters due to the very aggressive flue gas.

High steam temperature can, in part, be obtained by improving the corrosion resistance of the materials used in the superheaters, and, in part, through stable and robust operation control of the waste incineration and the full cycle, so that the flue gas and steam temperatures are stabilised. Doing so prevents great temperature fluctuations, which can accelerate the corrosion process.

High pressure can be obtained by using Inconel coating in the evaporator part of the boiler. The higher the pressure, the more Inconel. As such, the surfaces of the boiler’s evaporator part are protected from increasing corrosion resulting from the increasing vaporisation temperature, which, in turn, results from increasing pressure.

When a plant produces district heating, low temperatures may not be used in the turbine’s condenser. On the other hand, it is possible to use two-step condensation, i.e. one step at high temperature and one step at low temperature. This results in partial condensation at low temperatures, thereby improving electrical efficiency.
The entire cycle can be optimised by preheating the condensate before the feed water tank. By using e.g. flue gas cooling, grate cooling and steam extraction from the turbine’s low-pressure end, half and full percentage points can be added to the efficiency rating.

<table>
<thead>
<tr>
<th>Item</th>
<th>unit price</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate fee incoming waste</td>
<td>635 DKK/ton (85 €/ton)</td>
<td>83.000</td>
</tr>
<tr>
<td>Sale of Heat</td>
<td>72 DKK/GJ (9,66 €/GJ)</td>
<td>87.000</td>
</tr>
<tr>
<td>Sale of electricity</td>
<td>500 DKK/MWh (67 €/MWh)</td>
<td>20.000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>190.000</strong></td>
</tr>
</tbody>
</table>

It can be difficult to create uniform operating conditions, as the waste’s composition can vary significantly. However, stable and robust control ensures that the incineration process is optimal, and that the entire process runs without significant fluctuations.

As such, all settings can be put closer to their upper limits without resulting in problems with corrosion. At the same time, the turbine’s efficiency is better assessed over a longer period of time because the plant runs stably without significant upward or downward adjustments.

In the immediate future, requirements for incineration plants’ production of electricity will grow significantly, pushing steam data up to the ranges of 440–480°C and 70–160 bar. Today there are plants that experiment with such steam data, and the future will show what provides the best balance between electricity production and operating costs.

In the long term, concepts such as two-step waste incineration will constitute the solutions that lift steam data to an even higher level.

Two-step waste incineration is based on dividing the incineration process into two phases by building a partition wall inside the furnace. In the first phase, chlorine and other aggressive substances are extracted from the waste to provide a purer incineration in the second phase, which takes place further down on the combustion grate.

The flue gas from the pure incineration is led up through an extra superheater, where the steam temperature can be raised even more.

Economy

It is not possible to obtain a specific operation budget for the incinerator. However, based upon official figures from I/S Reno Nord on gate fees and incoming waste amounts, data from the district heating company in Aalborg and the unit prices on electricity and heat, following estimate can be established for the annual turnover of the plant:

The annual turnover is 28% of the investment.

Source: I/S Reno Nord [http://www.renonord.dk/](http://www.renonord.dk/)
4.10 Waste to Energy: Gasification a Clean Energy Technology that Generates Added Value

Gasification technology has been of growing interest in the waste management industry. The concept is not new, as gasification techniques were used to produce town gas for heating and lighting in Europe during the 19th century, typically using coal or peat as the raw materials. Today there are a number of technologies available that claim to solve many of the problems of large scale gasification of mixed solid wastes.

Small gasification projects have been successfully developed and the technology is proven for plants producing up to 10MW of electricity. In June 2016 the UK Secretary of State for Communities and Local Government approved a 9.6 MW waste to energy gasification facility in Nottinghamshire, UK.

The Bilsthorpe Energy Centre comprises two elements, a materials recycling facility that will produce fuel and recover valuable recyclable materials from residual waste; and a waste to energy gasification facility to generate electricity and heat. Once completed the facility will divert up to 117,000 tons of waste from landfill and recover up to 22,000 tonnes of recyclable materials per year.

Another example is a 12 MW plasma gasification facility in Morcenx, southwest France, pictured below, which was constructed by Bordeaux, France based CHO Power. The facility processes are divided into three main stages. Waste is first crushed and heavy inert substances and metals are removed. The crushed material may need to be dried, following which it is mixed to produce a homogenous fuel that is fed into the gasification reactor where it is transformed into syngas. The gas is then refined at high temperatures and the tars generated by the gasification process are thermally cracked at 1200 degrees C. The facility generates power from 150 tons per day of industrial and wood waste.
However, initial teething problems resulted in the facility being unable to deliver consistent performance. It is hoped that digital automation technology will help control the processes.

A 50MW plasmas gasification facility was proposed in Teeside, in the north east of England and was going to be the largest gasification project of its kind anywhere in the world, generating electricity for 50,000 homes, and diverting 350,000 tonnes of non-recyclable waste from landfill per year. It promised to provide more efficient, cleaner conversion of waste into power than traditional waste to energy technologies and had the potential to generate a wider range of useful products including heat, hydrogen, chemicals and fuels.

However, problems with escalating costs and technology resulted in the company, Air Products withdrawing completely from the energy from waste business.

Sources:
http://www.gazettelive.co.uk/business/business-news/final-detail-closure-air-products-12293263
http://www.chroniclelive.co.uk/business/business-news/hopes-energy-waste-scheme-teesside-11250693
Case 30 Germany: Gasification – Waste to Energy (INTEC Thermolytic Cracking Process)

Gasification of solid waste is going to replace existing waste incineration practice. Gasification is the new environmentally friendly, clean technology which reduced the final left-overs (residuals) and produces value added through its waste to energy technology. One of the leading procurers of this technology, the German firm INTEC is promoting the technology in Europe, South America and China.

“The INTEC Thermolytic Cracking Process (INTEC-TCP®). The process is determined by the energetic utilisation of substantially not further treatable organic waste. The patent-secured INTEC Technology involves a closed and thus completely emission-free thermal waste treatment primarily consisting of the procedural steps degassing/smouldering (thermolysis) and gasification. The INTEC Thermolytic Cracking Process operates with coupled procedural steps, yet in spatially separated devices. With this system, the respective necessary process parameters can be optimally adjusted, allowing an above-average utilisation by more than 99 % of the energy content of the waste material applied.

The generated synthesis gas is primarily utilised in gas engines which drive low or medium voltage generators according to the customers’ requirements regarding electricity generation. By additional application of exhaust heat from the engines in downstream ORC units (Organic Rankine Cycle), the electrical efficiency reaches up to 48 %. The INTEC Synthesis Gas Systems are characterised by a particularly consequent utilisation of the accrued exhaust heat for maintaining the overall process. “

Process Scheme


Characteristics of the Process

- Power generation of up to 2.2 MWh from one tonne of organic waste
- Carbon conversion to synthesis gas more than 99 %
- Thermal total efficiency degree approx. 88 %
- High availability due to modular and redundant design
Environmental Benefits of the INTEC Thermolytic Cracking Process (INTEC-TCP®):

- No flue-gases
- No dioxins and furans
- No residues such as oil, tar, coke or the like
- No incineration
- Synthesis gas generation in closed system
- The INTEC Synthesis Gas System is not a pyrolysis system
- No external heat source required – autothermal process
- Compliance with valid emission control acts and guidelines

Waste to Energy: Gasification a Clean Energy Technology

INTEC WASTE ENERGY GmbH
SyntheseBox Rostock
INTEC 50.000
Power generation from type H waste
Space requirements ca. 250 m x 200 m


Further Advantages

- Most modern technology Made in Germany
- Administrative approval in Germany for plant operation
- Very low electricity generation costs per kWh
- High profits for the operator

Utilisable input materials. Household waste; Industrial waste; Plastic, also PVC; Hospital waste; End-of-life tyres; Waste rubber; Waste oils; Scheduled waste; Bio waste; Residues from Paper industries, etc.; Sewage sludge; Administrative approval, amongst others, according to the German Federal Pollution Control Act (BImSchG) granted in 2011.39

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4.11 Disposal of Waste – Engineered Landfills

Landfill disposal is an unavoidable element of waste management as small percentage of waste remains. Thus, the construction of an engineered landfill is an important element of the future waste management system.

An engineered landfill is a waste disposal facility, which by its design and operation, aims at minimising the adverse impact on the environment and public health from landfill of waste, until the waste is stabilised and rendered harmless through the biological, chemical and physical processes of the nature. Its design in Romania is governed through construction norms.

The landfill is defined as a waste disposal site for the deposit of waste onto or into land (underground).

Depending on the types of accepted waste, landfills are classified as follows:

- Landfills for hazardous waste (class A);
- Landfills for non-hazardous waste (class B); and
- Landfills for inert waste (class C).

Image 28: Designing a waste landfill

Landfill design is based on:

- the quantity and nature of waste;
- the characteristics of the site – dimensions, lifetime, distance on which waste will be transported;
- protection measures for the environment and human health;
- closure and rehabilitation and further usage possibilities.
Site selection is based on:

- geological and hydro-geological criteria – characteristics and layout of the geological layers, characteristics of the underground water layer, distance to the water courses, state of flooding of the area, land usage, seismicity class etc;
- climatic criteria – dominating winds direction in respect to human settlements in the area, rainfall;
- economic criteria – landfill capacity and lifetime, average transport distance for the disposed waste, necessity of connecting to utilities;
- other criteria: visibility of the site and means of placing it in the landscape, existence of protected areas in the area, etc.

The detailed design of a landfill includes:

- access road and entrance, security and surveillance system;
- utilities such as water supply, electricity, discharge of treated waste water;
- weighing and registering equipment;
- laboratory for tests regarding waste;
- inner roads;
- area for waste depositing – for which waterproofing is ensured by the use of artificial membranes (geo-membrane and geo-textile);
- a system for the monitoring of underground water quality, that can include the monitoring of the state of the landfill base waterproofing system;
- facilities for leachate treatment and collection and (possibly) reuse of landfill gas;
- garages, workshops and parking spaces for the equipment in use;
- administrative offices and civil constructions.

Operation for landfills may vary based on: the nature of accepted waste and the conditions imposed by the environmental permit, the type of wastes, weather conditions in the area of the site, etc. Other operating conditions include:

- continuous compaction of the waste layer;
- maintaining of the maximum waste layer thickness of 0.5 m;
- daily coverage of the layer to avoid the odour emissions and attraction of opportunistic species/pest;
- leachate collection and treatment;
- collection and (possibly) treatment and reuse of landfill gas;
- optimization of the landfill cells surfaces.

Case 31 Germany: Closure of Halle-Lochau landfill

**Background**

The German landfill “Halle-Lochau” is located approximately 5km southeast of Halle in a former open cast mining site. It first became operational in 1976 and had an approximate tipping area and filled volume of 81.5ha and 17 million m³ respectively by the end of 2004. The landfill’s height is believed to have exceeded 20m around this time.

The landfill was built in a worked-out open pit and had some interesting hydrogeological properties. The plan to permanently close the landfill led to the cessation of active dewatering to reduce the ground water table. As such, the ground water was anticipated to rise again and reach the landfill body. EU regulations at the time stated that landfills that lie below the
groundwater level should not be operational after 2009, while in Germany this period was reduced to 2005.

No technical guidelines existed at the time in relation to sustainability and environmental protection considerations as regards (old) subaquatic landfills, therefore the government sought to find economic and ecological long-term solutions to this issue, authorizing a research project whose results would serve as the groundwork for such regulations. The company Abfallwirtschaft GmbH Halle-Lochau led the research project and was responsible for conducting an assessment and technical classification of local conditions and processes that are present during landfill closure and after-care.

**Image 29: Overview of “Halle-Lochau” landfill**


**Results of the research project**

Six options were developed for the final design of the closed landfill which consider the conditions and current situation of the landfill. A feature shared by all the options was the rise of the groundwater level caused by the discontinuation of the present groundwater lowering. Halting the groundwater control system would result in the generation of a lake for most of the options. The research project looked at what kind of pollution would occur during flooding and their effects on the environment, comparing all six options, and deciding on the optimal solution.

The research project’s investigation proposed that landfill gas should be generated to help make the landfill body become partially inert. Once the landfill is closed, the landfill gas would be collected and incinerated, while leachate would be used to stimulate microbial biodegradation of pollutants in the landfill body. Non-permeable materials should be used to build special underwater sealing systems in the lake designed to limit contact with the landfill.
body. Once the landfill gas has been generated, the landfill area would be flooded and a lake generated.

**Closure of landfill**

In the preferred option, inert materials would be used to ensure the western section of the site was completely infilled as part of closure operations. This would help to ensure the landfill body was geotechnically secure, and allow for the commencement of landfill closure and restoration operations. A restoration layer would be raised on the landfill body and vegetation planted on it.

In order to make the wastes inert, the construction of an additional facility during the landfill closure phase would be required. The leachate that is collected would be fed through a complex humidification system into the landfill body, enabling an optimal humidity content to be attained in the waste. The material arising from the decomposition of harmful substances is then collected with the landfill gas and incinerated in the gas utilisation station.

The research project expected that the completion of the landfill closure phase and aftercare would occur approximately 20-30 years after the completion of the landfilling stage. After-use of the site may entail construction of commercial premises or development of a local recreational area. The lake that is generated could serve as a scenic tourist spot with accompanying recreational activities, while the worked-out open cut would be surrounded by wooded and park areas.


**Image 30: Example of an Engineered Landfill Gas Utilisation Plant**


4.12 Construction and Demolition Waste

Usually CDW waste is divided into 2 groups:

- inert mineral waste, including excavation material, road refurbishment waste and concrete waste from demolition of buildings
• mixed CDW waste, which includes waste resulting from the degrading of the packaging of construction materials, from removed interior finishing or other materials from the refurbishing of flats and houses collected in containers.

However, many other waste fractions do also appear on a construction site, like packaging materials. Case 32 below illustrates how C&D waste must be sorted before it is transported to the waste treatment facilities.

**Case 32 Guldborgsund, Denmark: Sorting of Construction Waste – Local Directive for Sorting of waste at a Construction site**

<table>
<thead>
<tr>
<th>Sorting of Construction Waste:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction waste must always be sorted at the source - irrespective of volume - either directly on site or at a reception facility approved for the separation of construction and demolition waste.</td>
</tr>
</tbody>
</table>

The waste must be sorted into the following fractions:

- Natural stone, for example, granite and flint
- Unglazed tiles (brick and roof tiles)
- Concrete
- Mixtures of materials from natural stone, unglazed tiles and concrete
- Iron and steel
- Gypsum
- Stone wool
- Soil
- Asphalt
- Mixtures of concrete and asphalt
- Cardboard
- Plastics
- Wood
- PCB-containing joint material (hazardous waste)
- Hollow glass and other flat glass
- Glazed tiles
- PVC waste
- Impregnated wood
- Asbestos-containing waste

The use of sorted and uncontaminated construction waste:

- The following types of waste can without permission directly used for the same or related purposes as originally:
  - Natural stone, for example, granite and flint
  - Unglazed tiles (brick and roof tiles)
  - Concrete
  - Mixtures of materials from natural stone, unglazed tiles and concrete
  - Iron and steel
  - Gypsum
  - Stone wool
The following types of waste can without permission used as a substitute for primary raw materials:

- Natural stone, for example, granite and flint
- Unglazed tiles (brick and roof tiles)
- Concrete
- Mixtures of materials from natural stone, unglazed tiles and concrete

Notification of the use of uncontaminated construction waste:

Within 2 weeks before using sorted and uncontaminated construction waste as a substitute for primary raw materials, the user of the materials must report it in writing to the municipality.

Notification form can be downloaded from the municipal website, see www.guldborgsund.dk.


CDW should be first sorted to recycle/reuse/recover many materials. The remained rubble is generally crushed and sieved with reinforcement steel segregated by magnets, wood and plastics removed by water separators and the solid fraction crushed to dimensions useable for aggregates in concrete production and/or filling materials.

Use of rubble as concrete aggregate in low strength concrete replaces virgin aggregates.

Other common options for mineral inert waste are:

- its use as filling material for landscaping, and, if the waste grain size allows it, its use for the elevation of land;
- use of crushing facilities to reduce the dimensions – the crushed waste may be used for road ballast or as filling material for landscape development;
- use of asphalt crushing plants in view of reuse in road construction.

Options for the management of mixed construction and demolition waste:

- separation at source, on the construction site, per at least four fractions of the C&D waste; through source separation and selective demolition where wood, PVC and cables are removed before demolition, etc.;
- landfill of the mixed waste on compliant landfills, or in case these are contaminated, inclusion in the hazardous waste management system; and
- sorting a specialized sorting facility. European experience has shown that this method is less attractive than on site sorting.
Image 31: Crushing of Construction and Demolition Waste


Construction Waste in Germany

Construction Waste in the UK

Case 33 UK: Reclamation, reuse and recycling on the London Olympic Park

Background

On 6 July 2005, it was announced by the International Olympic Committee that London had been selected as the host of the 2012 Olympic and Paralympic Games. A 2.5 km² site in the Lower Lea Valley, East London, had been identified by the London 2012 bid as the site for the 2012 Olympic Park redevelopment.

220 buildings needed to be demolished in addition to walls, bridges and roads. The delivery partner to the Olympic Delivery Authority (ODA) was a consortium comprising CH2M Hill International, Laing O’Rourke and Mace (CLM), while Atkins acted as project manager.

Strict deadlines, tight timescales and the size of the site presented demanding challenges for the partners involved in the demolition phase, in particular in relation to reclamation and reuse of materials, as this can be more time-consuming than traditional demolition.

Image 32: Demolition at the Olympic Park


Reclamation and reuse of materials

The project involved the reuse and reclamation of various materials to varying degrees, including bricks, steel frame buildings, granite kerbs, granite setts, sandstone and concrete blockwork.
Bricks

Image 33: The demolition and reclamation of bricks involved both manual labour and machinery

Approximately 20,000 yellow stock bricks were reused around the Olympic Park. The reclamation process used was as quick as conventional demolition. Though two more operatives were used for this undertaking compared to purely mechanical demolition, the process adopted was able to be executed by demolition contractors without specialist reclamation experience.

Material damage caused by mechanisation meant that some bricks could not be reused. A balance between cost and programme needed to be found, and Health and Safety considerations taken into account, when weighing up manual stacking and cleaning of bricks against mechanisation.

Steel portal frame buildings

The process of reclamation of the steel portal frame building and other steel portal frames in the Olympic Park was successfully achieved and could be considered an exemplar case study in this area.

Steel portal frame buildings should be strongly considered for reclamation as they are a potential quick win in this regard. This is due to the structure's relative ease of dismantling, the fact that several operators will dismantle and resell portal frames, and that there is a strong market for pre-used buildings. 34 buildings on the Olympic Park were identified as containing reclaimable steel: 26 steel portal frame buildings and 8 buildings containing elements of structural steel, seven of which were reclaimed for reuse.

In addition to the financial benefits for the reclamation and demolition contractors, there were environmental advantages too, as approximately 190 tonnes of steel with an embodied CO$_2$ of 345 tonnes was reclaimed, resulting in an embodied CO$_2$ saving of 84 tonnes compared with recycling.
Granite kerbs and setts

Image 34: Granite setts on The Greenway

Granite kerbs were reused as drainage runs and for detailing on road sides in the northern section of the Olympic Park. The kerbs are still in a very good condition today, owing to the material's durability and resilience.

