Management Research Paper

Sustainable Solid Waste Management
(Best Practices – Global Benchmarks)

(Shailesh Kumar Jha¹)

Abstract
Every city can become smarter. Smart cities start with smart systems that work for the benefit of both residents and the environment. The cities that succeed in making the transition to ‘smart’ will be those that improve their critical systems by combining a bottom-up, systems-centric approach with a top-down, data-centric one.

It is the improvement and integration of various critical city systems — done in a step-by-step manner — that become the cornerstones to making a smart city a reality. With this approach to each critical domain of a city, obstacles to a more intelligent infrastructure can be solved, and smart cities can move from a distant dream to an accessible reality.

Urban infrastructures will need to better meet the challenges of city environments: energy and water scarcity; pollution and emissions; traffic congestion; crime; waste disposal; and safety risks from ageing infrastructures. The increased mobility of the societies has created intense competition between cities: for investment, for talent, and for jobs. To attract the most promising residents, companies, and organizations, as well as promote a thriving culture, cities must achieve three critical traits: become more efficient, more livable, and more sustainable.

Smart cities need not be thought of as cities of the future. They can be the cities of the present. By the end of the current decade, many technologies critical to a smart city, including monitoring and sensor technologies, intelligent traffic systems, and energy management systems for buildings, will be deployed on every continent.

While the challenges are many, the benefits are significant. Going beyond the obvious environmental benefits, the improvement of systems can contribute to social equality through universal access to a city’s public services. They save lives by allowing for more immediate access to emergency services. They make cities more resilient in times of crisis, allow cities to prepare for hazards, and help to restore city services from disruption in the wake of one. They create new economic zones that drive growth and prosperity.

Some of the forerunner cities which have initiated various strategies to cater the major issue of waste management are listed below. With synchronizing their vision with growth and zero waste, they have achieved a sustainable waste management with almost no waste for dumping.

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SMART CITIES AROUND THE GLOBE

*Climate Smart Waste Management Reducing GHGs and Growing New York's Economy*

The **GHG Cost of Solid Waste:** No material is a "waste" until it is destined for a landfill or other disposal. Until then, every product or item is a resource that has value and potential for other uses. This value has been added during all the steps in the product's life cycle - from raw material extraction and delivery, through manufacturing and distribution. When products are consigned to landfills or combusted, all the raw materials and most of the energy that went into making them are lost.

Most New York communities recycle some of their solid waste, but approximately four-fifths of it ends up in waste combustors or landfills. Their waste generation outpaces recycling: even increasingly efficient recycling programs cannot keep up with the flood of non-recyclable products and packaging entering the waste stream. The most recent inventory of New York State's GHG emissions estimates that the system of solid waste disposal generates almost 4 percent (about 9.8 million tons) of the state's GHG emissions. For communities that have landfills within their borders, however, waste management accounts for a much higher percentage of total municipal GHG emissions. GHGs come primarily from two steps in the management of solid wastes:

- **Transportation and Handling:** most solid waste management systems today collect, move and process large volumes of waste, using fossil fuel-powered vehicles and equipment that emit carbon dioxide (CO2), nitrous oxide (N2O) and methane (CH4).
- **Landfilling or combusting:** in a landfill's anaerobic environment, decomposing organic materials give off methane, a greenhouse gas 22 times as potent as CO2; combusting landfill gas or wastes generates heat-trapping CO2 and nitrogen compounds, but overall GHG emissions from combusted waste are lower than from the same amount of waste left to decompose.

**Conserving Resources, Cutting GHGs Emissions (Waste Management Practices):** The table below summarizes the types of waste management practices available to local communities, the GHG implications of each, and other benefits of each practice. The table begins with the most efficient practices, waste prevention and reuse, which emit the smallest amount of GHGs; practices that are more GHG-intensive follow. Replacing fossil fuels with low carbon systems (such as hydrogen or electric power) for transporting and handling waste would make any solid waste management practice more efficient and less polluting.
A hybrid electric truck for collecting solid waste and recyclables proclaims the intent of the City of New Rochelle, a Climate Smart Community, to reduce GHG emissions from managing its solid waste. (Photo courtesy City of New Rochelle)