High quality granite setts from the Olympic Park area were reused on The Greenway to break up the continuous strip of re-laid tarmac and add aesthetic value around utility access and drainage areas. They provide a unique finish to architectural features across the Park as well as augmenting the regeneration value of The Greenway.

Sandstone

Image 35: Sandstone paving in the Park

Pathways were forged on The Greenway and in some temporary areas on the Olympic Park that were made of reclaimed and reused sandstone paving blocks. The size and dimension of these blocks can often vary, so it was fortunate that in this case they were of similar proportions.

Concrete blockwork

Reclaimed concrete blockwork was placed in the ‘Dog Pound’ area of the Park, which served as a temporary exercise yard for security dogs working on the Park. The blockwork was used as a substitute for standard tarmac and provides greater aesthetic value for cars passing along the busy A12.

Outcome

The ODA managed to exceed its overall target of reusing or recycling at least 90% by weight of demolition material, achieving a 98% recycling rate and 0.5% reuse rate during the demolition of the Olympic Park. Less than 7,000 tonnes were landfilled, the majority being hazardous and general waste.

Key lessons

Currently, it makes more economic sense for businesses to recycle than to reuse material, therefore reuse requirements must be included in contracts from the earliest possible stage in order to achieve greater levels of reuse. However, since incentives for reclamation and reuse were not prioritised and separate reclamation and reuse targets were not stipulated in contracts, it meant that the local reclamation and reuse sector struggled to handle the vast amounts of demolition material that was generated in a very short timeframe in the Olympic Park. Investment in the reclamation/reuse sector and earlier deployment of workers would also have enabled the project to maximise reuse rates.

Source: Reuse and Recycling on the London Olympic Park (October 2011).

4.13 Recycling of Waste Electrical and Electronic Equipment

Electronic waste, "WEEE" or "Waste Electrical and Electronic Equipment" ("WEEE") is waste from broken, discarded or unwanted electrical or electronic appliances. WEEE is particularly difficult to treat as many WEEE components contain hazardous substances, (HS) that are toxic and are not biodegradable. Although manufactures remove many HSs, such as CFCs from refrigerators, -freezers and air conditioners or cadmium/lead/mercury from solders, etc. HS will continue to be present in WEEE, requiring there disassembly/treatment in specialized facilities, that protect both the environment and human health.

For example, recently, the EU has introduced a directive that phases out the traditional light bulb by the end of 2009. The alternative light bulbs are florescence bulbs and tubes, which, due to mercury, must be collected separately from glass and bottles to avoid contamination.

With the recent growth and replacement of electrical equipment, a system for WEEE collection and treatment are become more urgent. This is particularly true for household TV sets, computers, mobile phones, batteries, whereas as the growth of white goods (refrigerators, cookers, washing machines), is more slow and that many merchants participate in WEEE take back schemes.
4.14 Sludge from Municipal Waste Water Treatment Plants

Earlier, the use of WWTP sludge as fertilizer on agricultural lands was heralded as a solution for WWTP sludge disposal. However, new disposal standards restrict application on agricultural lands. As a consequence, a combination of treatment/disposal methods are used following the below principles:

To integrate existing process technologies, if these prove to be viable;
To recover the maximum energy potential, such as: biogas, thermal energy at a co-generation plant, thermal energy from digested sludge and possibly from treated waste water;
Technologies which follow the relevant national/EU directives/BREF with convincing references; and
To reduce to the minimum, the quantity of sludge sent for disposal.

From the above, the more common WWTP treatment methods are:

- Use on forest lands;
- Drying, following by incineration (with energy recovery);
- Secondary biological treatment, followed by drying and incineration, energy recovery; and
- Landfill disposal of the remainder.

Common technologies employed in the above are:

- Reception and pre-treatment area for industrial waste;
- Conditioning of the return biological sludge through physical methods to increase the digestion and sludge filtering rate;
- Recovery in agriculture/forest of the sludge cakes;
- Reduction of the humidity of the sludge through:
  - Mechanical dehydration;
  - Natural dehydration through solar energy;
  - Thermal drying;
  - Incineration or co-incineration.
- Landfill disposal.

Of the above methods, fluidized bed incineration and secondary digestion are the most common sludge treatment methods.
As all solutions must comply with environmental regulations and emission standards, treatment and disposal cost because the overriding factor. This can be restated as follows. The capital costs and the operational ones and any other potential incomes are essential aspects in the development of the final disposal solution, but shall not represent the main selection criteria only if the impact on the environment of the proposed solutions is the same. The options with low costs are often (but not necessarily) less safe and sustainable, so that all factors have to be assessed.

**Case 34 UK: Sludge reuse at Veolia’s Almond Valley, Seafield and Esk (AVSE) scheme**

**Opportunity**

The Almond Valley, Seafield and Esk scheme (AVSE) is a 30-year performance based contract awarded by Scottish Water in 1999 to Stirling Water Seafield Ltd, under the UK’s largest Private Finance Initiative (PFI) at the time, for the design, construction and operation of wastewater sites, trunk sewers and storm attenuation sites. The AVSE project area accounted for a population equivalent to 907,000 and involved the treatment of over 125,000,000m$^3$ of wastewater each year.
Solution

Veolia was appointed in 2000 and responsible for the operation of 15 sites in Edinburgh and Lothians and provision of a fully integrated recycling service. Veolia was also responsible for making improvements to a combined heat and power plant (CHP) as well as the construction of an advanced digestion plant.

Veolia identified key stakeholders early on in the process, such as Stirling Water, Scottish Water, the Scottish Environment Protection Agency, local Environmental Health Officers, farmers and land owners, and ensured active engagement with them so that stronger community relationships could be forged and their operations made transparent.

Veolia proposed a solution to recycle different forms of biosolids to various land-based projects, including dried pellets, digested sludge cake and dewatered sludge cake.

**Image 36: Wastewater treatment plant**

![Wastewater treatment plant](https://www.veolia.co.uk/sites/g/files/dvc151/f/assets/documents/2014/08/Proud_Case_Studies_-_August_2014.PDF)

Outcome

Stockpile quantities were maximised and haul distances minimised, enabling a cheaper and more efficient haulage and spreading operation.

The high quality and low cost of the project has meant that additional business has been generated from farmers and land owners in relation to the recycling of biosolids.

Various land-based solutions were proposed to recycle the sludge including conventional agriculture (arable and forage), industrial crops, off-site mobile lime processing, land restoration and composting, which is then spread on agricultural fields.

The project has succeeded in significantly minimising the waste sent to landfill, as well as preventing sewage sludge from being disposed of in the North Sea. 60,000 tonnes of waste sludge per year were recycled and 30,000 tonnes of treated sludge provided for agriculture. The efficiency of the CHP plant was also improved, allowing it to achieve 70% self-sufficiency in electricity.

Sources:
4.15 Using Organic Waste as a Construction Material

New innovative ways to use organic waste materials are being developed as a means to develop a circular economy and provide the construction and other industries with lower-cost low carbon materials such as bricks, insulation, partition boards and textiles. Consultancy firm Arup has predicted that waste materials from bananas, potatoes and peanuts could be used as building materials in the future, diverting the waste that would normally have been managed through landfill, incineration or composting. In 2014 more than 40 million tons of dried organic waste from agriculture and forestry was produced in Europe and this figure is rising year on year. Although the materials can be incinerated for energy recovery, the value of materials can be increased significantly when used for interior cladding.

Table 16: Potential use of organic waste materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Potential Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanuts</td>
<td>Shells can be used to produce low cost, moisture and flame retardant partition boards</td>
</tr>
<tr>
<td>Rice</td>
<td>Rice husks can be mixed with cement, reducing the need for fillers</td>
</tr>
<tr>
<td>Banana</td>
<td>Bananas and banana leaves are being used to make textiles. The fibres are durable, high strength and have good acoustic absorption properties</td>
</tr>
<tr>
<td>Potato</td>
<td>Peel can be used to make lightweight fire resistant, water repellant insulating material and acoustic absorption materials</td>
</tr>
</tbody>
</table>

Six main applications for organic waste materials have been identified:
- Interior partitions and finishes: seeds, stalks, shells, cellulose etc can be turned into flat boards,
- Furniture: natural fibres and small residual particles can be used in complex forms
- Acoustic absorption: using high porosity materials such as soy residue
- Thermal insulation using low conductivity natural fibres
- Carpets and moquette: using flexible, strong and lightweight natural fibres
- Envelope systems: may be combined with biopolymers to obtain stiff end products
Image 37: Furniture made from natural fibres; boards made from sunflower waste; Pineapple fibres

Mushroom tower: A temporary tower was made using mushrooms as the base materials for the MoMa in New York. The mycelium fungus was used as the base material for the bricks, and binds itself to its food source to create a strong, resilient matrix in any shape. For the MoMa structure mushrooms were fed on waste corn stalks and were grown in five days, producing no waste or carbon emissions. At the end of the installation, the structure can be taken down and composted.

Image 38: Mushroom tower at MoMa, New York

Orange Fiber: An Italian start-up company makes fashion textiles from orange, lemon and grapefruit skins, byproducts from the citrus juice industry. Each year Italy produces more than 700,000 tons of citrus waste products, which require disposal. Orange Fiber has patented a
process to turn waste citrus skins into a silk-like cellulose yarn that can be blended with other materials, reducing the amount of waste sent for disposal, and saving on costs. The fashion brand Salvatore Ferragamo was the first company to use Orange Fiber fabrics in their fashion collection.

**Image 39: Orange Fiber – made from orange peel**

![Orange Fiber](http://orangefiber.it/en/about/)

Other projects using citrus peel have been developed in the UK using waste from Brazilian and Spanish oranges. The process uses microwaves to degrade the cellulose and release volatile gases that can be collected and distilled to produce biodegradable chemicals that can be used in plastics, cleaning agents and water purifiers. The process is extremely efficient and can be used on almost any plant based waste such as straw or coffee grounds. Power stations in Brazil are interested in the process of microwaving waste before incineration as the calorific value of the waste doubles.

5. PERSPECTIVES FROM CHINA

This chapter gives an overview of waste management practices in China, providing information on waste management policies and regulations and giving examples of current practices, which include pilot programmes to introduce innovative technology.

China is one of the largest nations in the world, encompassing a vast area, with diversified nationalities and cultures, and a very large population. It is also the largest developing country and has relatively poor infrastructure and an underdeveloped waste management industry. China has been undergoing a rapid urbanization, resulting in the enormous generation of municipal solid waste (MSW). In terms of municipal solid waste management, no country has ever experienced such a rapid increase in MSW or such large quantities now being experienced in China. Along with this rapidly growing waste stream, MSW treatment technology has been improved, the environmental legal framework has been established and developed, and public environmental awareness has also been promoted in the past three decades, although the MSW management in China still faces many challenges.40

5.1 Sector overview and Policy Analysis

**Legal Basis.** The legal basis of the solid waste management sector determined by the existing urban planning legislation of the People’s Republic of China (PRC), and other guidelines of the Ministry of Housing, and Urban-Rural Development (MoHURD), particularly those pertaining to eco-city development.

The chart below outlines the different ministries, under the State Council, that have responsibility for different sectors of the waste management industry in China. The structure is extremely complex, with a total of 12 different divisions responsible for domestic waste, building waste and kitchen waste; industrial solid waste, hazardous waste and imported waste; renewable resource recycling; comprehensive resource utilization and PPP operations in public service.

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Figure 27: Solid Waste Management in China

5.1.1 Key Regulations and Laws

The relevant legal reference documents include:

  And based on the law, the detailed Enforcement Regulation has been developed, and undergone revisions for several times. The latest is the 2014 version.
- State Council. April, 2015, Suggestions on Enhancing Eco-civilization.

Specifically for the solid waste management sector, the following legal instruments apply:

- MoHURD, NDRC & MEP. 2010. Technical handbook for Municipal Waste Treatment

New Urbanization Policy 2016. Following the Central Urban Work Conference (20-21 December 2015) on 6 February 2016, the Communist Party of China Central Committee and the State Council issued a roadmap for city development which mentioned complete urban services.
- Build comfortable and liveable environment. Within 5 years, set up the system of collection and reutilization of kitchen and building waste. \( \rightarrow \) Tool SWM 2

China Development Bank Capital (CDBC) Policy for Green Urban Development. The CDBC’s policy document for Green Urban Development states several principles for the SWM sector:
- Waste Management: All buildings should have waste classification facilities. All household waste must be sorted and collection of hazardous waste must be prioritized. At least 30-50% of waste should be composted and 35-50% recycled or reused. \( \rightarrow \) Tool SWM 2, \( \rightarrow \) Tool SWM 3

- Smart waste management. Smart Technologies can advance green city management: smart technologies can improve waste flows and contribute to the implementation of integrated waste management practices. \( \rightarrow \) Tool SWM 1

“Optimising waste routes or understanding when to empty public waste bins can save on fuel and labour costs associated with waste management.” \( \rightarrow \) Tool SWM 2

A summary of the main policies and regulations regarding waste management is provided in the table below.

Table 17: Summary of Solid Waste Management Legislation in China

<table>
<thead>
<tr>
<th>中华人民共和国固体废物污染环境防治法</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Law of the People’s Republic of China on the Prevention and Control of Environmental Pollution by Solid wastes (Revised November 7, 2016)</strong></td>
<td></td>
</tr>
<tr>
<td>This law was first adopted in October 1995 and has been amended several times.</td>
<td></td>
</tr>
<tr>
<td>The provisions include supervision and management of environmental pollution prevention and control of solid waste; prevention and control of environmental pollution from solid waste; special provisions for the prevention and control of hazardous wastes; legal liabilities and supplementary provisions.</td>
<td></td>
</tr>
<tr>
<td>It does not cover the marine environment or radioactive waste.</td>
<td></td>
</tr>
<tr>
<td>The term “harmless disposal” is used to describe the treatment of solid waste to promote cleaner production and a recycling economy. The basic principle of the law is to encourage and support measures to increase recycling and utilisation of waste and to protect the environment and reduce pollution from waste.</td>
<td></td>
</tr>
<tr>
<td>Prevention and control of pollution from solid waste is the responsibility of the administrative departments of the environmental protection bureau of the local people’s governments at or above the county level, including supervision and administration of cleaning, collection, storage, transportation and disposal of domestic waste.</td>
<td></td>
</tr>
<tr>
<td>The import of solid waste is restricted to prohibit materials that cannot be rendered “harmless” or used as raw materials.</td>
<td></td>
</tr>
</tbody>
</table>

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Local governments are encouraged to plan the development of waste to energy facilities, including urban gas, natural gas and other clean energy, and arrange outlets to promote the recycling of domestic waste.

Units that produce hazardous waste are required to take measures to reduce the volume of waste produced and the level of hazard. A hazardous waste management plan must be submitted to the local government at or above the county level.

全国城市生活垃圾无害化处理设施建设“十三五”规划


The 13th FYP for the construction of non-hazardous disposal of facilities for municipal solid waste in China runs for the years 2016-2020. Tasks included in the Plan include speeding up construction of facilities; improving waste collection and transportation systems; increasing waste management; promoting the use of kitchen waste and "harmless treatment"; implementation of classification of domestic waste; strengthening regulatory capacity, standards, etc; and strengthening publicity and guidance.

The plan recognizes that with rapid urbanization in China the waste disposal capacity growth is inadequate and there is a need to improve the level of operation and management and expand services. Basic principles include coordinating the collection and transportation of waste and reducing the quantities of waste being sent to landfill. The process of waste management should be innovation driven and multi-collaborative, implementing PPP contracts to promote investment, construction and operation.

Targets include, by 2020:

- Municipalities directly under Central government, planned cities and provincial capitals to achieve a garbage treatment rate of at least 95%; Increase capacity from 758,300 tons/day to 1,104,900 tons/day by 2020.
- Other municipalities to achieve more than 80% (or 70% for difficult waste)
- Economically developed areas, especially those with large populations and limited available land should promote incineration; centralised fly-ash treatment and disposal
- Promote the use of food waste and harmless treatment. For food waste and recycling systems a comprehensive system of the management of urban household waste should be established.
- Municipalities and cities shall collect and utilise more than 35% of domestic food waste for recycling and use. The utilisation and harmless treatment of food waste shall be promoted; in particular through the recycling of waste food oil, production of organic fertiliser, soil improver and feed additives. Food waste may also be combined with other organic bio-degradable waste. By the end of the 13th FYP the capacity for food waste disposal should have reached 34,400 tons/day.
- Improve the waste disposal fee system to include collection, removal and disposal; increase policy support
- Improve the waste collection and transportation system to handle 442,200 tons/day of domestic waste (161 million tons/year)
- Encourage cross-regional and cross sectoral cooperation to encourage the development of large scale enterprises.
- Strengthen publicity and guidance, particularly regarding waste classification and recycling.
- Strengthen law enforcement, monitoring and supervision regarding pollution

Food waste shall be collected in a timely manner to prevent environmental pollution, and the waste shall meet quality standards and the use of kitchen waste fertilizer shall be strictly monitored.

It is estimated that during the 13th FYP period the total investment in MSW treatment facilities will be approximately 251.84 billion Yuan; of which 169.9 billion Yuan will be spent on transportation and transportation construction; 18.3 billion Yuan on food waste project investments; 24.14 billion Yuan for renovation project investments; 9.41 billion Yuan for waste classification demonstration projects and 4.23 billion Yuan on monitoring systems construction investment.

**State Council and NCRC – Policy Guidelines for Enhancing Municipal Waste Management**

This is a work plan for energy saving and emissions reduction for the 13th FYP to strengthen the construction of waste recycling facilities; strengthen management and supervision of classification, collection and treatment of waste; improve the recycling and treatment level of municipal waste and comprehensively promote rural waste management, establishing a village cleaning system, promoting waste classification and local resource utilization. By 2020 waste from more than 90% of administrative villages should be treated.

**生活垃圾焚烧污染控制标准 Standard for Pollution Control on the Municipal Solid Waste Incineration**

The standard was first published in 2000, with a first revision in 2001 and second revision in 2005. Further revisions were made in 2014, and implemented in 2016.

The principle contents of the revision were to:

- Adjust the scope of application of the standard to include waste sludge generated by sewage treatment facilities and pollution control of the incinerators that generate general industrial solid waste
- Increased pollutant discharge control requirements for start-up, shutdown, failure or accidents relating to domestic waste incinerators.
- Controls on the emissions of particulate matter, sulfur dioxide, nitrogen oxides, hydrogen chloride, heavy metals, and their compounds in the flue gas from municipal solid waste incineration plants.