Leading by example is crucial in moving to efficient, GHG-reducing materials and waste management. The Town of North Hempstead involved all eleven school districts within its jurisdiction in a highly visible effort to increase recycling. (Photo courtesy of the Town of North Hempstead)
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<th>Solid Waste Management Practice</th>
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<th>GHG Outcome</th>
<th>Other Benefits</th>
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<tr>
<td><strong>Waste prevention</strong>&lt;br&gt;Avoid generating waste in the first place</td>
<td>Product stewardship/producer responsibility, Waste prevention incentives, Technical assistance</td>
<td>Avoids GHG emissions from transportation, handling and disposal of wastes not generated</td>
<td>Avoids disposal cost and non-GHG pollutants, can save money for manufacturers by conserving raw materials</td>
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<td><strong>Reuse</strong>&lt;br&gt;Redirect to new users items that still have value for their original purpose</td>
<td>Usable wastes (e.g., clothing, furniture, building materials) given or sold to be used for their original purpose</td>
<td>Avoids GHGs from virgin material extraction/delivery, from manufacturing/distribution of new items, and from waste disposal</td>
<td>Saves money for users of redirected materials, recovers material and energy value, avoids cost and non-GHG pollution from disposal</td>
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<td><strong>Beneficial use</strong>&lt;br&gt;Redirect items with value for uses other than their original purpose</td>
<td>Use waste paper for animal bedding, waste glass and tires for civil engineering applications; some preparation (e.g. shredding or crushing) may be required</td>
<td>Avoids GHG emissions from disposal and from virgin material extraction and manufacturing for new use; transport and preparation may emit some GHGs</td>
<td>Recovers material, energy value of waste; saves the cost of virgin material acquisition; reduces new user's cost and pollution</td>
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<td><strong>Comprehensive recycling</strong>&lt;br&gt;Include new materials and venues; expand participation &amp; capture of targeted recyclables</td>
<td>Add recycling in new venues (e.g., workplaces, public spaces, public events), recycle new materials, recruit new recycling participants, replace demolition with deconstruction</td>
<td>Avoids GHGs from virgin material extraction/delivery; reduces GHG emissions from disposal (transportation and separation are still necessary, but Landfilling or combusting is avoided)</td>
<td>Avoids cost and non-GHG pollution from disposal, provides cheaper raw materials for manufacturers, sale of recovered materials can help pay for solid waste management</td>
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<td><strong>Recovery of waste organics</strong>&lt;br&gt;Make nutrients in organic wastes available to people, soil organisms, plants</td>
<td>Distribute excess prepared food to institutions or agricultural users; compost food scraps, non-recyclable paper, yard debris; transport, some handling needed</td>
<td>Avoids or reduces GHGs from disposal (in particular, methane from decomposition of organics in landfill), sequesters carbon in soil</td>
<td>Makes food available for people or animals, provides soil-building compost for landscaping and gardening, avoids or reduces disposal cost, avoids non-GHG pollutants from disposal</td>
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<td><strong>Energy recovery</strong>&lt;br&gt;Burn under controlled conditions waste materials that cannot be recycled, capturing combustion heat</td>
<td>Properly equipped combustors can convert water into steam; steam used to heat buildings or generate electricity</td>
<td>Recovers energy value from wastes; when substituted for fossil fuelled heat or power, eliminates that amount of fossil fuel CO₂</td>
<td>Burning at high temperatures destroys chemicals and disease-causing bacteria; some combustion ash is used beneficially (e.g. cover in landfills)</td>
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<tr>
<td><strong>Best residual management</strong>&lt;br&gt;Dispose of remaining wastes in a way that is environmentally sound and sustainable</td>
<td>Landfills with liners, leachate collection/removal, best operating practices, groundwater monitoring, closure/post closure care, financial assurance, gas recovery</td>
<td>Decomposing wastes generate methane, a powerful GHG; capturing and combusting for power generation destroys methane and can avoid some fossil fuel use but still emits CO₂</td>
<td>Methane combution captures some energy value from land-filled wastes; non-degradable wastes remain available for future recovery</td>
</tr>
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By adopting a mix of solid waste management practices that reduce waste and favour efficiency, leaving only limited residues for combustion or Landfilling, communities can minimize the tax dollars they spend for waste disposal, conserve materials and avoid GHG emissions. New York's Climate Smart Communities are taking the lead in testing and adopting efficient solid waste management. Industries and other private sector concerns that generate a large amount of waste can reap the same benefits from more efficient waste management practices.

Material Management – The way of the Future: In a materials-efficient economy

- Goods and services are designed to require much less virgin material
- Strategies are in place for materials efficiency and waste prevention in homes, businesses and institutions
- Promotion and support are widespread for materials conservation, recovery and efficiency
- A robust economy exists for secondary (recovered) materials
- The maximum amount of material is recovered from the waste stream

With material resources used much more efficiently, New York will significantly reduce GHG emissions, resource depletion, energy use and pollution. Managing materials efficiently will help sustain the low-energy economy and provide good local jobs.