The standard refers to the following documents:

- GB 8978 Integrated wastewater discharge standard
- GB14554 Odour pollution discharge standard
- GB16889 Standard for pollution control of domestic refuse landfill
- GB30485 Standard for pollution control of solid waste in cement kilns
- GB/T16157 Determination of particulate matter and sampling method of gaseous pollutants in exhaust gas of fixed pollution source
- HJ 77.2 Ambient air and exhaust dioxins Determination of isotope dilution High resolution gas chromatography - High resolution mass spectrometry
- HJ 543 Fixed source of waste gas Determination of mercury by cold atomic absorption spectrophotometry (provisional)
<table>
<thead>
<tr>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>HJ 548  Determination of hydrogen chloride in the exhaust gas of fixed sources - Silver nitrate volumetric method (provisional)</td>
</tr>
<tr>
<td>HJ 549  Ambient air and waste gas Determination of hydrogen chloride Ion chromatography (provisional)</td>
</tr>
<tr>
<td>HJ 629  Determination of sulfur dioxide in fixed sources - Non-dispersive infrared absorption method</td>
</tr>
<tr>
<td>HJ 657  Determination of lead and other metal elements in air and waste particulate matter - Inductively coupled plasma mass spectrometry</td>
</tr>
<tr>
<td>HJ 693  Determination of nitrogen oxides for fixed sources of waste gas by electrodeposition</td>
</tr>
<tr>
<td>HJ / T 20 Technical specification for sampling of industrial solid waste</td>
</tr>
<tr>
<td>HJ / T 27 Determination of hydrogen chloride in the exhaust gas of fixed sources - Mercury thiocyanate spectrophotometric method</td>
</tr>
<tr>
<td>HJ / T 42 Determination of nitrogen oxides in the exhaust gas of fixed sources - Ultraviolet spectrophotometric method</td>
</tr>
<tr>
<td>HJ / T 43 Determination of nitrogen oxides in the exhaust gas of fixed sources - Naphthalenediamine hydrochloride spectrophotometric method</td>
</tr>
<tr>
<td>HJ / T 44 Determination of carbon monoxide in exhaust gas from fixed sources - Non-dispersive infrared absorption method</td>
</tr>
<tr>
<td>HJ / T 56 Determination of sulfur dioxide in exhaust gas from fixed sources</td>
</tr>
<tr>
<td>HJ / T 57 Determination of Sulfur Dioxide in Fixed Pollutant Exhaust</td>
</tr>
<tr>
<td>HJ / T 75 Technical specification for continuous monitoring system for flue gas emissions from fixed sources</td>
</tr>
<tr>
<td>HJ / T 228 Medical waste chemical disinfection centralized treatment engineering technical specifications (Trial)</td>
</tr>
<tr>
<td>HJ / T 229 Medical waste microwave disinfection centralized treatment engineering technical specifications (Trial)</td>
</tr>
<tr>
<td>HJ / T 276 Technical specification for centralized treatment of high temperature steam for medical waste (Trial)</td>
</tr>
<tr>
<td>HJ / T 397 Technical specification for fixed source exhaust gas monitoring</td>
</tr>
</tbody>
</table>

Online monitoring indicators should at least, include carbon monoxide, particulate matter, sulfur dioxide, nitrogen oxides and hydrogen chloride in the flue gas.

### Regulations for the Importation of Solid Waste

 Entered into force on 1 August 2011.

The Measure covers licensing management of solid waste, inspection and quarantine and customs procedures; supervision and management; special provision on special regulatory areas and locations; penalties and supplementary provisions.

The provision of the measures is to prevent the import of solid waste pollution. Solid waste import licenses are required and there is a prohibition on the re-export of solid waste. The local administrative departments for environmental protection are responsible for supervision, administration and management. Importing of hazardous waste is forbidden. Waste may not be imported for the purposes of heat recovery; and import of waste that cannot be used as raw materials or used in a harmless manner is also prohibited. Foreign suppliers of imported solid waste are issued with registration certificates, and a registration system is also implemented for domestic consignees.

---

**固体废物进口管理办法 Regulations for the Importation of Solid Waste**

Entered into force on 1 August 2011.

The Measure covers licensing management of solid waste, inspection and quarantine and customs procedures; supervision and management; special provision on special regulatory areas and locations; penalties and supplementary provisions.

The provision of the measures is to prevent the import of solid waste pollution. Solid waste import licenses are required and there is a prohibition on the re-export of solid waste. The local administrative departments for environmental protection are responsible for supervision, administration and management. Importing of hazardous waste is forbidden. Waste may not be imported for the purposes of heat recovery; and import of waste that cannot be used as raw materials or used in a harmless manner is also prohibited. Foreign suppliers of imported solid waste are issued with registration certificates, and a registration system is also implemented for domestic consignees. 2011
In April 2017 the 34th session of the CPC held a meeting on the implementation of the Measures for the implementation of the Regulation on the Administration of the Importation of Solid Waste, emphasising environmental protection, and with the intention of developing a ban on the importation of solid waste; to strengthen solid waste recycling management and develop a circular economy (http://www.mep.gov.cn/xxgk/hjyw/201704/t20170419_411714.shtml).

On 18 July 2017 China notified the WTO that it would stop the importation of waste shipments, including waste plastic, paper, wool, ash, cotton and yarn, and slag from steel making by the end of 2017. This is discussed further below.

### Circular Economy Promotion Law

The Law came into force in January 2009 and is designed to facilitate development of a circular economy; raise resource utilisation rates; reduce pollutant discharges; protect and improve the environment and boost sustainable development.

A Circular Economy is the term used for decrement (reduction in resource use), recycling and resource recovery in production, circulation and consumption. Recycling is the direct use of wastes as products or after repair, renovation or reproduction, or the use of wastes wholly or partly as parts of other products. Resource recovery means the direct use of wastes as raw materials, or waste regeneration.

The law includes the basic administrative system; reduction in resource use, recycling and resource recovery; incentive measures (including special funds and tax preferences); legal responsibility and supplementary provisions.

### National Catalogue of Hazardous Wastes

According to the Law of the PRC on the Prevention and Control of Environmental Pollution by Solid Waste, hazardous wastes include:

- Corrosive, toxic, flammable, reactive or infectious waste
- Waste that may cause harm to the environment or human health
- Medical waste
- Hazardous chemicals – are hazardous waste after disposal

### Regulation for the administration of Municipal Solid Waste

This regulation was developed in order to strengthen municipal solid waste management to improve city appearance and environmental sanitation according to the “Solid Waste Pollution Prevention Law of People’s Republic of China”, “City Appearance and Environmental Sanitation Management Regulations” and other laws.

Relates to the implementation of reduction and recycling.

A municipal solid waste disposal fee is charged for the collection, transportation and disposal of MSW. The provisions include governance planning and facilities construction; cleaning, collecting and transportation; disposal; legal liability and penalties;
### Site selection for sanitary landfills, composting plants and incineration plants shall conform to urban and rural planning.

<table>
<thead>
<tr>
<th><strong>Site selection for sanitary landfills, composting plants and incineration plants shall conform to urban and rural planning.</strong></th>
</tr>
</thead>
</table>

### Measures for the administration of the collection and handling of food and beverage waste in Beijing

**Regulation for Collection, Transportation and Disposal of Kitchen Waste in Beijing**

Measures to control the collection and handling of food and beverage waste in Beijing came into effect in January 2006.

Food waste is defined as food residue from hotels, restaurants, institutions, units, enterprises, including liquid waste oil and other waste. The measures apply to the collection, transportation, handling and management of waste in urban and suburban areas.

Beijing Municipal Administration Committee is responsible for the supervision and administration of the measures according to the standards, which must meet the requirements of health and environmental protection.

**Regulation on the administration of Construction Waste**

This regulation is to strengthen the management of urban construction waste and protect city appearance and environmental sanitation. The regulations apply to disposal activities such as dumping, transportation, transit, backfilling, consumption and utilisation of construction waste in urban planning areas.

The competent department of construction under the State Council shall be responsible for the management of urban construction waste and should encourage waste reduction, resource use and harmless treatment. Construction waste disposal plans should be developed. Units that are responsible for the disposal of construction waste should apply to the competent department prior to disposal of waste. Construction waste shall not include industrial waste, domestic waste or toxic and hazardous waste.

### Technical Code for Municipal Solid Waste Sanitary Landfill

This note was approved for sanitary waste landfill technical specifications, for mandatory provisions to be strictly implemented for urban sanitation.

The content of the specification includes landfill site, overall layout, foundation and seepage control, collection and treatment, gas and leachate collection and explosion protection, operations and management, closure, and environmental protection and health and safety.

Landfills should not be located in areas where:
- groundwater is used for water supply, or is a supply area flood area
- boundary reserve area between landfill and residential area/water supply area
- boundary reserve area on borders of rivers or lakes
- boundary area for civil airports
- subsidence areas in limestone

**Regulation on the administration of Construction Waste**

- 2006
- 2005
- 2004
Landfills must be consistent with current national construction of domestic waste landfill pollution control and must meet the requirements of local urban planning and regional environmental planning and urban health and safety. Provisions are made for the use of lining systems to prevent seepage into groundwater.

一般工业固体废物贮存、处置场污染控制标准

Standard for Pollution Control on the Storage and Disposal Site for General Industrial Solid Wastes

This standard was approved by the State Environmental Protection Administration on November 2, 2001.

The standard applies to new industrial waste, and does not apply to hazardous waste or domestic landfill. Industrial solid waste should be stored in a centralised site that complies with the standard, particularly with regard to leachate (permeability coefficient, water penetration etc). The site must meet the conditions required in the local urban and rural construction master plan, being downwind of residential areas, avoiding fault zones or cave areas. Sites are prohibited near rivers or lakes and reservoirs; and nature reserves and scenic areas or areas that require special protection. Priority should be given to abandoned mining and collapsed areas.

Measures should be taken to prevent dust, and rainwater runoff from entering the storage area thus increasing leachate volumes.

Measures must be taken to prevent spontaneous combustion

Geological and hydrogeological data must indicate that deep aquifers will not be contaminated by the site.

Monitoring must be undertaken to ensure there is no seepage, and to ensure that leachate is treated effectively.

Before closure of the site a closure plan must be developed, including the restoration of vegetation. Monitoring must continue after closure.
### Policy on Municipal Solid Waste Disposal and Pollution Control Techniques

Technical policy for the development of municipal solid waste treatment and pollution prevention and control technology to improve urban health. The policy applies to the whole process of waste management, including the encouragement of an integrated approach; investment diversification and development of a market; and the participation of the community in waste reduction, classification, collection and recycling. The development of waste disposal technology must be based on scientific research.

Waste reduction should include limits to excessive packaging, and the establishment of a consumer goods packaging recycling system.

Kitchen waste volumes to be reduced.

Development of recycling for paper, scrap metal, glass, plastics and other recycling.

Encouragement of waste incineration with waste heat utilisation and landfill gas recycling, as well as organic waste composting and anaerobic digestion.

Waste should be collected in closed vehicles with compactors. Hazardous waste is prohibited from inclusion in household waste. Resource recycling and re-use is encouraged to reduce the volume of waste collected, transported and disposed of.

It is expected that gradually, an independent system for the collection and transport of waste batteries, fluorescent tubes, insecticidal containers etc. will be established.

Disposal of waste in sanitary landfills is currently the main method for waste disposal in China. The planning, design, construction, operation and management of landfills should be strictly in accordance with municipal solid waste sanitary landfill technical standards. Anti-seepage and leachate control measures must be in place, as well as measures to prevent landfill gas migration. Landfill gas recovery should be implemented as far as possible.

Due to restrictions on development of landfills, incineration should be adopted. Incinerators should use mature technology that meets control standards. Waste heat should be recycled to minimise thermal pollution. Slag and fly ash that are hazardous must be disposed of as hazardous waste.

Composting should be adopted for biodegradable waste with an organic matter content greater than 40%. Residues produced during composting can be incinerated or sanitised.

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### Regulation on Household Waste Classification

In March 2017, the State Council published a landmark policy about Household Waste which will introduce waste separation, recycling and support the concept of 3Rs of waste management (reduce, recycle, and reuse). While the recycling target is still low in comparison to other industrialised countries (where the target has reached 80% already). This is an important urban innovation.

### Implementation Plan of Household Waste Classification Regulation

In 2000 the Ministry of Construction identified eight pilot cities for municipal waste collection: Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, Nanjing, Xiamen and Guilin. The subsequent development of relevant laws and policy documents for waste collection and
domestic waste disposal systems optimised the processes, technology and facilities to improve the quality of domestic waste disposal. These included:

2003: People’s Republic of China Cleaner Production Promotion Law

2005: People’s Republic of China Law on the Prevention and Control of Environmental Pollution by Solid Wastes

2009: People’s Republic of China Law on the promotion of a Circular Economy

2012: the General Office of the State Council issued a document: “Notice of the general office of the State Council on printing and distributing the construction plan of the domestic sewage treatment facilities for the 12th FYP” and “the State Council approved the Ministry of Housing and Urban Construction and other departments further strengthening of municipal solid waste disposal notice.

The notice provides important support and some cities have made progress with waste classification, collection, and transportation.

1. The goal is by the end of 2020, the jurisdiction and standard system of waste classification is established, the classification model which is replicable and up-scalable is developed. In the cities where waste classification is mandatory, at least 35% of household waste is recycled.

2. For the following types of cities the household waste classification is mandatory:
   - 4 Municipalities directly under central government (i.e. Beijing, Shanghai, Tianjin, Chongqing)
   - All provincial capital cities
   - 5 Cities specifically designated in the state plan (Dalian, Ningbo, Xiamen, Qingdao, Shenzhen)
   - the first batch of cities listed as demonstration city for household classification

Other cities are encouraged to implement household waste classification, while new districts/towns, national eco-civilization demonstration districts/zones shall take the leading role.

These cities shall by the end of 2017 develop the regulation, to elaborate the detailed requirement on waste classification, which on the basis of dangerous waste classification, implements classification of other types of waste. Public institutes and enterprises are the main bodies for implementing the classification.

3. The local municipal government could develop guidelines based on their actual situation, in order to raise the awareness of citizens, and help them to implement the waste classification in a scientific way. Cities who implement mandatory waste classification, shall choose various types of communities for the demonstration effect.

4. It is emphasized that, strengthen the establishment of corresponding systems, set up the collection system which matches the classification, set up the recycling system which is coordinated with the reusing system, complement the corresponding terminal waste treatment facilities, explore building up synergy treatment facilities. (translation: EC-Link)

Source: State Council, 30 March 2017 (drafted by NDRC and MoHURD).
http://www.gov.cn/zhengce/content/2017-03/30/content_5182124.htm
Case 35 China: Waste Classification Pilot cities

Beijing: stage 1 2000-2006 – little impact was made. Stage 2: 2006-2008 provided increased opportunities for rapid development of waste classification, due to the opportunities provided by the Olympic Games. However the concept of waste classification was still not deeply instilled in the minds of the general public. Stage 3, since 2009, issued “Beijing solid waste management regulations”. Pilot projects were launched in 15 districts, 59 party and government organisations and schools and a team of 147 classification instructors was established. In 2010 600 terminal processing facilities were combined to complete the classification after processing. Chaoyang District was selected for a waste collection system and demonstration pilot project.

Beijing results and modes:
- Simple classification: waste is divided into three categories: kitchen waste, recyclable waste, other waste. This enabled easy recognition by residents.
- Classification of transport facilities and terminal classification processing facilities complete;
- Set of five staff to supervise waste classification
- Improved management system – creation of specialised waste sorting office

Image 40: Waste transfer station, rural northeast Chaoyang District, Beijing

Source: Annabelle Cleeve (Mott MacDonald)

Shanghai Pilot:
In 2011 Shanghai commenced a municipal solid waste separation pilot in residential areas involving 580,000 residents. As a result waste per capita was reduced by the target 5% and awareness of waste management and waste reduction was increased and continues to improve.

Shanghai will continue to further expand the scope of the pilot, decreasing the waste disposal per capita per day. The pilot project is further planned to be expanded to include more residential areas, enterprises, institutions, markets and schools.
A policy document entitled “Shanghai municipal solid waste collection and disposal management approach” was issued and the awareness of waste management was greatly increased.

**Hangzhou:** Implemented a pilot waste classification project including a “real name system”, starting with 30 households and increasing to 1200 households. Waste sorting classification accuracy increased to more than 80%. In 2011 a total of 843 communities had implemented waste separation, which was about 55% of all cells in Hangzhou.

**Guangzhou:** In 2012 the city started to promote waste classification. “Interim provisions on the classification and management of urban domestic refuse in Guangzhou” was issued in April 2011.

**Xiamen:** Classification of household waste will be divided into three stages. 2011 consolidation of the original waste collection pilot areas, replacement of containers and classification instructions and strengthening of waste classification publicity. By the end of 2013 waste collection and recycling for urban residents reached 50% of district offices, aiming to reach 100% by 2015.

The “Xiamen City, municipal solid waste management approach” was issued.

**Nanjing:** By 2015 Nanjing had achieved a waste collection rate of 85%, and was striving to achieve a 50% reduction in waste sent to landfill. There are now more than 300 standardised waste recycling points. A number of institutions have set up food waste biochemical processors. The Nanjing municipal solid waste separation and collection action plan was issued.

**Shenzhen City:** Under the current pilot project nearly 80% of the public did not participate in waste classification, requiring recyclable waste to be picked out manually.

Further to the regulations and laws detailed above the following key policies were issued in 2017 regarding domestic waste:


### 5.1.2 China’s solid waste sector – towards an integrated approach

With rapid urbanization and urban residents accounting for more than half of the total population, China is experiencing rapid increases in solid waste generation and growing pressure for a more integrated approach to solid waste management in cities. The quantity of municipal solid waste collected and transported surged from about 31 million tons in 1980 to 157 million tons in 2009, and is projected to reach 585 million tons in 2030. As it is increasingly difficult to build more landfills and incineration facilities due to land scarcity and public concern, China has been exploring alternative approaches for solid waste management, including waste separation and recycling. However, the challenges to waste separation in Chinese cities include a lack of:

- adequate facilities for distinct transport, sorting and recycling;
• effective regulatory and policy instruments including financial incentive tools for waste minimization and recycling, and
• public awareness and participation in waste separation at source. 42

A three pronged approach is suggested to provide, firstly, bio-safety in waste management through the provision of adequate disposal facilities (incinerators and landfills); recycling, mainly targeting renewable resources and organic waste; and lastly reduction in the volume of waste quantities generated.

In China, along with urbanization, population growth and industrialization, the quantity of municipal solid waste (MSW) generation has been increasing rapidly. The total MSW amount increased from 31.3 million tonnes in 1980 to 212 million tonnes in 2006, and the waste generation rate increased from 0.50 kg/capita/day in 1980 to 0.98 kg/capita/year in 2006. Currently, waste composition in China is dominated by a high organic and moisture content, since the concentration of kitchen waste in urban solid waste makes up the highest proportion (at approximately 60%) of the waste stream. The total amount of MSW collected and transported was 148 million tonnes in 2006, of which 91.4% was landfilled, 6.4% was incinerated and 2.2% was composted. 43

China has the largest population (1.33 billion) on Earth and is experiencing rapid economic growth. This country has a GDP of $8.8 trillion in terms of Purchasing Power Parity (PPP), which is the third largest in the world after the EU and the US. However, its population is over four times that of the US so the actual per capita GDP is only $6.800 and corresponds to a fraction of the US GDP per capita.

China recently surpassed the US as the world’s biggest municipal solid waste generator. In 2004, the urban areas of China produced approximately 190,000 tonnes of municipal solid waste. By 2030, this amount will increase to at least 480,000,000 tonnes. No country has ever seen as large or as rapid an increase in solid waste. The implications both for China and for the world are enormous.

Waste collection and treatment figures for 2010 and 2015 are given in the table below.

<table>
<thead>
<tr>
<th>Table 18: 12th Five Year Plan National Waste Management Indicators</th>
<th>Main indicator</th>
<th>2010</th>
<th>2015</th>
<th>12th FYP planning objectives</th>
<th>Target Completion</th>
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<tbody>
<tr>
<td>Harmless treatment rate (%)</td>
<td>Cities and counties</td>
<td>63.5</td>
<td>90.2</td>
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<td>Completed</td>
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<tr>
<td></td>
<td>Cities</td>
<td>77.9</td>
<td>94.1</td>
<td>90</td>
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<td>County</td>
<td>27.4</td>
<td>79.04</td>
<td>70</td>
<td>Completed</td>
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<tr>
<td>Number of harmless treatment facilities</td>
<td>Cities and counties</td>
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<td>2077</td>
<td></td>
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<tr>
<td></td>
<td>Cities</td>
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</tr>
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<tr>
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<table>
<thead>
<tr>
<th>Other</th>
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<th>Cities</th>
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<tr>
<th>Harmless treatment capacity (10,000 tons/day)</th>
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<th>Cities</th>
<th>County</th>
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</table>

<table>
<thead>
<tr>
<th>Waste incineration plants</th>
<th>Cities and counties</th>
<th>Cities</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cities</td>
<td>8.9</td>
<td>23.5</td>
<td></td>
</tr>
<tr>
<td>County</td>
<td>8.4</td>
<td>21.9</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other</th>
<th>Cities and counties</th>
<th>Cities</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cities</td>
<td>1.5</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>County</td>
<td>1.3</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage incineration (%)</th>
<th>Incineration ratio</th>
<th>31</th>
<th>35</th>
<th>Almost complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern area incineration</td>
<td>48</td>
<td>48</td>
<td></td>
<td>completed</td>
</tr>
</tbody>
</table>

| County harmless waste processing capacity | 43 cities and 367 counties not equipped with harmless processing capacity | Every county to have the processing capacity | Almost complete |

| Investment (cumulative for the planning period) (100 million yuan) | 1294 | 2636 | -1342 |

Source: 13th Five Year Plan for the Construction of Non-Hazardous Disposal Facilities

The rate of waste treatment (bio-safe) for domestic waste generated in cities and county towns has risen dramatically from 53% and 6.6% respectively in 2006, to over 94% and 79% in 2015, with the rate of growth in waste treatment in cities exceeding the rise in urbanisation.

Guandong Province cleared and treated the highest volume of waste in 2015, with nearly half the waste going to landfill and about 25% being incinerated, as shown below. Jiangsu and Zhejiang had the highest rates for incineration.
According to the “13th Five Year Plan for the construction of non-hazardous disposal facilities” the processing facilities will increase as shown in the table below.

Table 19: Processing facilities in China during the 13th Five Year Plan

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Processing facilities 10,000 tons/day</td>
<td>Processing facilities (%)</td>
</tr>
<tr>
<td>Landfill</td>
<td>50.15</td>
<td>66</td>
</tr>
<tr>
<td>Incineration</td>
<td>23.52</td>
<td>31</td>
</tr>
<tr>
<td>Other</td>
<td>2.16</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: 13th Five Year Plan for the Construction of Non-hazardous Disposal Facilities

Overall, of the approximately 700 million people who live in cities, 400 million have access to collection and treatment of waste, and a further 100 million have access to waste collection, with about 500,000 t/d of waste collected. Approximately 200 million people living in cities, generating about 100,000 t/d, do not have access to waste collection or disposal. In rural areas about 530 million people, generating 220,000 t/d of waste do not have access to waste collection or disposal, whereas 170 million people, generating 180,000 t/d have access to collection and transportation.

Figures for different categories of waste collected are given in the figure below.
Since 2000 many Chinese cities have multiplied their investment in waste collection and treatment many times. However, critical issues remain and are identified below:

a) Waste Quantities: unsurpassed rate of growth in waste generation, dramatically changing composition, and minimal waste reduction efforts;

b) Information Availability: lack of reliable and consistent waste quantity and cost data makes planning for waste management strategies extremely difficult;

c) Decision-Making Process: lack of consistent policy and strategic planning toward technology selection, private sector involvement, cost recovery, inadequate public access and participation in the planning process;

d) Site selection: difficulties with site selection for incineration plants and provision of adequate land reservation for landfill sites;

e) Operations: facilities do not always meet design standards, particularly in pollution control, and facility operations are deficient, waste collection operations are often not rationalized;

f) Financing: inadequate cost recovery through user charges and tipping fees;

g) Institutional Arrangements: inadequate decentralization of collection and transfer services, inadequate municipal capacity for technology planning and private sector involvement, and inadequate clarity on mandates between government agencies, e.g. MOC and SEPA, and inadequate delineation between central and local government responsibilities;

h) Private sector involvement: The government’s goal of increased private sector participation in solid waste services is hindered by unclear and inconsistent ‘rules of engagement’, non-transparent purchase practices, non-sustainable subsidies, inadequate municipal cash flows, unclear and inconsistent cost accounting practices, and an unclear regulatory framework; and

i) Carbon financing: Increasing in importance in the Chinese MSW sector. China’s cities could generate as much as $1 Billion per year from sale of carbon emissions reductions, resulting from landfill gas recovery, composting, recycling, and anaerobic digestion.

The opportunity may however be time limited so quick interventions are needed.44

5.1.3 Kitchen Waste Pilot Projects

In 2010 NDRC, MOHURD and the Ministry of Agriculture established a pilot program for recycling and non-hazardous treatment of kitchen waste in urban areas.

Chengdu City Kitchen Waste Harmless Treatment Project.

The core technology used by this project obtained a Chinese Patent gold medal and National Invention Award.

Chengdu is in the first group of 33 food waste and recycling pilot cities. The project is designed to treat 200 tons of food waste per day from central Chengdu. Food waste is collected from provincial and municipal government buildings, institutions, hospitals, schools and large and medium sized hotels and restaurants. The treatment plant covers an area of 20,879m², and had a total investment of 78.6 million yuan.

In September 2013 the plant was formally put into operation. Humic acid treatment technology is used to produce 40,000 tons of biological humic acid fertilizer, through high temperature composite microbial and enzyme conversion during 8-10 hours of degradation, condensation, and polymerization.

Linyi City, Kitchen waste disposal and resource utilization project

The project was developed by the NDRC to treat 200 tons per day including pre-treatment sorting, oil separation, anaerobic digestion and biological desulfurization. The project was constructed by the Qingdao Heaven and Earth Environmental Co. Ltd under an EPC contract, and completed in December 2014.

The project uses a number advanced technologies including anaerobic digestion, and combination of kitchen waste with municipal sludge. There are precise temperature controls, desulfurization, gas control and SCADA control. The project was developed along the lines of an industrial park, including energy generation from waste incineration, kitchen waste disposal, animal waste treatment, biodiesel production and sewage treatment, using an energy cascade through the park, delivering faster investment recovery and economic benefits.

As of October 2015 the project had produced more than 50 million cubic metres of biogas, handling more than 7,000 tons of waste from Linyi City and more than 3,000 tons of sludge, providing significant environmental and social benefits.

Tai An City Kitchen Waste Disposal

The project was developed by NDRC and is located in Tai An Dity, Daiyue District Industrial Park covering 20 areas. The facility treats 200 t/d of kitchen waste and municipal sludge. The project uses pre-treatment, oil and water separation and anaerobic processes. It was developed under a PPP investment model.

The project was complete in November 2014. By October 2015 production of biogas reached 50 million cubic metres, handling more than 6,000 tons of food waste and more than 4000 tons of sludge, realizing significant environmental and social benefits.

Qingdao City, Shandong Province, Kitchen Waste Disposal

The project is being operated as a BOT project under a 25 year agreement. The first phase of the project has a capacity of 200 tons/day. The project utilized “pre-treatment-anaerobic digestion processes” and produces bio-oil, bio-gas and other byproducts. Approximately 1.65 million cubic metres of gas are produced, at the GB/T13610-2003 standard.
Chongqing Food waste disposal project

The Chongqing food waste disposal project uses food waste and municipal sludge. The total processing capacity of the project is 1000 tons/day. The first phase of the project was signed and started construction in June 2009, with an initial processing scale of 167 tons/day. Subsequent phases were started in 2001, of 333 tons/day and 2012 for 500 tons/day. In 2014 the project added capacity of 480 tons/day to treat food waste slurry, using a proprietary process to recover oil. It is expected to recover approximately 15 tons of oil of 99% purity per day. The main technology is ANAMET high temperature anaerobic digestion, which has a high production of biogas with high purity. The generated biogas is used for power generation or as a vehicle fuel after further purification and biological desulfurization. Approximately 80 tons per day of sewage sludge are added to the food waste to achieve optimal gas production.

Tangshan City Kitchen Waste Recycling and Harmless Treatment Project

The Tangshan kitchen waste recycling project uses a fully automated and enclosed process. The disposal capacity is 240t/d of kitchen waste, plus 40 t/d of waste oil. This project uses an Erwan AAe pretreatment system and AAe anaerobic digestion system, and an AAe sun drying system process. The organic matter in the kitchen waste is converted into biogas and clean energy. Oil recovered during the process is used as industrial grease. The biogas residue is sold as a biological organic fertilizer. The project was successfully launched in August 2015.

South China Sea Solid Waste Treatment and Environmental Protection Kitchen Waste Disposal Project

This project is located in the Nanhai solid waste treatment environmental protection industry park and includes incineration; sludge treatment; food waste disposal; fly ash treatment; and a landfill leachate system. The kitchen waste project uses anaerobic digestion to produce biogas and converts waste oil to biodiesel.

HohHot City Environmental Science and Technology Demonstration Garden Recycling Project: Oil Recovery

A package of comprehensive waste solutions were developed for this project to include municipal solid waste, municipal sludge, food waste, e-waste etc and achieve a circular economy. Food waste treatment processing for the first phase was 150 t/d, with a long term plan to increase to 300 t/d. Food waste disposal includes sterilization and fermentation, combined with processes to solve issues relating to food waste additives with high salinity, and animal fat, effectively improving the oil recovery rate.

Hangzhou Jinjiang Group, Kitchen Waste Disposal Project

The Hangzhou Jinjiang group developed a waste incineration project to process sludge, food waste, biomass and other solid waste. The project uses high temperatures and biological treatment through a combination of processes so that 100% of resources are utilized and there is no secondary pollution. The project was rated by the National Science and Technology Department as an advanced kitchen waste disposal process. At present the Jinjiang Group has 10 building projects, including Shenyang, Wuhan, Zhengzhou, Suzhou, Lianyungan and other regions.
Case 36 Zhuhai, Guangdong Province: Carbon and Resource Efficient Domestic Waste Management Framework

A waste management framework was developed for Zhuhai City in Guangdong Province as part of a British Embassy funded project in collaboration with Zhuhai City.

The study looked at existing waste management practices, major disposal and recovery installations and made recommendations for developing a framework to inform further development and practices. Existing facilities in Zhuhai include the Xikeng landfill site, which covers an area of 64 hectares and processes 1,000 tons of waste daily; waste incinerator with a daily processing capacity of 600 tons per day; Huaxin newly constructed cement kiln with a capacity of 1,000 tons per day; and a leachate treatment plant (80/tons per day mixed with centralized treatment).

Key issues included management and definition of responsibilities; provision of waste management in island communities; recycling, and kitchen waste processing.
Zhuhai: Existing Waste Management Facilities
Xikeng Landfill site and Incinerator Plant

Source: MottMacDonald. 2016
Analysis of Waste Management Process

Developing an Integrated Solid Waste Management Process

5.2 Key Performance Indicators

Key Performance Indicators (KPI) are instruments to measure sector performance. KPIs evaluate the success of an organization or of a particular activity in which it engages. Choosing the right KPIs relies upon a good understanding of what is important to an organization. KPI’s are developed as a part of a strategic management tool and need to be easy to measure. A key performance indicator (KPI) is a business metric used to evaluate factors that are crucial to the success of an organization, and what are presented here are political ambitions that are not simple to measure.

5.2.1 Discussion of KPI outlined by the World Bank

Six KPIs which should be met by the Sino-Singapore Tianjin Eco-City by 2020 (or earlier) have been highlighted also in the 2009 World Bank study45 of the SSTEC experience:

- KPI 5: Carbon emissions per unit GDP: ≤150 tons C per one million US$ GDP;
- KPI 7: proportion of green buildings: 100 %;

• KPI 11: per capita domestic waste generation: ≤0.8 kg per day (by 2013);
• KPI 12: Proportion of green trips: > 90%.
• KPI 13: Overall solid waste recycling rate: ≥60% (by 2013);
• KPI 19: Renewable energy usage: ≥20%;
• KPI 20: Water supply from non-conventional resources: ≥50%.

Re. KPI 5: Carbon emissions per unit GDP: ≤150 tons C per one million US$ GDP

This KPI is related to solid waste management (SWM), but not limited to SWM. Less fuel per collected amount of waste will contribute positively to the index. Production of heat and electricity using waste incineration may displace the consumption of oil, gas, and coal. Recycling may also have a positive impact since it is minimising the need of new raw materials. However, it is not an easy KPI to measure and a number of sub-KPI have to be elaborated in order to be able to measure.

Re. KPI 11: per capita domestic waste generation: ≤0.8 kg per day

This KPI is problematic. It is not possible to measure waste generation. It is only possible to measure collected amount of waste, which is performed by the formal sector. The activities of the informal sector – Scavengers – cannot be measured.

The correct KPI should be amount of waste and recyclable materials collected.

a) Is the ambition to have less than 0.8 kg per person per day?
b) What will happen if there is more?
c) When studying the household waste figures in Europe it is clear that:
   • Higher GDP per capita gives a higher waste amounts;
   • Economic growth generates more waste; and
   • Improved waste collection system gives higher waste amounts.

Several studies have tried to disconnect economic wealth and waste amounts but it has, so far, failed. It is better to measure: collected waste amount per capita, waste landfilled per capita, waste recycled per capita, and waste incinerated per capita, in order to make the KPI operational. (This, could, for instance be the number of citizens being serviced by waste collection. But it should rather not be the number of citizens paying for the service.

Re. KPI 13: Overall solid waste recycling rate: ≥60%. Depending on what is defined as recycling the ambition of 60% is high. It is not clear whether composting or bio-gasification of organic waste is considered as recycling? This KPI has to be divided into several sub-KPI’s: for instance, one for glass, one for newspaper, one for office paper, one for plastic in order to be measurable.

By elaborating sub-KPI’s, changes in consumer habits will also be taken into consideration. In Europe in 1990s it was easy to get a high recycling percentage just by collecting glass bottles and newspapers. Today we have replaced all the glass bottles are with PET and the newspapers are read on the internet. The recycling percent would have dropped if not other materials and processes where included as recycling.

The following KPIs represent an overview of the most common primary indicators for the solid waste management sector.
Table 20: Proposed Solid Waste Management KPIs

<table>
<thead>
<tr>
<th>Indicator Category</th>
<th>Indicators: indicative values</th>
<th>Current achievements / Time frame for accomplishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Domestic waste generation [1]</td>
<td>≤ 0.8 kg / day / person [1]</td>
<td>By 2013 [1]</td>
</tr>
<tr>
<td>2 Garbage collation ratio [2]</td>
<td>- Household waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100% [2]</td>
<td></td>
</tr>
<tr>
<td>3 Treatment to render hazardous and domestic solid waste non-toxic [1]</td>
<td>100% [1]</td>
<td>Immediate [1]</td>
</tr>
<tr>
<td>4 Rate of reuse of domestic waste [3]</td>
<td>Non-hazardous waste: 100%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recycling rate: ≥50% [3]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>reuse rate ≥50% [3] [5]</td>
<td></td>
</tr>
<tr>
<td>6 Waste conversion to energy [4]</td>
<td>__ % of total waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>__ KW of energy produced</td>
<td></td>
</tr>
</tbody>
</table>

Sources:

5.3 Waste minimization as critical priority

China needs to achieve more waste reduction, recycling and reuse, and recovery (through composting and digestion), thus minimizing the amount of waste disposed. Particular emphasis is required for the organic waste (household waste, agricultural waste, etc.). Organic waste will be 50% of the total waste stream in the foreseeable future, and for paper which is the fastest-growing component of the waste stream. The recycling industry needs to be improved. Higher professionalization needs to be achieved through improved product standards, market development strategies, and better operating standards.

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46 These key performance indicators were prepared and compiled by the EC-Link Project. See: EC-Link. 2016. Sino-EU Key Performance Indicators for Eco-Cities. Beijing (unpublished draft)
**5.4 Waste Treatment Technologies**

Since 2000 the People's Republic of China has invested huge amounts in waste treatment facilities, as part of a plan to introduce more environmentally friendly treatment methods in the country.
This is not a complete review of the waste treatment technologies which are in use in China, but only a short presentation of some of the challenges that are involved when introducing new technologies.

5.4.1 Incineration

Since the beginning of the 21st century, China has increased its WTE capacity from 2 to 14 million tons of municipal solid wastes. This makes China the fourth largest user of waste-to-energy (WTE), after the EU, Japan, and the US. There were 66 WTE plants in China by 2007 this was projected to increase to one hundred by 2012 and 225 by 2017. Two thirds of these plants employ either imported or domestic versions of combustion on a moving grate; and the other third various forms of a home-developed technology, the circulating fluid bed reactor47.

China’s waste incineration practice focuses mainly on power generation. Cogeneration is often difficult due to the remote location of incinerators and the lack of local residents who would benefit from the provision of heat. Energy efficiency therefore tends to be relatively low.

Figure 32: Incinerators in China

The Figure above shows the average amount of waste incinerated per day, and the number of incineration facilities. Current policy is for large and medium sized cities to develop incineration technology and encourage joint construction and sharing of treatment facilities. The rate of incineration is targeted to rise to 40% by 2020, with urban waste incineration in cities accounting for over 50% of the national total by the end of 2020.

Although China is well experienced in incineration project implementation, the main challenge is to operate and maintain the facilities and at all time keep the operation up to the standards. This can be achieved by focussing on lowering emissions, and keeping the processes optimised in order to utilise both the energy generated and the bottom-ash slag resulting from the process. Governmental regulators are understaffed and in urgent need of developing greater capabilities.

The burning question of household waste in China

"Concerns about harmful emissions have resulted in construction being halted at a number of incineration plants around the country. Now, experts are claiming the country will drown under a deluge of garbage if the situation doesn't change soon. …

China is facing a mountain of unprocessed household waste after public protests disrupted the construction of incineration facilities, and as landfill sites reach capacity, according to experts. In 2014, 179 million metric tons of household waste was collected nationwide, according to data provided by the National Bureau of Statistics. Meanwhile, statements released by the central government say the volume of waste is expected to grow at between 7 and 10 percent every year in large cities, such as Beijing.