Beyond Waste: A Sustainable Materials Management Strategy for New York: Achieving materials efficiency will require action by governments and the private sector. The recently-published state materials management strategy, Beyond Waste, begins New York's shift from "end-of-the-pipe" waste management to looking "upstream" at how materials that would otherwise become waste can be more sustainably managed throughout the economy. The plan projects that this kind of materials management could:

- Save more than 280 trillion BTUs of energy each year-as much energy as is consumed by more than 2.6 million homes.
- Add as many as 67,000 jobs in the state by 2030.
- Reduce New York's GHG emissions by nearly 21 million metric tons annually.

Beyond Waste targets a progressive reduction in the daily amount of municipal solid waste destined for disposal, from the current 4.1 pounds per person per day to 0.6 pounds by 2030. To accomplish this reduction, the plan focuses on increasing local solid waste management planning; expanded technical assistance, guidance, tools and funding would help address challenging planning issues.
The Sino-Singapore Tianjin Eco-City, Singapore

The Sino-Singapore Tianjin Eco-city is the result of a collaborative agreement between the governments of China and Singapore to jointly develop a socially harmonious, environmentally friendly and resource-conserving city in China.

Effective Waste Management & Recycling: To promote effective waste management, residents will be encouraged to sort their waste into categories. Recyclable waste will be sent to recycling stations located within the Eco-City. Non-recyclable waste will be collected via a Pneumatic Waste Collection System and incinerated to generate electricity.

With increasing concerns over greenhouse gas emissions and the effects of climate change, the concept of eco-cities as a model of sustainable development has gained traction, of which the Tianjin Eco-City project is one prominent example. Singapore’s reputation as a clean green city in Asia, together with its track record of close collaboration with China, made it a suitable partner for this undertaking.
Singapore’s National Environment Agency (NEA) has worked closely with the Eco-City Administrative Committee (ECAC) to develop an integrated environmental and waste quality monitoring system for the Eco-City. NEA is also working with the ECAC to ensure that Eco-City's various environmental-related KPIs, such as treatment of hazardous waste, noise pollution levels, ambient air quality, carbon emissions level, per capita domestic waste generated and overall recycling rate, are met.

**Barcelona Smart City**

The Barcelona Smart City model identifies 12 areas under which Smart City projects are initiated: environmental, ICT, mobility, water, energy, matter (waste), nature, built domain, public space, open government, information flows, and services.

Regarding the concept of Smart City thanks to its strategy based on a transformational vision of the city on a long-term. It has an objective to become a self-sufficient city of productive neighbourhoods, human speed, in a hipper connected metropolis with no emissions. This city evolution strategy is focused to guarantee the citizen living quality, social and urban improvement, trying to add value to the neighbourhoods, encouraging all its urban potential in the sustainable development and green economy. This vision encompasses projects of different areas, thanks to technology and innovation. It
pretends to achieve an improvement in the services that the City council provides to the citizens as well as a better management and general knowledge of the city.

Barcelona collaborates to international level with numerous institutions and other cities with the aim to find solutions to the city challenges of today and it is widely thoughtful for these; a reference in Smart Cities.

Barcelona developed the urban platform in 2013 as a new ICT architecture that provides a single, transversal platform that interconnects the entire city. The project was proposed to create a sustainable city model that can manage different resources in an efficient way, including water, public services, temperature regulation, CO2 emissions, civil works, humidity and energy efficiency.

The platform has three components; Sentilo (raw source data), City OS (intelligence component) and Applications (City Council and third parties as output information providers). Thanks to the use of an intelligent process engine that connects different events in real time, emergency situations can be anticipated and responses from different services coordinated in a more efficient and expedited way.

**Smart Sensors in Waste management:** Sensors installed inside containers to monitor the fill level. This data is sent in real time to a control centre, which enables optimal management of collection.

EV (Electric Vehicles) charging stations, sensors on trash and recycling bins to minimize costs and the environmental footprint for city waste and recycling collectors, water sensors in parks to ensure water is used more intelligently, sensors in parking areas to indicate empty spaces (minimizing driving time and emissions), and sensors on streetlights that detect movement and adjust the illumination accordingly. This is an initiative to allow Sant Cugat and its residents to save money, be more efficient, reduce their environmental footprint, and illustrate the potential of smart cities.