Public protests. On April 21, the government of Haiyan county in the eastern province of Zhejiang, announced that it was cancelling construction of a new waste incineration project in response to two days of public protests. However, it also released a statement calling for public support, saying the new plant was urgently needed to prevent a build-up of waste that could result in widespread pollution. Residents of the county, which is administered by Hangzhou city, voiced concerns about the potential health risks from emissions via online forums and through direct representations to the government. Some protesters even blocked roads and attacked and injured a number of police officers and government officials. Most of Haiyan's household waste used to be processed at incineration plants in other counties, but late last year the plants were so overloaded that the operators refused to burn waste from outside their own area, leaving Haiyan's landfill sites close to full. "Without new facilities to deal with the waste, the county will soon see severe pollution from a flood of waste," the government's statement said.

Nationwide issue. The problem isn't just confined to Haiyan, though. Several areas of the country—including Beijing and the provinces of Guangdong and Hainan—have seen protests against new incineration plants, despite the ever-rising volume of waste as a result of urban expansion.
Methods for processing of household waste: At present, the three main methods of disposing of household waste are landfill sites, incineration and composting.

Limitation of landfills. However, experts say it's not feasible to bury such enormous amounts of waste in landfills—the most widely used method—partly because most of them are nearly full and partly because of a lack of land to build more. Incineration has become the most popular treatment because the plants require less land than waste-burial sites, the materials are easy to deal with once burned and the incineration process generates heat and power. Those advantages saw the number of incineration plants rise to 188 in 2014 from 104 in 2010, according to government data. Meanwhile, a survey conducted by the Power Generation Branch of the China Association of Circular Economy, an industry association in Beijing, estimated that the number of facilities has doubled in the past six years, reaching 225 by May.

'Not in my backyard'. In the 13th Five-Year Plan (2016-20), the central government has encouraged the construction of waste incineration plants to protect the environment. However, public opinion is divided. Some people have objected to the construction of new plants, even though they acknowledge the need for them—the "not in my backyard" syndrome—while others seem unfazed.

Guo Gaoyun, secretary-general of the Power Generation Branch, who has conducted research into incinerator operations for many years, said the key factors are the implementation of emissions standards, strict supervision and smooth, timely communications.

"It's easy to set stringent standards, but it's never easy to implement them strictly," he said, adding that the public perception is that many plants fail to adhere to the standards and governments don't supervise them adequately.

An incineration plant run by China Everbright International has been operating in Jianhu, a village in Changzhou, Jiangsu, since 2008. It deals with waste from five large residential communities and villages scattered across the neighborhood, with a population of more than 100,000.

During the planning stage, a number of residents voiced concerns about possible pollution from the incinerator, said Liao Guoyong, the plant's deputy manager, who added that the city government invited local residents to visit the plant and get a clearer picture of its operations.
"Our plant is open to the public, giving people access to emissions data. We also hold quarterly meetings to answer any questions people may have," said Liao, during a welcoming address for a group of researchers from the All-China Environment Federation. According to a survey conducted by the plant, 56.5 percent of respondents (mostly local residents) said their confidence in the facility had risen and they now support its work. ...Public concerns about health risks and pollution caused by incineration have focused on dioxins, the malodorous gases and dust discharged during burning and wastewater from leachates (liquid that has percolated through a solid object and contains traces of the original material), Wu said. Dioxins are highly toxic, persistent environmental pollutants that can cause cancers, result in reproductive and developmental problems, and also damage the immune system. To control pollution, the Ministry of Housing and Urban-Rural Development released tough guidelines—the Standard for Pollution Control on Municipal Solid Waste Incineration—on July 1, 2014. The standard adheres to the strictest European standards, especially those related to the emission of dioxins. In addition, dioxin emissions from incinerators cannot be compared with the large amounts of dioxins emitted by chemical
plants, which cause far more air pollution," said Yan Weifu, an engineer with Everbright's technology department.

There were no indications of noxious gases or dust when China Daily visited plants in four cities in East China: Ningbo in Zhejiang—which is home to the largest number of incineration facilities in the country—plus Changzhou, Nanjing and Suqian, all in Jiangsu. A better way to win public support for incineration projects would be for governments at all levels to strengthen supervision and communicate fully with the public…

**Construction resumes.** For the public to accept existing incineration plants, local governments will have to adopt the methods used in Suqian and strengthen supervision to ensure that emissions meet national standards, experts said. Faced with the problem of a rapidly rising amount of household waste, many cities will have to improve communications with the public so that aborted incineration projects can be restarted...


5.4.2 Sludge Treatment

The treatment and disposal of sewage sludge in China is a major issue being addressed by government. In 2012 China generated more than 68.5 billion tons of wastewater, and was predicted to produce more than 78.4 billion tons in 2015. The amount of sewage sludge produced from this wastewater is estimated to be 30 million tons for 2012, and 34 million tons in 2015.

Historically sludge has received little if any treatment, with the majority being disposed of in landfills, or applied without treatment as a soil conditioner. However, this latter practice is a major source of pollution to the environment, as the sludge may have a high heavy metal and pathogen content.

Anaerobic digestion/aerobic composting and land application have been widely recommended in China as a preferred method of disposal. However, sludge in China has a low organic matter content (40-50% compared to 70% internationally), resulting from mixing of stormwater with municipal wastewater, resulting in ineffective treatment. In 2013, although 2600 sludge treatment plants had been built, only 60 plants adopted anaerobic digestion processes, and only 10-30 of these plants were actually operating (Leiyu Feng, Jingyang Luo, and Yinguang Chen, 2015 [https://wenku.baidu.com/view/f9c868d76edb6f1afe001fba.html](https://wenku.baidu.com/view/f9c868d76edb6f1afe001fba.html)).
Image 42: Sludge Treatment in China

Source: https://www.newsecuritybeat.org/2016/05/innovative-sludge-to-energy-plant-breakthrough-china/

Case 37 China: Sludge used for forestry compost

The Haitao sludge composting facility, located in Guangdong in south China, is an example of sludge treatment and reuse as a compost for forestry and municipal planting. The municipal sludge is delivered from other wastewater facilities by truck, and also directly from the adjoining wastewater treatment plant onsite. Processes include conditioning, mechanical dewatering, and composting in a specially designed facility. The treated compost is stored and bagged prior to delivery off site. The facility was permitted to increase its capacity to treat sludge from 200 to 900 tons per day in 2015 Source: (http://en.chongto.com/?page_id=3888).

Image 43: Haitao Sludge Composting, Guangzhou, China
Case 38 China: Innovative Sludge-to-Energy Treatment, Xiangyang

Xiangyang is a prefecture level city located in Hubei Province in central China. Attempts were made to treat municipal sludge produced by the city and turn it into compost. However, this project failed due to the low organic content of the sludge, and resulted in the dumping of 150,000 tons of sludge on an island in the Han River, which flows through the city.

In 2011 TOVEN, a Wuhan headquartered firm specializing in waste to energy started a project to solve the problem of sludge disposal. The low organic matter content of locally produced sludge resulted in low levels of methane generation. However, after visits to sludge treatment plants in Europe the developers designed their own system to incorporate kitchen waste collected from restaurants to increase the organic matter content of the waste.

Image 44: Xiangyang sludge treatment facility

Anaerobic digestion tanks treat 450 tons of sludge and kitchen waste and produce 12,000 m$^3$ of methane per day. Half the methane generated is used onsite to power operations, and the rest is processed into compressed natural gas and sold as a cleaner burning transportation fuel. The residues from the digestion process are sterilized to be used in fertilizer or converted into biochar, an alternative soil used for potted trees.

It is estimated that if all the sludge and kitchen waste produced in Chinese cities was treated using the waste to energy approach, 6.6 billion m$^3$ of methane could be produced, providing enough energy to power wastewater treatment plus the meeting the energy demands of 2.8
In recent years interest in the use of advanced thermal plasma technology (TPT) as a method for processing waste in China has increased enormously. The pollutant emissions from this process can be reduced to almost zero by gasifying the combustible parts into syngas for heat and power generation, and vitrification of the non-combustible parts into dense, inert, leach-resistant vitrified slag.

The Chinese Academy of Sciences has been an important player in pioneering research in this area in China over the last 30 years. Several successful laboratory scale projects have been undertaken by CAS, Zhejiang University, Guangzhou University and others as shown in the table below.

Table 21: Main organisations engaged in solid wastes plasma research in China

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Type of plasma</th>
<th>Feedback</th>
<th>Major contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>IM, CAS</td>
<td>Chemical waste</td>
<td>DC arc (30 kW)</td>
<td>Plasma-arc can be used to destroy polychlorinated biphenyls-containing chemical solids; destruction efficiency was more than 99.999%; polychlorinated biphenyls in solid residues 12.3 mg/kg was well below the Chinese emission limits (Li et al., 2009)</td>
</tr>
<tr>
<td>IM, CAS</td>
<td>MSW &amp; coal fuel FA</td>
<td>DC arc (30 kW)</td>
<td>A new crucible-type plasma furnace was built to test the volume-reduction of FA by TPT; reduction and weight reduction ratios were 80.2% and 36%, respectively; water-cooled or composite-cooled methods took advantages (Zhou et al., 2010)</td>
</tr>
<tr>
<td>IPP, CAS</td>
<td>MSW &amp; FA</td>
<td>DC arc (100 kW)</td>
<td>Glassy slag was produced by a DC double anode plasma torch; heavy metals were mostly immobilized and T-TOC of PCDD/Fs in FA was destroyed more than 99.9% (Pan et al., 2008; 2009; Wang et al., 2009, 2010)</td>
</tr>
<tr>
<td>IPP</td>
<td>LRW</td>
<td>DC arc</td>
<td></td>
</tr>
<tr>
<td>Zhejiang University</td>
<td>MSW FA</td>
<td>DC double anode</td>
<td></td>
</tr>
<tr>
<td>Zhejiang University</td>
<td>Simulated medical waste</td>
<td>DC double anode</td>
<td></td>
</tr>
<tr>
<td>Guangzhou IEC, CAS</td>
<td>Polypropylene</td>
<td>DC arc</td>
<td>Plasma pyrolysis of polypropylene was studied; water steam injection improve the product gas productivity 2160 m³/kg hydrogen and carbon monoxide up to 40% in gasous product conversion 90% (Tang et al., 2003)</td>
</tr>
<tr>
<td>Guangzhou IEC, CAS</td>
<td>Waste tire</td>
<td>DC arc</td>
<td>Sulfur distributed in char was more than 90% of total sulfur and the main sulfur form in inorganic sulfate; Transformation and the distribution of sulfur in pyrolysis process was affected by input power; feed rate, addition of steam, and dolomite absorbent to the process and Huang, 2004)</td>
</tr>
<tr>
<td>Guangzhou IEC, CAS</td>
<td>Waste rubber</td>
<td>DC arc</td>
<td>Plasma pyrolysis of waste rubber was studied; the heat value of syngas was 5.9 MJ/Nm³; carbon black may be used as semireinforcing carbon black in mortar rubber applications, upgrading, as carbon black filler for tire (Huang et al., 2003)</td>
</tr>
<tr>
<td>Guangzhou University</td>
<td>Polypropylene</td>
<td>DC arc</td>
<td>TPT showed great decomposition performance of polypropylene compared to the traditional pyrolysis (Yang et al., 2005)</td>
</tr>
<tr>
<td>Guangzhou University</td>
<td>Waste tire powder</td>
<td>Radio frequency plasma</td>
<td>Pyrolysis of waste tire powder in a radio frequency plasma reactor under reduced pressure studied; solid conversion ranged from 40% to 76.4%; major gaseous products were hydrogen, monoxide, methane, and carbon dioxide (Huang and Tang, 2009)</td>
</tr>
<tr>
<td>National Taipei University of Technology</td>
<td>MSW &amp; FA</td>
<td>DC transferred arc</td>
<td>Porous materials were produced using water-quinched vitrified slag; bulk density was 0.36 g/cm³; porosity 50–65%; thermal conductivity 0.194 W/mK (Yang et al., 2014)</td>
</tr>
<tr>
<td>National Taipei University of Technology</td>
<td>LRW</td>
<td>DC transferred arc</td>
<td>A crucible-type plasma melter and a 10 kHz plasma furnace system were established to simulated radioactive waste (Tsai et al., 1998)</td>
</tr>
<tr>
<td>National Taipei University of Technology</td>
<td>Inorganic ash</td>
<td>Non-transferred arc (100 kW)</td>
<td>Several one-step heat treatment processes were carried out to obtain various microstructural materials; major phase to form these materials was a solid solution of gehlenite and alite belonging to the melilite group (Cheng et al., 2002)</td>
</tr>
<tr>
<td>RITS</td>
<td>Medical waste</td>
<td>DC transferred arc (100 kW)</td>
<td>Compared with INER systems (Chen et al., 1998; Tsai et al., 1998) the improved RITS system achieved more success in the way of energy conservation, densitisation, reducing brick thickness and improving the start-stop speed (Wang et al., 2006)</td>
</tr>
</tbody>
</table>

Source: J. Li et al/Waste Management 58 (2016) 260-269

In 2006 the first industrial scale plasma system for hazardous chemical waste was established in Zigong, Sichuan Province, with a capacity of 3 tons per day and producing 150 kW of electricity. Other projects are shown in the table below.
Table 22: Typical plasma demonstration plants for solid waste management in China

<table>
<thead>
<tr>
<th>Location</th>
<th>Feedstock</th>
<th>Capacity</th>
<th>Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zigong, Sichuan Province</td>
<td>Hazardous chemical waste</td>
<td>3 t/d</td>
<td>2006</td>
</tr>
<tr>
<td>Liquan, Shanxi Province</td>
<td>Persistent organic waste, medical waste</td>
<td>5 t/d</td>
<td>2008</td>
</tr>
<tr>
<td>Taiwan Province</td>
<td>LLRW</td>
<td>250 kg/h</td>
<td>2006</td>
</tr>
<tr>
<td>Shanghai Municipality</td>
<td>Medical waste, FA</td>
<td>30 t/d</td>
<td>2014</td>
</tr>
<tr>
<td>Shanghai Municipality</td>
<td>Medical waste</td>
<td>60 kg/h</td>
<td>2013</td>
</tr>
<tr>
<td>Taizhou, Zhejiang Province</td>
<td>HW, ISW</td>
<td>3-5 t/d</td>
<td>2005</td>
</tr>
<tr>
<td>Kaoshiung, Taiwan Province</td>
<td>HW, ISW</td>
<td>20 kg/h</td>
<td>2007</td>
</tr>
<tr>
<td>Taichung, Taiwan Province</td>
<td>HW, ISW</td>
<td>60 kg/h</td>
<td>2013</td>
</tr>
<tr>
<td>Dongguan, Guangdong Province</td>
<td>MSWI FA</td>
<td>30 t/d</td>
<td>2018</td>
</tr>
<tr>
<td>Bijie, Guizhou Province</td>
<td>MSW</td>
<td>9000 t/yr</td>
<td>Unde</td>
</tr>
</tbody>
</table>

Source: J. Li et al/Waste Management 58 (2016) 260-269

Wuhan, Hubei, China

Chinese company, Wuhan Kaidi commissioned an Alter NRG plasma gasification waste to biofuel system in January 2013 at their demonstration facility in Wuhan, Hubei, China. ([https://waste-management-world.com/a/plasma-gasification-turning-waste-to-fuel-in-china](https://waste-management-world.com/a/plasma-gasification-turning-waste-to-fuel-in-china)). The facility converts 100 tons of biomass, per day, into 63,000 Nm3/d or 8.75 MWth syngas. The syngas is then converted into diesel fuel and other transportation fuels at the Kaidi facility.

Image 45: Kaidi plasma gasification waste to biofuel plant, Wuhan, China


Shanghai, China

In February 2014 Alter NRG commissioned Westinghouse Plasma torches used at a new incinerator ash vitrification facility constructed by GTS Energy in Shanghai. As well as incinerator ash, the plasma gasifier can also receive medical and hazardous waste. The plant turns the potentially hazardous ash into a benign glass-like slag that can be used in other industries, such as the construction industry, as well as creating syngas and steam. ([Source: https://waste-management-world.com/a/plasma-gasification-plant-commissioned-for-treating-incinerator-ash-in-china](https://waste-management-world.com/a/plasma-gasification-plant-commissioned-for-treating-incinerator-ash-in-china))

The Shanghai facility has a processing capacity of 30 tons per day and consists of a feeding system; a plasma gasifier, a second combuster, a waste boiler, an electrostatic precipitator, a dry reaction tower, a bag filter and a wet scrubber.
The facility is co-located with Shanghai Environmental (a subsidiary of state-owned enterprise Shanghai Chengtou Holding Co. Ltd.). Shanghai Environmental operates other businesses including transportation of domestic waste to landfills and incinerators, primarily in Jiangsu, Zhejiang, Sichuan and Shandong provinces in China.

**Image 46: Shanghai gasification facility**

![Image of Shanghai gasification facility](http://www.alternrg.com/waste_to_energy/projects/)


**Bijie, China**

In 2014 plasma gasification technology company, Alter NRG, was set to develop a 15 MW municipal solid waste to energy facility in the city of Bijie, China. The 600 tonne per day facility has been given approval and designated as a key project by the Provincial Government of Guizhou, and is expected to deliver environmental benefits. This is the first project in China to be designed on the basis of the characteristics of Chinese MSW, as shown in the figure below.
The average physical combustible and non-combustible fractions of the MSW are 56.07% and 43.93% respectively. The combustible MSW primarily consists of kitchen waste and plastics, with smaller amounts of paper, textiles, wood and fruit. The low heating value of these wastes is much lower than in other developed countries (Zhou et al., 2014), and some auxiliary fuels are needed to enhance thermal conversion efficiency.

Nearly 90,000 tons of glassy slag will be produced each year. The project intends to convert the vitrified slag from the gasifier into block foam insulation building materials (10,000 t/yr), providing further uses for process outputs.

The system at Bijie is an MSW plasma-gasification recycling (MPR) plant and offers several advantages over other systems already in use, including:

- Improved heat efficiency provided by the non-transferred arc thermal plasma torches
- Longer syngas residence time and more stable flow rate leading to decrease in particulate matter carry-over and tar formation
- Cleaning of the syngas through a three-stage cyclone collector, three stage desulfurization and dichlorination, mercury removal, and electrostatic precipitator, preventing the formation of secondary pollution, especially dioxins.

Barriers to Plasma Gasification in China include the need to design systems limited to specific waste streams. Enormous disparity in the characteristics of the feedstock cause difficulties for regulating the treatment processes and pre-treatment is a key step to ensure more efficient gasification. The high cost of investment is also a factor, and financial support from local government is important as well as guaranteed revenue from power output and other materials produced. However thermal plasma technology has advantages over other thermal treatments in safeguarding the environment from toxic wastes, producing harmless and predictable wastes.
5.4.4 Other Treatment Facilities

Some further examples of investment in other facilities is provided below.

Case 39 China: Zhuhai, Guangdong Province, Huaxin Environmental Protection Ecological Plant – Production of RDF

The RDF plant is under construction. The main product – RDF (Refuse Derived Fuel) – will be transported to a cement kiln approximately 150 km away, where the product will be used in cement production.