ICT is key to reaching this goal as it enables the city to manage resources efficiently and reduce the impact of urban infrastructure on the environment. With the urban platform, the city can also capture information in real time, allowing for quicker decision making and response times. The result is a more sustainable, resilient city.

**Selective pneumatic waste-collection network:** Differentiates between organic and inorganic waste and paper. Jointly applied for a European project on intelligent automated urban waste collection.
The urban platform installation will help the city save energy and reduce pollution thanks to sensors monitoring water levels for irrigation, garbage containers, parking, people flow, energy efficiency in city buildings, civil works, etc. Moreover, the intelligence processes engine will make it possible to provide contingency plans for situations such as heavy snow or urban flooding. Cost reduction will also be achieved by the deployment and maintenance of sensors and processes that deliver information using a unified directory, thereby minimizing duplicity of data and infrastructure.

**Building the Bridge to the Future, New Sangdo City, South Korea**

New Songdo City's origins are clearly rooted in the business hub strategy, especially South Korea’s recognition of its economic vulnerabilities and advantages within globalization’s maturing regime of neo-liberalism. The Ministry of Finance and Economy understood that South Korea’s model for economic growth was encountering a process of deindustrialization and needed reform to be competitive with Japan and contend with China’s emergence as a global economic power. A key part of the strategy was to entice corporations to set up offices in South Korea by creating an “optimal living environment,” including world-class educational and medical facilities demanded by foreign nationals.

Designed as a low-carbon, eco-friendly city, New Songdo City has abundant green areas and high-technology waste management systems. New Songdo City hosts a vibrant, rapidly growing international community. With outstanding public security, the GCF and its staff will enjoy a safe living environment. Easy access to well-equipped hospitals providing specialized services for foreign patients, and abundant leisure and cultural facilities are also available.

Conveniently located within the Seoul metropolitan area, New Songdo City is only 20 minutes from Incheon Airport, connecting it to 182 international cities. Proximity to 101 embassies will keep the GCF and its staff close to the diplomatic community and the children of the GCF will have access to 16 international schools as well. The city's location also provides convenient access to Korea’s financial infrastructure and trained personnel.
Vision of New Sangdo City:

- Reduce carbon emissions to 38% below BAU levels by 2020.
- Achieve the goals of reusing 40% of waste water and 76% of waste.

Waste Management Strategy for New Sangdo City:

Despite being a very urban environment, Sangdo international city was planned to be a green city since its initial conception. The city was designed to use clean energy sources to reduce greenhouse gas emission and the Central Park has been designed with truck-free garbage disposal system. The city will become a model example for implementation of waste management in a metropolis.

Sangdo is known for its innovation system for trash removal. Trash is directly deposited from the home through an autonomous system which can be used as a model for other cities. Apartments and office buildings have garbage chutes which feed into a central dump beneath the basement where heat energy from the waste is captured and reused to heat the buildings. There are currently five garbage processing facilities in the Sangdo area, all of which are low-profile, inconspicuous buildings that give off no smell. These five facilities recycle 76.3% of their waste.

Songdo international city aims to recycle all resources, including water, carbon, and waste. By 2020, the city plans to reuse 40% of its sewage by sending it to be processed and sanitized rather dumping it. These actions will help reach the goal of reducing carbon monoxide emissions by 26,500 tons and saving about $44 million in water and waste cost for the city.

The citywide information network enables TelePresence to connect apartments, offices and schools through video. In Sangdo, video conferencing compliments the delivery of education, health care and government services. The same network also regulates electricity and water use in all the buildings, effectively cutting operational costs and curbing waste.

Canary Wharf, Developing Sustainable Communities, London

Construction of Canary Wharf, one of the biggest and most successful initiatives of its kind in Europe – began in 1988. It kick-started regeneration across London’s Docklands. Just over two decades later, and have transformed previously derelict areas into more than 16 million square feet of office, retail and leisure space – creating a world-famous business and shopping district in central London.

Throughout this process, Canary Wharf has sought to enhance the environmental, social and economic well-being of the local communities in which it operate. This report outlines the 2012 progress in meeting this commitment.
Vision Canary Wharf City:

- Manage their properties and infrastructure in ways that cut carbon emissions created by the use of energy
- Reduce the amount of general waste produced in every aspect of their operations and segregate and divert as much as possible from landfill for reuse/recycling or energy recovery
- Reduce the use of natural resources and source recycled material when available

It has built and managed working environments. It aims to carry out those responsibilities in ways that are safe and sustainable with minimal negative impact on the wider world. This involves careful management of construction, energy use and carbon emissions, water use, waste disposal and recycling and transport.

When Canary Wharf was originally planned and its first buildings opened almost a quarter of a century ago, the project demonstrated the latest thinking and technology related to energy use. Times have changed. So has Canary Wharf Group. Now, more efficient and creative management of energy and the reduction of carbon emissions are among the most important business priorities. It is what all of the stakeholders, including shareholders, tenants, local communities and employees, rightly expect of them.

Strategies for Waste Management:

With over 70 restaurants, cafes and bars, Canary Wharf is as much a food destination as it is a business district. Inevitably, this has a bearing on waste as well as waists. To keep the former under control, in 2012 they decided to expand a pilot programme launched in Jubilee Place Shopping Mall in 2011 which saw an increase of overall recycling there from 16% to 60%.

Moreover, thanks to a switch in recycling technique from composting to anaerobic digestion, waste food from Canary Wharf was used to fuel generators that feed power back to the National Grid.

For the office buildings they manage, 72% of waste was recycled, beating the target of 70% for 2012. One reason for the overall success of recycling in the buildings managed is the fact that they make recycling easy and convenient for tenants, visitors and for their own people. Every office and retail outlet has either a two or three bin system: one for mixed recyclable waste, one for non-recyclable waste and a third for food waste, where appropriate. Oil used in Canary Wharf restaurants is recycled as bio-fuel.
The achievements:

- In 2012, they recycled more than 72% of the waste in their office buildings.
- They manage all the waste from public areas, retail units and office tenants.
- In 2013, they have aim to expand their food recycling programme. They will also aim to recycle at least 40% of their infrastructure waste and 60% of the waste generated by their retail tenants.
Mexico City, Barter Market Project

In March 2012, Mexico City’s administration initiated a barter market project to trade clean and separated household solid waste recyclables for locally produced agricultural products. The overall objective of the barter market is to build an educational program promoting a culture of recycling and local consumption among the population of Mexico City. There was a definite need for this kind of action. With about 12,500 tons of municipal solid waste generated per day ending up in landfills, the City created the barter market to explore sustainable alternatives to Landfilling, as well as develop and maintain a culture of waste minimization and recycling. Additionally, there is a growing need to provide support to local producers and traditional forms of agriculture in the rural areas of Mexico City.

The barter market takes place once a month on a Sunday morning in public places such as parks or plazas. The market is itinerant in order to gradually cover the different boroughs of Mexico City. Each citizen can trade up to 10 kilograms of waste per market day in one or more category of valuable recyclable, which currently includes paper, cardboard, PET, glass, tetra-pack, aluminium and tin cans and electronic waste. The agricultural products traded are grown by local producers in the rural areas of Mexico City and range from fruits and vegetables, to plants and homemade jams. The barter market has developed strategic partnerships with 80 local producers and several recycling companies that are responsible for collecting the waste gathered during the event and transporting it to recycling facilities.

Although the project does not include major recycling targets or CO2 emissions reduction projections, it has yielded significant results on a small scale. In 2013, 12 editions of the barter market were conducted (one every month), with nearly 20,000 citizens trading their recyclable solid waste, adding up to approximately 151,000 tons of material across all categories.

The main environmental goal of this project is to divert valuable recyclable waste from final disposal in landfills, but it is also expected to bring significant co-benefits:

- **Health benefits:** The products traded at barter markets are good quality and contribute to the fight against malnutrition, a recurrent health issue in Mexico.

- **Economic and social benefits:** The market not only benefits local agricultural producers, who receive subsidies from the City in the trading process, it also benefits the private waste industry by generating jobs in recollecting and reusing valuable recyclables traded on market days.
Buenos Aires, Solid Waste Reduction Project

An estimated 3 million people live in Buenos Aires – a number that doubles during the day with the influx of commuters – generating more than 6,000 tonnes of waste per day. The city faces the twofold problem of a large solid waste load and limited capacity to absorb waste in landfills. There is little available free land for the construction of Solid Urban Waste (SUW) treatment plants, and the installation of landfills inside the territory of the City of Buenos Aires is also unfeasible.

Therefore, the Solid Urban Waste Reduction Project aims to reduce the amount of SUW sent to landfills, guaranteeing a prior treatment of 100% of waste. This will be accomplished through waste separation at origin, recovery, recycling and valorisation, as well as measures ranging from infrastructure development – including the opening of new treatment plants – to awareness campaigns, aimed at holding both citizens and businesses accountable for their waste.