Zhuhai Huaxin Domestic Waste Ecological Processing Plant is located in Xikengwei Landfill. The investment is approximately 150 million Yuan (22.25 million Euro) and has a capacity of 1000 ton waste /day (incoming). The plant is in test phase and it is expected that the plant will be in full operation by the end of 2015.

In coming waste is crushed and dried, and sorted, before the RDF part is transported to the Huaxin Cement Co., Ltd. Leachate is sent for treatment at the leachate treatment plant.


Photo: Mikael Boldt; Mott MacDonald
Image 47: Zhuhai Huaxin RDF Plant

Source: Mott MacDonald
Case 40 China Jiangxi Province: Manure is Being Turned into Money

By 2020, the livestock industry in the PRC will have produced nearly 7 billion tonnes of waste. In the photo, pigs being fed in the Qi Bu farm in Jiangxi Province.

Staff salaries have risen at the Jiangxi Wannian Xinxing Agro-pastoral Co. Ltd., pictured here, which is preparing to list on the Shanghai Stock Exchange. Manure from the pigs bred in the Qi Bu farm in Jiangxi Province, PRC, is turned into biogas, which is then stored in containers (see photos).

By converting waste into clean energy, livestock farms in Jiangxi Province, People’s Republic of China, help manage an environmental threat, contribute to the national energy grid, and boost their income.

Jiangxi Province, People’s Republic of China. In the People’s Republic of China, many small, family farms have grown into large scale commercial livestock operations to provide meat, eggs, and milk to the increasingly prosperous residents of the country’s big cities.

This is creating a life-threatening mountain of waste in the Chinese countryside.

By 2020, the livestock industry in the country will have produced nearly 7 billion tons of waste, according to the Ministry of Environmental Protection. Less than half of commercial livestock farms have waste treatment facilities.

One solution: turn some of that waste into clean energy and organic fertilizer.

The People’s Republic of China and the Asian Development Bank are working together to help about 118 livestock farms improve their waste treatment facilities and convert an estimated 7 million tons of waste into biogas that is estimated to produce 92 million kilowatt hours of electricity.

Turning manure into cash. This solution is being put to the test at the Qi Bu farm in Jiangxi Province, in the southeastern part of the country. The manure produced by the 20,000 pigs bred in the farm is collected and fed into a digester where it is slowly turned into biogas. This is then used in a power plant onsite to generate electricity, which is sold to the grid.

Selling the additional energy is a new source of income for the farm, says 45-year-old Wang Zhanjun, General Manager of the Jiangxi Wannian Xinxing Agriculture & Animal Husbandry Co., Ltd., a company that runs the Qi Bu farm and plant along with seven more similar facilities, “We can only keep our local river clean if we manage pig farming well.” Chen Zhangxin. Around 200,000 tons a year of organic fertilizer are produced in the Qi Bu plant and then sold to local farmers. Adding the production of electricity and fertilizer to pig farming has significantly improved the company’s finances. Jiangxi Wannian Xinxing Agro-
pastoral Co. Ltd., is now preparing to list on the Shanghai Stock Exchange. Employees have also benefitted from the plant’s upgrade. Their salaries went from an average of RMB 20,000 (about $3,000) per year to over RMB 30,000 per year.

The introduction of a biogas electricity generation system along with the production of organic fertilizer has reduced the farm’s environmental impact. Waste that is left over after the process is cleaned in a pond system before being safely discharged in the environment. This includes introducing algae to help purify the water to a level fit for agriculture and animal consumption.

An example in green farming. The project is providing the companies running the farms with access to loans in a region where it is difficult to obtain capital to modernize agricultural practices. The success in Wannian County is being noticed by its neighbours.

"With our project well under way, we are now setting an example for nearby counties," says Jiang Wuping, Deputy Director of the Jiangxi Provincial Rural Social Affairs Development Bureau. "Other authorities are closely following what the companies involved in this project are doing, learning from our experience."

More income, less pesticide. The project is helping dozens of big livestock operators but it is also assisting the small farms. Peng Xueying, 52, from Shewan, a village in Jiangxi Province, grows rice in a small piece of farmland that provides her family their only source of income.

In 2014, she started using a locally-produced organic fertilizer and her harvest yields have been growing steadily, raising her income with them.

"We used to harvest about 500 kg of rice per crop. Now, it is more than 650 kg and we also use less pesticide," she says. 48

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5.4.5 Landfills

No matter how sophisticated the available technology to recycle products and to operate waste treatment facilities, there is always a waste residue that requires disposal in sanitary landfills.

There are 3 main problems with the landfills in China today:

a) Lack of understanding on how to operate a Sanitary Landfill. Improvements of the overall operating conditions are needed. For instance Landfills need be organised in cells or stages and filled and compacted properly in order to minimize the generation of leachate.

b) More attention is needed to properly closing, sealing, and aftercare of old landfill sites. The old landfills may be converted to new land uses, like recreational areas, green spaces, parks, or sports facilities - golf courses or trekking fields.

c) There will always be a need for landfills. Chinese cities will most likely need and additional 1,400 landfills over the next 25 years. It is important that these landfills are constructed well and take into consideration that the remaining waste deposited on a landfill will become more hazardous when more recycling and energy recover is introduced.

→Tool SWM 3

Due to the higher organic content of waste disposed of in landfills in China, gas generation is typically higher than in western countries. However, in the future, with increased use of incinerators for organic waste disposal, the proportions of inorganic waste disposed of in landfills will increase, reducing the quantities of gas generated.

Case 41 China, Wuhan, Hubei Province: Ecological Restoration Project of Jinkou Landfill

Projected Outcomes

- The project re-utilises previously unusable land (52 hectares total), taking the city’s landscape into account, and satisfying the needs of urban development. The expo garden was constructed following the landfill restoration, increasing the surrounding price of land around and promoting economic development. The project drastically reduces safety and sanitary issues for 100,000 residents nearby, providing much needed leisure sites and improves quality of life for these residents. The project turns previously unusable land into an ecological park,
increasing land values and promoting economic development in surrounding areas. The built expo garden is to become a key attraction in Wuhan, and the unique garden is certain attract many tourists.

- The field facilities will showcase the concept of ecological restoration and land re-utilisation to tourists, and the project will be a model for land re-utilisation of waste landfill.

Actions
As described in the General Urban Planning of Wuhan (2010-2020), ecological restoration is carried out to improve environmental quality and promote urban sustainable development. Reinforcing and controlling sources of pollution, fully utilising existing land resources, increasing green space in the city, are all activities aiming to transform Wuhan into a national ecological garden city. The project is one of the key pillars for Wuhan to become the national garden city. The project solicited public opinions and suggestions on the Chinese Government Public Information Online platform.

The main climate change objective of the landfill restoration project is mitigating emissions, particularly by planting local trees and plants and creating an area for carbon sequestration to offset the GHG emissions produced from the waste landfill. The conservative estimate is of 66t CO₂ absorbed. The project restores 52 hectares of land, improves the living environment for 100,000 residents, reduces water and air pollution, eliminates risks of methane release and potential explosions, lowers surrounding temperatures through green cover, shortens degradation time of waste, and contributes to the local ecosystem by planting local species on the restored land.

Challenges
Jinkou landfill was opened in 1989 and closed in June 2005, after 17 years of operation. Due to issues with the design and technology at the time, safety standards were low and, after the landfill was closed. Environmental issues began to surface, including landfill gas pollution, liquid infiltration and damages to the landfill site landscape. The context made the restoration project even more challenging than normal. The waste landfill has been restored and made into a garden expo, through not only reforestation, but also thorough ecological restoration from the foundations. For environmental and safety reasons, the waste gas from waste infiltration liquid and fermentation is to be gathered and processed, and the waste hill must be reinforced to prevent geological accidents. In comparison, implementation of the reforestation reconstruction plan is simple.

Award Winning Best Practice of Closure of Sanitary Landfill

CITY: WUHAN

Transformation from Landfill to Garden

The Chinese City of Wuhan has restored more than 50 hectares of land from a closed landfill in less than a year, improving the living environment for residents and solving pollution challenges.

The closed Shinkou landfill in Wuhan caused pollution, which natural degradation would have taken decades to remove, affecting not only the environment but also residents in nearby areas. To restore this wasteland more efficiently, the city began an aerobic ecological restoration project. Not only does it alleviate risks of long-term safety issues from pollutants and eliminate the threat of methane explosions, this project also restores more than 50 hectares of land for city landscaping. Proving that even the most polluted areas can become ecological havens, this former landfill site hosted the China International Garden Expo in 2015.

The restoration process, which began in 2014, introduced proper planting techniques, diverse plants, and measures to improve the soil aiming to promote continuity of the fundamental ecological system. The project fits in with Wuhan’s General Urban Planning scheme to improve the quality of the city’s ecological environment and enhance sustainable urban development, and eventually become a National Garden City, which is a role the Ministry of Housing and Urban-Rural Development grants to Chinese cities focusing on green, sustainable development.

Source: C40.2015. Cities 100. 100 solutions for climate action in cities.
http://sustainia.me/resources/publications/Cities100_2015.pdf
Case 42 China, Tianjin: Qiaooyuan Wetland Park

<table>
<thead>
<tr>
<th>Former Garbage Dump in Tianjin City: Qiaooyuan Wetland Park with paved pedestrian paths and rainwater ponds for irrigation and remediation of saline-alkali soil</th>
</tr>
</thead>
</table>

On the site of a former garbage dump in Tianjin City, China, Turenscape’s Tianjin Qiaoyuan Wetland Park features paved pedestrian paths and a rainwater pond designed to irrigate vegetation that remediates saline-alkali soil. Photograph by Kongjian Yu.


Case 43 China: Qingyuan Solid Waste Disposal and Resource Utilisation Centre

The Qingyuan Solid waste disposal and resource utilisation centre is an example of a landfill and waste utilisation project. Construction and operation management is undertaken by the Qingyuan Lvyou Environmental Technology Company Limited (QLETCL), and was founded in July 2009. The project provides the largest facility for the treatment of municipal sludge waste in Guangdong and was a key 12th Five Year Plan infrastructure project in Qingyuan City.

The primary purpose of the facility is solid waste and regulated waste disposal and resource utilisation, including reduction, stabilisation and treatment to render the waste harmless. The permitted waste treatment capacity is 150,000 tons/year of textile and dying sludge; 75,000 tons/year of pulp and paper sludge; 330,000 tons/year of municipal sludge and 820,000 tons/year of industrial solid waste.

The processes and design capacity at the facility are given in the table below.
Table 23: Qingyuan Solid Waste Disposal, Processes and Design Capacity

<table>
<thead>
<tr>
<th>Category</th>
<th>Design Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction, stabilisation and harmless treatment</td>
<td></td>
</tr>
<tr>
<td>Sludge dewatering</td>
<td>800 t/day</td>
</tr>
<tr>
<td>Wastewater treatment</td>
<td>Phase 1: 500 m3/day</td>
</tr>
<tr>
<td></td>
<td>Phase 2 (planned) 1000 m3/day</td>
</tr>
<tr>
<td>Sludge drying</td>
<td>600 tons/day</td>
</tr>
<tr>
<td>Solid waste landfill</td>
<td>100,000 tons/year</td>
</tr>
<tr>
<td></td>
<td>4 phases each of 500,000 m3, totally</td>
</tr>
<tr>
<td></td>
<td>2,000,000 m3</td>
</tr>
<tr>
<td>Resource Utilisation</td>
<td></td>
</tr>
<tr>
<td>Green bricks manufacture (planned)</td>
<td>Fired bricks: 120,000,000 pieces/year</td>
</tr>
<tr>
<td></td>
<td>Non-fired bricks 45,000,000 pieces/year</td>
</tr>
<tr>
<td></td>
<td>Square of facing bricks: 45,000 pieces/year</td>
</tr>
<tr>
<td>Green ceramsite manufacture</td>
<td>4000,000 m3/year</td>
</tr>
<tr>
<td>Nutritional soil production (planned)</td>
<td>50,000 tons/year</td>
</tr>
<tr>
<td>Green Energy</td>
<td></td>
</tr>
<tr>
<td>Biofuel production (planned)</td>
<td>50 tons/day</td>
</tr>
<tr>
<td>Gasification (planned)</td>
<td>4 tons/hr/furnace</td>
</tr>
</tbody>
</table>

Source: http://en.chongto.com

Image 48: Qingyuan Landfill Site

Source: http://en.chongto.com/?page_id=3988
Case 44 China : Laogang Landfill Site: Landfill Gas Collection, Shanghai,

China’s conventional landfills are often different from those in western countries since they typically receive higher quantities of organic waste, and therefore generate higher volumes of methane.

A landfill gas project has been developed at the Laogang landfill site in Pudong New Area, Shanghai, and began operation in November 2012. At the time it was Asia’s largest landfill-gass-powered generation project and was expected to provide nearly 110 million KWh of energy each year, providing enough for approximately 100,000 households.

The Laogang landfill covers an area of more than 14 square kilometers and receives nearly 10,000 tons of household waste each day, accounting for 70% of the city’s total waste. Methane and carbon dioxide formed from the degradation of the waste is harvested as part of the project for power generation, reducing 80 million cubic meters of greenhouse gas emissions annually and improving utilization of resources. The plant has two 1250 kW/h, two 1356 kW/h and seven 1409 kW/h gas engines producing a combined total of 15 MW of power.

The burning of the landfill gas is expected to save 37,800 tons of coal each year.
Image 50: Workers check the landfill, with the landfill-gas-powered plant in the background

![Image of landfill and workers](http://www.shanghai.gov.cn/shanghai/node27118/node27818/u22ai69252.html)

Source: http://www.shanghai.gov.cn/shanghai/node27118/node27818/u22ai69252.html

**Sources:**
- http://www.globaltimes.cn/content/964225.shtml

### 5.5 Collection of Waste

#### 5.5.1 Municipal Waste Collection

Collection of waste was observed in 2 different ways:

a) Using standard containers and vehicles

b) Street sweepers and waste collectors collecting from a neighbourhood and bringing to a collection point or transfer station.

*Waste collection has developed considerably over the last 10 to 15 years.*
Image 51: Waste transfer station, central Beijing 2006

Source: Annabelle Cleeve (Mott MacDonald)

Image 52: Waste collection vehicle, Beijing 2015

Source: Annabelle Cleeve (Mott MacDonald)
Disposal point
This point services 80 apartments in the neighbourhood.
2-line collection:
Recyclable materials
Waste.

Inside the building are 2 approx. 750-litre wheel-containers – one for each fraction – and a 160-litre wheel bin with water for cleaning. Emptying frequency is once a day or whenever needed.

Waste collector bringing household waste to a transfer station in a hand-cart.

Transfer station for small vehicles and hand-carts.
Building with room for 2 press containers. One container at a time with a capacity of approx. 16 m³ or 8 ton (depending on the capacity of the truck carrying. Not known.)

Case 46 China, Shenzhen, Guangdong Province: Dealing With Household Garbage – Separation at Source in Yantian District

Since 2012, the district government started to explore the way of integrated waste treatment, including waste reduction & segregation, and kitchen waste treatment.

In 2013, as the waste amount has increased for 7.7%, while no increase of the amount for incineration, and in 2014, even a further reduction has been achieved. In the same year, the kitchen waste treatment project of Yantian district of Shenzhen city, has won China’s National Model Prize for Residential Environment, and it’s the only one in kitchen waste treatment sector.

Yantian district has not only found a replicable way of waste reduction and segregation, but explored a creative sustainable business model for kitchen waste treatment.

The main experiences are:

1. Segregation at source first.
   The local government has issued <Implementation Plan (2012-2015) for Urban Household Waste Reduction and Segregation>. Then under this framework, they have issued detailed <Facility Standard> and <Waste Segregation Standard>, and <Guidebook for Waste Segregation and Reduction> individually for residential blocks, government and affiliated institutes, schools and parks.

   The biggest challenge come from household waste. Finally, they chose to set up pilot communities, which involves multiple stakeholders including street administration unit, stocking company, housing management company and residents, through direct subsidy. The subsidy amounts CNY160,000 per 1,000 households, and 6%-8% adjustment when 100 households are added or quit.

   The waste are segregated in four categories, i.e. kitchen waste, recyclable waste, hazardous waste, and others. According to ranking of waste segregation times, which are graded as 1-20, 21-40, 41-60, residents will get some minor rewards for encouragement.

   So far, 223 or 65% communities and other institutes in Yantian district are undergoing waste segregation, which include 93 institutes/enterprises, 78 residential blocks, 40 schools, 9 markets and 3 parks.

2. Kitchen waste is transported in closed vehicles; cooperation between local government and enterprises in way of BOT.
   The daily kitchen waste from restaurants amounts 88 tons, accounting for 1/3 of total 260 tons of household waste. The percentage is higher than the average level of Shenzhen city, which is 18%, because of hundreds of thousands of tourists each year.

Source: [http://sz.southcn.com/content/2015-01/12/content_116116150.htm](http://sz.southcn.com/content/2015-01/12/content_116116150.htm)
In 2012, with the cooperation with Shenzhen Ruisaier Environment Protection Stocking Company (www.ruisaier.com), the district government has established the integrated kitchen waste treatment system, which are No. 1-composed of segregated collection and closed transport, No. 2-high-temperature bio-treatment (to reduce the size), No. 3-processing of solid part of kitchen waste, No. 4-processing of oil part, and No. 5-internet of things management.

3. Successful business model.
Technically, the liquid part of kitchen waste has been produced into bio-fuel, the solid part has been produced into fuel-bar or organic fertilizer.

To make the kitchen waste treatment sustainable, the enterprise can’t depend on the government subsidy in the long run. The technique and its implementation are the key factors. There are several technologies to make use of kitchen waste, but not everyone can achieve both the economic benefit and social benefit.

The Ruisaier Company use their unique technique to separate the liquid from solid for the first step, then to degrade the solid part with specific bacterial at 60°C for 18-23 hours. After that, for 1 ton of kitchen waste, only 100-150kg degradation product remain (which means 85% reduction), then to be further processed as bio-fertilizer or bio-fuel bar. And the liquid will be processed into bio-diesel.

So far there are 9 waste treatment stations in the district, capable of treating 110 tons of solid kitchen waste and 60 tons of liquid.

4. Decentral treatment, which means to set up treatment facility based on existing waste transfer stations in the communities. This on one hand can avoid the transportation, on the other hand avoid the possibility that raw materials are not enough for one large facility. The existing kitchen waste treatment stations are not uniform in size or shape, but have been designed according to individual locations. At present the treatment stations have even turned out to be education sites on eco city development.

5. Institutional set-up.
Waste segregation standards have been drafted, and waste treatment work has been integrated into the local government officials’ evaluation.

The personnel, facilities, vehicles in all the involved steps have been assigned digital identification. The monitoring and recording for the whole process have been achieved with the application of technologies of video monitoring, RFID, GPS, 3G data transmission, etc.

Source: EC-Link
Case 47 Beijing: Composting of fallen leaves in a residential neighborhood

To treat the green waste by composting is one of classic environment friendly ways of waste treatment, but not popular yet in China. In the capital city of Beijing. A try-out has just started recently in a neighborhood. It’s interesting that the initiative does not come from local government or administrative unit, the original purpose was not for environment protection either, but from the housing management company, in order to save costs.