One of the central elements of the plan is SUW separation at the source, which explains the key role played by citizens. The city’s administration is currently implementing an intensive awareness campaign to educate citizens – children and adults – on how to sort, separate and deposit waste correctly. As of January 2014, there has been a 44% reduction in waste sent to landfills compared with the previous year. Progress has been made in containerization and lateral collection of SUW in order to avoid garbage bags on the streets, mitigate smell and improve the street's aesthetics. Waste transfer stations have been installed, which has had a positive impact in CO2 reduction generated by transportation. The City has also launched ‘Green Centers’ for recyclable materials, arid waste and pruning residue, and installed a Mechanical Biological Treatment (MBT) plant.

There are two major environmental goals for this project: to treat 100% of waste prior to being sent to landfills, and to reduce overall waste sent to landfills by 83% by 2017, with the recycling rate expected to reach 68% by the end of the project. The project has also been designed to generate new employment opportunities and foster greater social participation and transparency in the waste and recycling chain. Thus far, 4,500 ‘urban recoverer’ jobs have been created, with 2,000 more expected, in a sustained effort to create long-term formal employment growth.
The Kista Science City, Stockholm, Sweden

To achieve the City's environmental goals, an efficient cooperation between inhabitants, the private industry, the public sector and many other players is crucial. Environmental and information technology are both key priorities in developing a sustainable society.

Kista Science City is a creative melting pot in Stockholm where companies, researchers and students collaborate in order to develop and grow. The foremost sector in Kista is ICT (Information and Communication Technology). Figures show that few places on the planet can demonstrate the same high concentration of expertise, innovation and business opportunities within ICT. Explore the 3D-world for a deeper insight in what Kista Science City can offer people and their business.

Green IT Strategy: Green IT is the collective name for the measures designed to improve their environment with the help of IT. It involves using information technology to reduce negative impact on the environment, as well as lowering the energy consumption and environmental impact of the IT sector as a whole.

Efficient public services are key factors in a thriving city and they should be characterised by a common desire to prioritize citizens' different needs and desires. The city's responsibility is to provide support and facilitate in everyday life. Applying for permits, schools, elderly care or to plan the commuting route to work, are just a few examples of popular e-services offered.

Sweden's Waste Management Strategy: Due to Sweden’s innovative waste-to-energy program and highly efficient recycling habits, the Scandinavian nation faces an interesting dilemma. They have run out of trash.

Sweden’s waste management and recycling programs are second to none as only four percent of the nation’s waste ends up in landfills. By contrast, according to the U.S. Environmental Protection Agency, over half of the waste produced by U.S. households ends up in landfills.

Because the Swedish manage waste so effectively and then use what remains to partly power their country, they are now living an environmentalist’s dream; a shortage of garbage.

Waste Prevention & Reduction Program of Stockholm City: The Waste Management Administration in Stockholm is assigned to create an environmental friendly, cost-efficient and service minded waste management. Since the Stockholm citizens have a key role in reaching this goal, communication activities and customer guidance are two key activities for the Administration. The aim is to achieve increased confidence in the waste management system and to increase the number of customers who consider themselves well informed about waste management.
Reduction of the amount of generated waste is one of the most important challenges within the environmental field and in accordance to the waste hierarchy; this is the primary environmental objective for waste management in the City of Stockholm. The city has small instrument to impact directly on the waste flows. To increase the awareness of the consumers the communication efforts should origin from the hierarchy of waste.

The Stockholm Waste administration focuses on awareness of people residing in the city. They arrange “Guide for source segregation”, conferences, Educational Programs, dissemination and promotion of best practices, waste recycling be focussed etc to make their people fully understand. They have also issued certain bylaws and penetrate it to city council level for a robust waste management.

The City of Stockholm is a stockpile organisation. That means all waste collection and treatment is purchased. Waste management with conventional vehicle cause pollutions with large environmental impact and in the procurement process the city set specifications for requirements in terms of environmental standards collective vehicles and work machines. For example bio-fuel, tires, bio-degradable lubricants.

The main stance of policy of waste collection is biogas and mechanised waste collection to decrease the transportation. But also to collect as much of the hazardous waste as possible, increase the recycling of material and reuse it so many times as possible to decrease the amount of virgin raw material but also the amount of fossil fuel by energy recover at the last step. The City of Stockholm needs all the heat and energy that is produced by the waste, there by nothing is placed on landfill.

As waste management has developed towards less manual collection with safer workers environment and reduced environmental impact from waste collection and transportation, the City of Stockholm recommend mechanical systems for waste collection.