Jingbangyuan neighborhood, located in Changping District in the north of Beijing, was built in 2001. Every year in the winter, the problem of dealing with large amount of falling tree leaves challenges Huiren Housing Management Company of this neighborhood. The usual way is to transport the leaves to the landfill, which amounts roughly 60 truckload, with a cost of CNY300 per truck. It’s a big share for their budget, as the human labor in the metropolis has been increasing over the years.

Then they came up with the idea to smash the leaves to reduce the size, while the cost is calculated based on size, not weight. It worked, the size has been reduced to a half.

Later, an expert from Harmonious Community Development Center of Haidian District has by chance proposed to the manager of Huiren Housing Management Company the idea of treating leaves by composting. With his guidance, now they have mastered the techniques. First the fermentation of kitchen waste to get enzymes, then to mix it with leaves to produce bio-fertilizer. The fertilizer is warmly welcome by residents who plant flowers at home, and some are put into the grassland in the neighborhood.

Therefore, since 2015 the leaves never left the neighborhood. Economically, the cost of human labor for composting plus facilities are much lower than sending them away to the landfill, as expected.

Such a win-win solution could be widely spread at least for cities in north China, where leaves fall in winter and cities are surrounded by landfills or dumping sites.

http://bjwb.bj.cn/html/2016-12/20/content_90291.htm

5.5.2 Privately organized Waste Collection

Some of the new dwelling complexes in the main cities, do not have municipal collection, but is performing the service themselves as a part of a service contract where they deliver cleaning
and maintenance of common areas together with waste removal. Even informal waste picking does exist.

**Case 48 China, Beijing: The secret lives of urban waste pickers**

Lengshui village near Beijing is home to a community of waste pickers. Beijing's informal economy of waste management relies on close-knit networks of migrant workers.  

Image by Zhang Jieying  

### 5.6 Recycling

For three decades China has been the world’s largest importer of waste. An estimated 87% of Europe’s waste is exported to China and the largest import from the USA to China is scrap and waste (UN Statistics Division 2012). The UK exports approximately 70% of domestic plastic waste, with 90% imported by China. Between 2005-2015 the imports of recyclable waste materials from the UK have increased ten-fold.

China has facilitated the importation of recyclable waste materials to sustain and grow its manufacturing sector. In 2015 China imported more than 46 million tonnes of waste, which was recycled into products including paper, plastics, aluminium, and copper. However, it is thought that the actual amount of waste imported is much higher, as some is brought in illegally, and has caused serious environmental problems.
Image 53: Technological is a source of air pollution

![Image 53: Technological is a source of air pollution](https://www.theguardian.com/lifeandstyle/2014/jul/16/plastic-poverty-pollution-china-recycling-dead-zone)

Technological waste is also a source of pollution in China. Here computer parts are being burnt near a Chinese river. Photograph: Durand Patrick/ABACA/PA Photos

Source: https://www.theguardian.com/lifeandstyle/2014/jul/16/plastic-poverty-pollution-china-recycling-dead-zone

Image 54: Labourer at a bottle recycling centre

![Image 54: Labourer at a bottle recycling centre](https://www.theguardian.com/lifeandstyle/2014/jul/16/plastic-poverty-pollution-china-recycling-dead-zone)

A labourer looks up as she sorts plastic bottles at a garbage recycling centre in Hefei, Anhui province May 20, 2014. Photograph: Jianan Yu/Reuters

Source: https://www.theguardian.com/lifeandstyle/2014/jul/16/plastic-poverty-pollution-china-recycling-dead-zone
On 18th July 2017 China notified the WTO that it would stop accepting shipments of 24 different categories of waste including plastic, paper, slag from steel making, waste wool, ash, cotton, and yarn, by the end of 2017.

Image 55: Plastic bottle recycling

The WTO filing said: “we found that large amounts of dirty waste, or even hazardous waste is mixed in the solid waste that can be used as raw materials. This seriously polluted China’s environment... To protect China’s environmental interests and people’s health, we urgently adjust the imported solid wastes list, and forbid the import of solid wastes that are highly polluted.”

According to Professor Liu Jianguo at Tsinghua University (http://www.globaltimes.cn/content/1060480.shtml), most of the banned waste types were already on the “restricted” list. According to the State Council, apart from environmentally hazardous solid waste China will also ban imports of solid waste that can be replaced by domestic resources by the end of 2019.
Domestic Collection of Recyclable Materials. Collection of recyclable materials is often performed by the informal sector. It is the understanding of the author that this voluntary collection of recyclable materials is volatile and declining, although it is hoped that the ban on imports will push China’s domestic recycling industry to upgrade its technology and standards. The main reasons for this situation are:

As economic growth reaches the lower levels of society, the worst reputed activities, such as waste collection and scavenging, become the first activities to decrease, as the most disadvantaged people leave in favor of better-paid activities.

The public may seem to be more indifferent to the environment. Or they no longer see this as a common activity or their concern, but more like a municipal activity which has already been paid for through taxes.

In 2015 191.42 million tons of urban domestic waste was collected and 73.69 million tons of renewable resources were recovered from this source of waste, accounting for 45% of the national total. However, it is estimated that this only accounted for approximately 30% of the renewable resources available from urban domestic waste sources. The rate of recycling is highly dependent on the market demand and price for materials.

Case 49 China, Beijing: Local Recycling Initiative, Roundabout

Roundabout is a social recycling enterprise run by volunteers, and with 30 paid staff. It was founded in 2008 and was the first charity store of its kind to open in mainland China. They receive donations of many types of goods for recycling and sale, including: working electrical goods; car seats, bags, baby equipment, heaters, blankets, garden equipment, art work, clothing, books, exercise equipment, soft furnishings, jewellery, garden furniture, toys, sports goods, fabric, kitchenware, craft items, all furniture, bicycles, storage containers, games, stationery, bedding and pillows.
They do not accept: open, prescription or out of date medicine; underwear; anything used by an animal; magazines over 6 months old; or computers, monitors and printers over 4 years old.

The goods are received at their main reception centre, or small items can be left at collection bins, which are located in Shunyi and Chaoyang district. Large items can be collected by truck/van by prior arrangement.

The goods are sorted into different categories. Electrical goods are checked to make sure they are in working order, and repairs are made as necessary. Clothes are sorted into new and nearly new categories, and anything that is unsuitable for reuse as clothing is sent for recycling into items such as floor mops.

Some goods are given to charities – depending on the requests from charities for particular items; some goods are sold in the shop directly to the public to raise money; some goods are shipped to other locations in China depending on the need (e.g. clothing sent to earthquake victims in Qinghai).

Regular book sales are held at various locations around Beijing. These books are often returned to Roundabout after having been read, for resale, providing a truly circular economy!

All the money is given to charities. In 2016 they raised over 8 million RMB. They provide aid to a wide range of people including the elderly, children in orphanages and from poor families, mentally or physically challenged people and women from disadvantaged backgrounds. The money is used to pay for medical costs for orphans and others in need, and sheltered housing for the elderly etc.

**Image 57: Roundabout Recycling Facility, Beijing**
5.6.1 Recycling of Waste Electrical and Electronic Equipment (WEE)

Historically China was the largest importer of WEE globally, receiving approximately 70% of global e-waste. Most of this waste was processed in southeastern China, often using informal practices and causing serious environmental damage and health risks. China’s own domestic production of e-waste is also significant, and in 2012 it was the world’s second largest producer of e-waste after the US. The growth in e-waste in China is expected to continue to rise, with increasing urbanisation, technology development and innovation.

The Chinese government has passed a variety of regulations controlling the e-waste sector. The Ministry of Environmental Protection passed a set of regulations in 2008 requiring environmental impact assessments and official licenses. The Collection and Treatment Decree on Wastes of Electric and Electronic Equipment was passed in 2011 to strengthen national standards. In 2012 China adopted the “extended producer responsibility” (EPR) from the EU which holds manufacturers responsible for the collection and recycling of their electronics.

There have also been several provincial programmes. The regulation on the management of the recycling and disposal of waste electrical and electronic products, which came into effect on January 1, 2011, is a comprehensive and feasible administrative regulation document for the management of electronic waste in china. The regulation stipulated a series of systems, such as the disposal catalogue of waste electrical and electronic products, the disposal and development plan, funding, disposal qualification permission, centralized disposal and the information reporting.

Image 58: WEE Recycling in China
5.6.2 Construction and Demolition Waste

The growth in the volumes of construction and demolition waste in China have placed a huge burden on landfill capacity around the country. Civil engineering waste volumes have reached approximately 30-40% of the total waste generated by cities as a result of large scale urban regeneration, construction and demolition. The recycling of materials depends on the current market conditions, and often only valuable materials such as copper and steel are recycled, whereas concrete may be transported directly to landfill.

The NDRC reported in 2013 that China generated approximately 1 billion tons of construction and demolition waste, which was 5 times more than the amount of municipal solid waste generated for that year. However, only about 5% of construction and demolition waste was reused or recycled. The amount of construction and demolition waste is expected to increase, and is already higher than volumes generated in the EU.

There is insufficient capacity at landfills to accept these enormous volumes of waste, and waste is often disposed of at unlicensed sites in order to avoid high transportation costs and landfill fees charged at formal sites.
Image 59: Informal dumping of mixed construction and demolition waste in Chaoyang District, Beijing

The photo above shows an area of land where mixed construction and demolition waste was dumped near a river in Beijing. The waste was subsequently removed and previous ground levels were restored.

A few cities, such as Beijing, Shanghai and Shenzhen have adopted measures to manage construction and demolition waste. The regulation on the administration of construction waste disposal in Shanghai was adopted at the 163rd executive meeting of the municipal government on September 11, 2017 and is promulgated and shall come into force on January 1, 2018.

Huabo Duan, Jinhui Li, Construction and demolition waste management : China’s lessons, SAGE Journals, May 2016.
Image 60: Aggregate Recycling, China
Source: http://image.baidu.com/search/index?tn=baiduimage&ps=1&ct=201326592&lm=1&cl=2&nc=1&ie=utf8&word=%E5%BB%BA%E7%AD%91%E5%9E%83%E5%9C%BE%E5%A4%84%E7%BD%AE
5.7 Outlook

UNEP has observed that:

- the increasing volume and complexity of waste associates with economic growth are posing major risks to ecosystems and health;
- the growth of the waste market, increasing resource scarcity and the availability of new technologies offer opportunities for greening the waste sector;
• there is no one-size-fits all when it comes to greening the waste sector, but there are commonalities;
• investing in greening the waste sector can generate multiple economic benefits; and
• greening the waste sector requires financing, economic incentives, policy and regulatory measures, and institutional arrangements.49

For cities to progress in the field of waste management, the national government level will need to develop comprehensive solid waste management policies. Such policies should encourage cross-agency jurisdiction and coordination, and facilitate use of economic instruments like collection of revenues for improving waste management.

An integrated waste management approach with consistent and holistic concept; waste minimization, collection, transfer, treatment, recycling, resource recovery and final disposal are necessary especially when a Green City development strategy is outlined.

Green Cities need to be encouraged to develop integrated waste management plans in order to pursue waste minimization strategies, generate credible and comprehensive waste management data (especially costs and quantities), and to implement new concepts for sorting, collection and treatment of waste and recyclable materials.

Green Cities must serve as ‘centers of excellence’ for waste management technologies, and best waste practices. Green Cities will by other cities and municipalities be seen as lighthouses guiding the way.

Special attentions also need to be given to the technical issues of composting, processing of biomass, incineration, special waste treatment, and clean-up of brownfields and old dump sites:

a) Composting
The processing of biodegradable materials through Composting could increase substantially. However, Composting needs to be supported by the public sector, for instance in parks and public spaces, and in agriculture both as providers of waste but also as receivers of compost material as fertiliser and soil conditioner.

b) Biomass
Processing of biomass from human and animal waste (sewage sludge, manure, slaughterhouse waste and other wastes from food processing), and other biodegradable materials can be utilized as alternative form of energy (gas, heat and electricity) that can be used in public facilities. It is important to mention recycling of the fertiliser units in our organic waste will become the biggest challenge during the following decades, because chemical elements like phosphorous has become a limited resource and we cannot afford to flush this with the toilet water into the ocean or burn it in an incinerator.

c) Incinerators
The technology of incinerators is receiving more popularity. Its growth is usually driven by subsidies, and often the financing structures are not financially viable. Incinerators should meet EU emission standards for dioxin and mercury, and should have sufficient level of operating training. Cost-benefit analysis should be undertaken before committing to this technology.

d) Special Wastes
When introducing new waste treatment methods, attention have to be given to the waste fractions that may harm the treatment process. For instance: chemical substances in rechargeable batteries that end up in an incinerator may harm the emission.

e) Brownfields and old dump sites
Old industrial sites and inactive waste dumping sites are considered as “brownfields”. They will grow in number and (negative) importance in cities since these affect the environmental quality, health and land values. There are approximately 5,000 such brownfield sites in Chinese cities. The costs of cleaning these sites will be significant, and these will be higher than disposing wastes properly.

5.7.1 Investment and Financing

According to the Guiding Opinion of the State Council on Innovating the Investment and Financing Mechanism in High-priority Fields and Encouraging Social Investment (Guofa (2014) No. 60), (http://www.gov.cn/zhengce/content/2014-11/26/content_9260.htm) PPP models of investment shall be promoted and social capital shall be encouraged to participate in the investment in and operation of public welfare undertakings with a certain return on investment, such as urban infrastructure, including waste management, through such means as franchising. PPP projects may take the form of O&M contracts, BOT, BOO, TOT and ROT. As of December 31, 2016 there were 404 environmental sanitation projects, including 49 demonstration projects and 20 provincial level demonstration projects being carried out in China, including the following:

- 223 domestic garbage projects, including 128 waste incineration projects and 42 landfill projects.
- 31 garbage collection and transport projects;
- 48 kitchen waste projects;
- 12 construction debris projects;
- 9 cleaning projects.

PPP models provide some opportunities such as effectively alleviating the burden of government investment in infrastructure; and boosting domestic demand and stimulating economic growth. Challenges can include demanding requirements for the government’s contract management and regulatory capabilities and avoiding PPP capital speculation to ensure high quality project operation.
6. VALUE ADDED AND CROSS CUTTING THEMES

Value added
Better utilization of resources through 3-R ("Reduce-Recycle-Reuse") approach
Energy generation through waste maximization
Production of valuable by-products like compost and animal foods
Financial sustainability of waste services
Resilience to possible impacts of climate change

Cross-cutting themes
Governance
Municipal capacity/technical capacity
Sustainable management of land
Livelihoods from smart management of waste as a resource
Brownfield development as a land resource of the future.
Biodiversity
7. AVAILABLE RESOURCES AND TOOLS

7.1 UNEP, Asian Development Bank, and World Bank Publications


Federation of Prince Edward Island Municipalities. 2009. Municipal Sustainability Self-Assessment toolkit, CCRC.


http://www.pops.int/documents/guidance/Toolkit_Inv.pdf

http://www.fpeim.ca/userfiles/file/Viability_Toolkit-Complete-FOR-WEB.pdf
7.2 European Publications

EU Publications

General guide to LCT and LCA for waste experts and LCA practitioners

Guide to LCT and LCA in the context of Bio-waste management

Guide to LCT and LCA in the context of Construction and Demolition (C&D) waste management

Making sustainable consumption and production a reality. A guide for business and policy makers to Life Cycle Thinking and Assessment

Life Cycle Thinking and Assessment for Waste Management

A wealth of ideas for a greener Europe

EU Focus on Waste Management

Guide for waste management in mountain areas (German language)

Codes of practice for waste management on islands - Manual

Success stories on composting and separate collection

Workshop on "Problems around sludge", 18-19 November 1999, Stresa (Italy)"

Workshop on harmonisation of sampling and analysis methods for heavy metals, organic pollutants and pathogens in soil and sludge
Part I:
Part II:

European Green Capital publications
Making our cities attractive and sustainable. How the EU contributes to improving the urban environment

European Green Leaf 2015. Good Practice Report

Urban Environment Good Practice & Benchmarking Report. European Green Capital Award 2017


7.3 Other Publications


On The Road to Zero Waste


http://noburn.org/downloads/On%20the%20Road%20to%20Zero%20Waste.pdf

http://www.mckinsey.com/insights/urbanization/preparing_for_urban_billion_in_china

http://www.worldbank.org/eco2

**ANNEXES**


**Name:** Integrated Solid Waste Management Plans

**What this tool does:** Integrated Solid Waste Management Plans (ISWMPs) are an important tool for urban management. These ISWMPs organize waste streams and processing procedures at a city-wide level. The ISWMPs will seek full waste collection coverage for a city, ensure proper application of required environmental safeguards for collection, interim storage, onward transport, disposal to sanitary landfills or incinerators or waste recycling plants (Materials Recovery Facilities - MRF).

“[D]eveloping countries face uphill challenges to properly manage their waste with most efforts being made to reduce the final volumes and to generate sufficient funds for waste management. If most of the waste could be diverted for material and resource recovery, then a substantial reduction in final volumes of waste could be achieved and the recovered material and resources could be utilized to generate revenue to fund waste management. This forms the premise for **Integrated Solid Waste Management (ISWM) system based on 3-R (reduce, reuse and recycle) principle.** ISWM system has been pilot tested in a few locations (Wuxi, PR China and others) and has been well received by local authorities. It has been shown that with appropriate segregation and recycling system significant quantity of waste can be diverted from landfills and converted into resource.” (UNEP)

**Concept of Integrated Solid Waste Management (ISWM)**

[Diagram of ISWM system]

Source: UNEP
**How does it work:** A hierarchy of planning documents – urban master plan, integrated solid waste management plan, urban landfill schedule - need to address a city’s SWM aspects. A ISWMP will cover the following principles:

1. Upholding the right of every citizen to a clean and healthy environment.
2. Protection of the common public goods for current and future generations.
3. The importance of addressing economic and social value addition to waste management in terms of job creation and income generation.
4. All citizens contributing to the growing problem and the potential to be part of the solution.
5. Primary focus on the promotion and implementation of the 3-R principles (Reduction \(\rightarrow\) Reuse \(\rightarrow\) Recycle).
6. Awareness and education with a focus on resource reduction and waste-to-resource conversion.
7. Building upon existing local capacities and experiences.
9. Putting the necessary policy and institutional framework in place.
10. Developing a built-in adaptive mechanism for the continuous monitoring and improvement of the system. (Source: UNEP)

**Process:**

*Steps in Strategic Planning for ISWMP*

Source: UNEP
Examples:

Detailed Planning Process of ISWMP

- Strategic Planning approach for ISWM
- Vision
- Identify
- Define Goals and Objectives
- Identification of External Actions
- Internal Capacity Building Enabling Framework
- Preparation of Preliminary Strategic Action Plan
- Detailing of Actions into Tasks
- Prioritization of Actions & Responsibility Allocation
- Preparation of Draft Action Plan
- Consultation with External Stakeholders
- Preparation of Final Strategic Action Plan

Participatory Process
- Launch Workshop
- Working Group Meeting
- Workshop (MSW)
- Workshop (C&D)
- Workshop (E-Waste)
- Workshop (BMW)
- Workshop (E-Waste)
- Consultations with Stakeholders

Source: UNEP

Literature / further information:

**Name:** 3-R Tools

**What this tool does:** This tool introduces the necessary steps to deal with waste in a non-conventional manner. It treats waste as potential resource. The waste hierarchy refers to the “3-Rs” – Reduce → Reuse → Recycle which classifies waste management approaches according to their desirability.

**Benefits.** Waste is not something that should be discarded or disposed of with no regard for future use. It can be a valuable resource if addressed correctly, through policy and practice. With rational and consistent waste management practices there is an opportunity to reap a range of benefits. Those benefits include:

1. Economic - Improving economic efficiency through the means of resource use, treatment and disposal and creating markets for recycles can lead to efficient practices in the production and consumption of products and materials resulting in valuable materials being recovered for reuse and the potential for new jobs and new business opportunities.
2. Social - By reducing adverse impacts on health by proper waste management practices, the resulting consequences are more appealing settlements. Better social advantages can lead to new sources of employment and potentially lifting communities out of poverty especially in some of the developing poorer countries and cities.
3. Environmental - Reducing or eliminating adverse impacts on the environmental through reducing, reusing and recycling, and minimizing resource extraction can provide improved air and water quality and help in the reduction of greenhouse emissions.
4. Inter-generational Equity - Following effective waste management practices can provide subsequent generations a more robust economy, a fairer and more inclusive society and a cleaner environment. ([https://en.wikipedia.org/wiki/Waste_management](https://en.wikipedia.org/wiki/Waste_management)).

The 3-Rs are meant to be a hierarchy, in order of importance.

---

![The Waste Hierarchy](image)

Source: UNEP
How does it work: 3-R Initiatives

<table>
<thead>
<tr>
<th>No.</th>
<th>Initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establishment of Standardized Guidelines for Operating EC Link</td>
</tr>
<tr>
<td>2</td>
<td>Establishment of a Cadre of Certified Operators for EC Link</td>
</tr>
<tr>
<td>3</td>
<td>Introducing Industry - University Partnerships</td>
</tr>
<tr>
<td>4</td>
<td>Establishment of a Waste Exchange Centre</td>
</tr>
<tr>
<td>5</td>
<td>Establishment of an ISWM Cell</td>
</tr>
<tr>
<td>6</td>
<td>Develop and introduce policy for O&amp;D Waste Management</td>
</tr>
<tr>
<td>7</td>
<td>Improving health and safety of O&amp;M workers, staff, partners, citizens</td>
</tr>
<tr>
<td>8</td>
<td>Strengthening of O&amp;M Registration Co-operatives</td>
</tr>
<tr>
<td>9</td>
<td>Design and launch of a Comprehensive Awareness Campaign on O&amp;M</td>
</tr>
<tr>
<td>10</td>
<td>Testing consumption of non-biodegradable plastic</td>
</tr>
<tr>
<td>11</td>
<td>Improving Awareness and Training for O&amp;M Management</td>
</tr>
<tr>
<td>12</td>
<td>Initiating school involvement in waste management</td>
</tr>
<tr>
<td>13</td>
<td>Improving waste management during festivals</td>
</tr>
</tbody>
</table>

Source: UNEP

Process:

A. Generation, Collection and Transportation.
   1. Establishment of a waste inventory.
   2. Development of local policies on segregation and collection.
   3. Development of awareness raising tools for 3-R waste management.
   4. Supply of waste bags for segregation of food waste.
   5. Construction / provision of collection points.
   6. Development of primary collection systems.
   8. Development of operational plan for collection and transportation.

B. Sorting, Treatment and Disposal
   1. Upgrading of transfer stations for material recovery.
   2. Development of biogas plant.
   3. (Upgrading of) incineration plant with resource recovery.
   4. (Upgrading of) sanitary landfill with landfill gas utilization.
   5. Establishment of waste exchange platform.
   7. Development of monitoring system for ISWMP. (Source: UNEP)

Literature / further information:

<table>
<thead>
<tr>
<th>Name: Management of Closure of Sanitary Landfills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What this tool does:</strong> This is a very technical issue, of a relevant environmental issue that is often and easily overlooked when investing in sanitary landfills: The eventual closure of sanitary landfills, and the associated costs of this additional investment and even monitoring costs.</td>
</tr>
<tr>
<td><strong>How does it work:</strong></td>
</tr>
<tr>
<td>“What does it mean to &quot;cap&quot; a landfill? The principle cause of groundwater pollution at landfills is the infiltration of water - rainwater and snowmelt - into the refuse. This water filters through the refuse, which dissolves a wide range of water-soluble pollutants out of the refuse, and encourages microbiological decay which releases even more contaminants. This mix of dissolved and suspended chemicals and rainwater is called &quot;leachate.&quot; Modern sanitary landfills are designed with liners of plastic and clay, leachate collection systems, and leachate storage facilities designed to intercept, collect, and contain the leachate, and hold it for treatment at the site or elsewhere. In unlined landfills, nothing but natural earth materials retard the migration of leachate into the groundwater. Some natural processes help reduce the concentration of many chemicals once leachate has migrated from the landfill, but in many instances groundwater contaminated by unlined landfills has been found to contain one or several chemicals at concentrations above the drinking water standards... In order to mitigate this environmental damage and threat to public health, landfills are permanently closed with low-permeability caps which cut off the infiltration of water into the refuse. Caps are useful even at lined sites, because they limit the amount of leachate that must be treated. At unlined sites, they are even more critical, and serve as a principal remedial technique to limit or prevent leachate migration, and reduce the need for other expensive techniques such as groundwater pumping.</td>
</tr>
<tr>
<td><strong>What does a cap cost?</strong> Installation of a cap can be quite substantial. The actual costs depend largely on the local availability of materials used to construct the cap, the topography and ease of installation at a particular site, the design selected, and cost reductions associated with bulk-buying. For example, if substantial quantities of clay are available nearby, and the clay is suitable for this use, it can eliminate the cost of purchasing the low permeability layer - although it will still entail excavation, installation, compaction, and testing costs. Where gravel is present, then the drainage layer could be composed of locally-available material.</td>
</tr>
</tbody>
</table>
| **Process:** Procedures governing landfill closure, normally prescribe that landfills must be monitored. It is necessary to inspect and maintain the landfill and its protective systems for at least 30 years following facility closure. This includes operation of the leachate collection system, extensive groundwater monitoring, inspection and repair as needed of the cap and other protective systems, and maintenance of the financial assurance bond or other security. Also, facilities which develop groundwater contamination have to institute remedial activities such as groundwater pumping and treatment, expanded monitoring, and additional financial assurance. Finally, in addition to water pollution, landfills have another by-product: landfill gas. This gas is created by the anaerobic decay of putrescible materials such as food waste, paper and wood, and is largely composed of carbon dioxide (CO2) and methane (CH4). Methane can migrate through the soil, and concentrate in enclosed structures, causing natural gas explosions and flash fires. Volatile Organic Chemicals (VOCs) such as benzene, chlorinated solvents, and Freons which are present in domestic refuse in small amounts can travel with the landfill gas, and degrade the ozone layer. Controls on these gases involve the installation of collection wells under the cap. Blowers and header pipes are used to collect the gas at a central point, where it is flared off (destroying the methane and VOCs) or used as fuel. Some facilities in Maryland recover some cost back by using the landfill gas to fuel boilers or generators, or even treat the gas and provide it to the local gas utility. The
installation of gas controls is being expanded due to increased requirements to control non-methane VOCs under the federal Clean Air Act. However, the additional systems needed to collect and destroy or use the gas create additional costs.

What goes into a cap? A cap is constructed of several layers, applied one at a time over areas of the landfill until the entire filled area is covered. Over the last layer of refuse, a two foot layer of soil called the “final cover” is installed to protect the cap from damage by sharp objects or settlement of the waste. This surface is graded to a 4% minimum slope to insure drainage, and compacted for stability. Then, a low permeability layer consisting of 12 to 18 inches of clay with a maximum permeability of 1x10-5 cm/sec, or more frequently a flexible membrane of PVC, HDPE, or a similar plastic is placed on the landfill. For clay, the permeability, density, and moisture content is measured and adjusted to assure minimum permeability; for plastic, the seams are sealed and tested to insure a leak-free cap. A 6" drainage blanket of sand or gravel, or sometimes a plastic drainage media, is applied on top of the liner. This blanket must have a minimum permeability of 1x10-3 cm/sec. Often a permeable geosynthetic fabric is placed between the collection blanket and the low permeability layer, to protect the layer and to provide additional support to the overlying elements of the system. This drains any precipitation which infiltrates the cap to be drained off to discharge to nearby streams without becoming contaminated through contact with the waste. Often another permeable geotextile is placed on top of the drainage blanket, to keep it from being clogged by fine soil particles from the final layer. Finally, another 2' layer of soil is applied, to protect the cap and allow for vegetative stabilization.

(adapted from: http://www.eolss.net/Sample-Chapters/C09/E6-65-02-05.pdf)

Examples:  
Section of a typical landfill closure cap

<table>
<thead>
<tr>
<th>Vegetative stabilization, to prevent soil erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2' of soil</td>
</tr>
<tr>
<td>permeable filter fabric, to keep soil out of drainage layer</td>
</tr>
<tr>
<td>6' gravel drainage layer</td>
</tr>
<tr>
<td>geotextile, to protect top of plastic</td>
</tr>
<tr>
<td>40 mil PVC or HDPE impermeable layer*</td>
</tr>
<tr>
<td>geotextile, to protect bottom of plastic</td>
</tr>
<tr>
<td>2' of soil</td>
</tr>
<tr>
<td>Refuse</td>
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Literature / further information:

<table>
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<th>Name: Management of Solid Waste Incinerators</th>
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**What this tool does:** Incinerators have become popular in China for processing of household waste. However, apart from their high capital costs, there is a lot of debate about the acceptability of this technology. Many cities are seeking advice, and express need to share experiences.

“A waste treatment technology, which includes the combustion of waste for recovering energy, is called as “incineration”. Incineration coupled with high temperature waste treatments are recognized as thermal treatments. During the process of incineration, the waste material that is treated is converted into gases, particles and heat. These products are later used for generation of electricity. The gases, flue gases are first treated for eradication of pollutants before going in to atmosphere. Among waste-to-energy technologies, incineration stands taller. Other technologies are gasification, PDG, anaerobic digestion and Pyrolysis. Sometimes Incineration is conducted without the reason for recovering energy. In [the] past, incineration was conducted without separating materials thus causing harm to environment. This un-separated waste was not free from bulky and recyclable materials, even. This resulted in risk for plant workers health and environment. Most of such plants and incinerations never generate electricity. Incineration reduces the mass of the waste from 95 to 96 percent. This reduction depends upon the recovery degree and composition of materials. This means that incineration however, does not replace the need for landflling but it reduced the amount to be thrown in it. Incineration comes with a number of benefits in specific areas like medical wastes and other life risking waste. In this process, toxins are destroyed when waste is treated with high temperature. Incineration or thermal treatment of waste is much popular in countries … where there is scarcity of land. The energy generated by incineration is highly demanded in countries like Denmark and Sweden. In year, 2005 it was estimated that 4.8 percent of the electricity as is consumed by Danish nation was produced by incineration and the amount of heat was some 13.7 percent out of total. Other than Denmark and Sweden many European countries are recovering heat and electricity from waste. “

(adapted from: [http://www.wrfound.org.uk/articles/incineration.html](http://www.wrfound.org.uk/articles/incineration.html))

**How does it work:**

**Incinerators and their types:** Incinerator can be understood more precisely as a furnace where waste is burnt. Modern incinerators are equipped with pollution improvement systems, which play their part in cleaning up the Flue gas and such toxicants. Following are the types of plants for burning waste:

**Moving Grate:** The incineration plant used for treating MSW is moving grate. This grate is capable for hauling waste from combustion chamber to give way for complete and effective combustion. A single such plant is capable for taking in thirty-five metric ton of waste every hour for treatment. Moving grates are more precisely known as incinerators of municipal solid waste. This waste is poured in the grate with a help of crane from and opening or throat. From here, the waste has to move towards the ash pit. Waste is further treated and water locks wash out ash from it. Air is then flown through the waste and this blown air works for cooling down the grate. Some of grates are cooled with help of water. Air is blown through the boiler for another time but this time comparatively faster than before. This air helps in complete burning of the flue gases with the introduction of turmoil leading to better mixing and excess of oxygen. In some grates, the combustion air at fast speed is blown in separate chamber. European Waste incineration Directive is of the view that an incineration plant must be designed so that operating worker must know that flue gases are reaching the temperature of eight fifty degrees centigrade with in two seconds. This would ensure...
complete and required breakdown of toxins of organic nature. In order to achieve this every time backup auxiliary burners must be installed.

1. **Fixed Grate:** This was the fixed and much older version for grate. This kind generally is lined with the brick while lower or ash pit is made up of metal. This grate generally has an opening at the top and for loading purpose; a side of the grate is left open. A number of fixed grate were first formed in houses, which today are replaced by waste compactors.

2. **Rotary-kiln:** Industries and municipalities generally use this sort of incinerator. This incinerator consists of two chambers i.e. primary and secondary chamber.

3. **Fluidized Bed:** In this sort of incineration, air is blown at high speed over a sand bed. The air gets going through the bed when a point come where sand granules separates and let air pass through them and here comes the part of mixing and churning. Therefore, a fluidized bed comes in to being and fuel and waste are then can be introduced. The sand along with the pretreated fuel or waste is kept suspended and is pumped through the air currents. The bed is thus mixed violently and is upright while small inert particles are kept suspended in air in form of fluid like form. This let the volume of the waste, sand and fuel to be circulated throughout the furnace, completely.

4. **Specialized incineration:** When it comes to the furniture factory for incineration of the waste, they need to take special precautions, as they have to handle inflammable material. For this purpose, they have incinerators, which are installed with burn back prevention systems and are very much necessary for the dust suspensions when they are more able to catch up the fire.

5. **Use of Heat:** The heat that is produced by an incinerator can be used for generating steam, which is used for driving a turbine in order to produce electricity. The typical amount as is produced by Municipal waste per ton is 2/3 MWh for electricity and two MWh for heating.

6. **Pollution:** Incineration is conducted with a number of outputs, which include ash and flue gas emission. Before the flue gas cleaning systems were introduced, the flue gas has to move to atmosphere thus leading to pollution.

7. **Emission of Gases:**
   
   a. **Furans and Dioxins:** The biggest most concern, which has caught thoughts of environmentalists about MSW’s incineration, is production of a huge amount of furans and dioxins. These are considered staidly injurious to health. Modern generators are equipped with special equipment to clean emission of gases from these injurious components. There was a time when no governmental regulation were there to bound incineration and save environment and atmosphere from this hazardous emission of gases but today there are strict and rigid rules and regulations to follow and conduct incineration.

   b. **Carbon dioxide:** Incineration while being conducted produces a vast amount of Carbon dioxide. Carbon dioxide plays a due role in global warming, as this is the greenhouse gas. It has been observed that almost everything which has carbon in its composition is when processed by incineration evolves out as carbon dioxide.

   c. **Extra Emissions:** Some other emissions of gases by waste processing are sulfur dioxide, hydrochloric acid, fine particles and heavy metals.

   d. **Cleaning out Flue Gas:** A number of processes are involved for the cleaning up of flue gas. The mixture of flue gas is collected by means of Particle filtration and this filtration is conducted using electrostatic precipitators and baghouse filters. Baghouse are very effective for fine particles. The next step of the processing and cleaning of flue gas is processing of scrubbers, which are critical for the removal of hydrochloric acid, nitric acid, mercury, hydrofluoric acid, lead and residuary heavy metals. With the reaction of lime, sulfur is converted in to gypsum. The wastewater, which comes out of scrubbers, is then passed through wastewater treatment plant. Desulphurization is a process that is used to remove sulfur dioxide with the limestone slurry injection directly in to flue gas. Nitric component or gases are reduced with catalytic reduction with help of ammonia application. Heavy metals are removed with the help of active carbon injection. Particles are the collected at filters.
8. **e. Solidify Outputs:** Flue ash and Bottom ash is produced with the processing of waste materials and settle at the bottom of the incineration plant. The ash, which is produced, is four to five percent of total weight of the waste processed while the flue ash makes up some ten to twenty percent of total weight of waste material. The heavy metals, which are contained in the flue or bottom ash, are lead, cadmium, zinc and copper. A small amount of furans and dioxins are also produced. It is to mention here that bottom ash seldom have heavy metals in it. Flue ash is hazardous while bottom ash is not that dangerous or injurious to health.

8. **F. Other issues related to Pollution:** Older models of incinerators have inconvenience that this produce odor pollution. However, in modern plants are saved from producing dust and odor pollution. They are designed to store waste in enclosed containers along with a negative pressure to keep from odor and dirt dispersal. Another issue that is affecting community is increased load of traffic due to weighted call value (WCV) for hauling waste materials. This is the issue, which has forced incinerators to move in to industrial areas. “

(adapted from: [http://www.wrfound.org.uk/articles/incineration.html](http://www.wrfound.org.uk/articles/incineration.html))

**A debate over Incineration:**

"Usage of incineration is for waste management is divisive. The debate for incinerators generally involves business interests, regulations of government, activists if environment and citizens.

**Arguments supporting incinerations:**
- The first concern for incineration stands against its injurious effects over health due to production of furans and dioxin emission. However, the emission is controlled to greater extent by developing of modern plants and governmental regulations.
- Incineration plants are capable for producing energy and can substitute power generation plants of other sort.
- The bottom ash after the process is completed is considered non-injurious that still is capable for being land filled and recycled.
- Fine particles are removable by processing through filters and scrubbers.
- Treating and processing medical and sewage waste produces non-injurious ash as product.

**Arguments against incinerations:**
- Extremely injurious matter needs adequate disposing off. This requires additional miles and need special locations for land filling this material.
- Although after a lot of regulations and restrictions and developments concerns are still alive about emission of furans and dioxins.
- Incinerating plants are producers of heavy metals, which are injurious even in minor amounts.
- IBA is consistent over a considerably high level of heavy metals and can prove fatal if they are not disposed of, or reused properly.
- Initial investment costs are only recovered through long periods of contract for incinerating plants.
- Local communities always have opposed the presence of incinerating plant in the locality.

The upheld view is to recycle, reuse and waste reduction instead of incineration."

(adapted from: [http://www.wrfound.org.uk/articles/incineration.html](http://www.wrfound.org.uk/articles/incineration.html))
Examples:

Conmat Controlled Air Furnace (CONSUTECH)

Rotary Kiln Incinerator (INTUSER)

Source: http://www.seller.co.uk/p_waste1.htm
**Fluidized Bed Incinerator (INTUSER)**

Image: Fluidized bed incinerator diagram

*Source: Southern Cross University (SCU), Australia*

**Literature / further information:**
http://www.users.abo.fi/jwerkeli/OOK%20I%202010/Knox%20-%20Overview%20of%20Incineration%202005.pdf
The Europe-China Eco Cities Link (EC-Link) Project is funded by the European Union in cooperation with the Ministry of Housing and Urban-Rural Development (MoHURD), implemented the European Consortium led by GIZ

中欧低碳生态城市合作项目由欧盟资助与住房与城乡建设部合作
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