Mechanical waste collection system for solid waste and sorted waste fractions used and recommended are:

- Stationary and mobile vacuum suction systems
- Large compacting containers and large containers partly underground
- Waste collection systems with waste grinders for food waste

Collection of Food Waste: To increase the collection and treatment of food waste, the Waste Administration will inform all restaurants in the city and invite them to rearrange their waste handling system towards separate collection of their high-quality food-waste. The information will be combined with a visit from the staff or external consults at restaurants that are interested to participate in the separate handling of food-waste.
The city will also continue the work on initiating more food-waste treatment facilities. This will be done both by purchasing treatment-capacity and establish new plants or increase capacity at e.g. waste-water treatment plants in the region or owned by the city. This work is both a short-term and a long-term. Short-term is preparing and sending out tenders for treatment of food-waste of different qualities and long-term is expanding permits for existing business or building new plants.

**Dhaka, Integrated Solid Waste management Plan (ISWMP)**

The Integrated Solid Waste Management Plan is a comprehensive 10-year plan aimed at reducing waste generation and improving overall waste management in the Bangladeshi capital city of Dhaka. Like many fast-developing cities in the region, Dhaka is facing growth challenges (Greater Dhaka’s population is expected to rise from 14.5 million in 2005 to 17 million by 2015). The City has a limited capacity to collect and treat waste, and in 2005 less than half (44%) of the waste produced in Dhaka was collected. This is partly due to a lack of awareness among local populations, who rely mainly on informal waste collectors (tokai), and partly because the Dhaka City Corporation (DCC) in charge of collection lacked the means and skills to set up an effective collection mechanism and a waste treatment policy that could recover materials through recycling.

The ISWMP aims to manage municipal solid waste throughout its life-cycle, reduce greenhouse gas emissions, and encourage public and private sector participation. It is based on the improvement of three key operational items: Waste Reduction, Waste Collection and Waste Disposal, with a strong emphasis on raising public awareness and a significant upgrade of the existing collection assets and landfills. The connection between the Dhaka population and local authorities was a necessary condition for the success of the ISWMP. Indeed, the Clean Dhaka Master Plan is based on a ward-by-ward approach and strongly mobilizes local communities. The ‘Clean Dhaka Award Competition’ exemplifies the communication strategies undertaken by both North and South administrations to mobilize citizen support. In addition, the tokai have been included in the new waste collection system: they will be in charge of collecting small containers dedicated to household recycling and will participate in awareness campaigns.

Dhaka authorities hope to collect and treat at least 68% of the waste produced in the inner metropolitan area, which would mean an accumulated 180% increase in collection and final disposal efficiency in comparison to 2005’s 44% collection rate. The plan intends to reduce CO2e emissions mostly through the re-engineering and improvement of waste disposal sites. The re-engineering of the existing site of Matuail and the controlled landfill in Amin Bazar are projected to reduce emissions by an average of 99,000 tons of CO2e per year. The opening of a composting facility in Dhaka is also projected to reduce an average 177,000 tons of CO2e emissions per year.
Yokohama Smart City

With a population of 3.7 million inhabitants, Yokohama is the second largest city in Japan. Rapid urbanization poses significant urban challenges in terms of energy use, traffic jams, and pollution, which have led to a significant increase in the volume of total greenhouse gas emissions. The Yokohama Smart City Project strives to achieve a better management of energy use and mitigate climate change.

The Yokohama Smart City Project (YSCP) is an effort to develop a model for smart cities by means of cooperation between citizens, private companies, and the municipality, and to export the successful model to Japan and the rest of the world. Large-scale operational experiments are being held with Yokohama, a large, advanced city with a diverse topographical range of districts, as the stage. The hierarchical bundling of Energy Management Systems (EMS) enables energy management at the level of individual EMS and demand-side management at the level of the overall system.

Yokohama Smart City Project (YSCP), an initiative to establish overseas expansion of Japan's smart grid, was selected as a Next Generation Energy Infrastructure and Social System Demonstration Area by the Ministry of Economy, Trade and Industry in April 2010.

The City is collaborating with the private sector (Accenture, Tokyo Gas, Toshiba, Nissan Motor, Panasonic, Meidensha, TEPCO, etc.) to work on various projects such as introduction of renewable energy, energy management of households, buildings and local communities and next generation transportation systems.
The aim is to transform a city already provided with social infrastructure into a low-carbon city while maintaining the comfort of its residents. In order to do so, we will introduce a CEMS and develop and operate energy management systems optimized for this specific region. Together with these efforts, we will use PV generation and other forms of renewable energy, and work to change the way that citizens relate to energy. Specifically, we will introduce HEMS for homes, BEMS for offices and commercial buildings, FEMS for factories, and EV and charging stations for the transport sector, and will curb peak energy demand and conserve energy through their mutual linkage.

Four waste treatment plants are currently in operation in the City of Yokohama, including Tsurumi, Tsuzuki, Asahi and Kanazawa. Each plant recovers thermal energy from waste incineration by converting it into steam, which is then used in steam turbine generators or for heat supply to nearby facilities. City blocks which have a high demand for heat exist near some of the waste treatment plants. In this case, there is a good chance that constructing steam pipelines and supplying heat to the neighbouring high demand areas will be effective.
## STANDARDS AND CODES

As recommended by CPHEEO/ CPCB guidelines/ manuals, following are the key standards/ norms which are being adopted in India and are somewhat a reflection of developed nations:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Types of Waste</th>
<th>Categories of Waste</th>
<th>Recommended Planning for Waste Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Municipal Solid Waste</td>
<td></td>
<td>A focus should be on reduction, reuse, recycle and reclamation of waste to make the overall system more sustainable on long-term perspective.</td>
</tr>
<tr>
<td></td>
<td>a) Household/ Residential Waste</td>
<td></td>
<td>1. As recommended in various prevalent guidelines in India and across globe, the quantification of waste shall be first stage of solid waste management.</td>
</tr>
<tr>
<td></td>
<td>b) Commercial Waste</td>
<td></td>
<td>2. Secondly, a robust and efficient collection system to integrate overall waste management. A partial segregation of waste at source to be encouraged to reduce the mixing of wet and dry waste.</td>
</tr>
<tr>
<td></td>
<td>c) Non-Hazardous Industrial Waste (from workforce)</td>
<td></td>
<td>3. Waste to be transported either manually or automatically using GPS enabled trucks or pneumatic system to a central waste collection facility centre.</td>
</tr>
<tr>
<td></td>
<td>d) Waste from Garden, Street Sweeping, STP sludge</td>
<td>a) Bio-Degradable Waste</td>
<td>4. The collected waste needs to be sorted out so as to reduce waste dumping and increase in waste recycling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Recyclable Waste</td>
<td>5. Organic/ Bio-degradable waste to be compost or shall be sent to Waste-to-Energy (WTE) site for energy production.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Non-Biodegradable Waste</td>
<td>6. Recyclable waste to be sent to Recycling centre where it can be processed and recycled for future use.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Inert/ Residual Waste</td>
<td>7. Inert/ residual waste, if any, shall be sent to nearby Landfill site for further treatment and final land disposal.</td>
</tr>
<tr>
<td>2</td>
<td>Bio-Medical Waste</td>
<td>Hazardous/ Electronic Waste</td>
<td>1. Quantification of waste to be done in project so as to envisage waste generation on the basis on standard norms.</td>
</tr>
<tr>
<td>3</td>
<td>E-Waste</td>
<td></td>
<td>2. No township/ city should process these waste without any consent of state pollution control board, if they are willing to process within their project area.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. As per prevalent Indian guidelines, these wastes are to be solely handled by authorized dealers/ vendors. The polluters shall collect</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Types of Waste</td>
<td>Categories of Waste</td>
<td>Recommended Planning for Waste Management</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------</td>
<td>---------------------</td>
<td>------------------------------------------</td>
</tr>
</tbody>
</table>
| 4      | Construction Waste     |                     | the waste from their premises to a central location within their premises which shall be accessible to the vendors.  
4. The vendors/ dealers shall collect waste from each unit/ premises, on timely basis so as to reduce chaos and other social issues  
5. The treatment, processing and final disposal of waste shall be done by the vendors equipped with any WTE plants. |
| 5      | Inert/ Residual Waste  |                     | Focus should be on optimal utilization of construction material so as to reduce construction waste quantity.  
1. Even after optimal utilization, it is assumed that some portion of construction material shall form a part of waste.  
2. These wastes shall be optimally utilized within the project area as filling/ base material for roads and embankment so as to have reduction in raw material consumption.  
3. Wood, plastics, metals shall be segregated to maximum extent and shall be sent to recycling centre.  
4. These wastes can also be dumped in nearby low-lying areas with due permission from concerned department.  
5. The residual construction waste of no use, shall only be sent to Landfill site for final disposal. Since, these wastes would have no adverse impact on either land or groundwater can be disposed in Landfill site. |
|        |                        |                     | The residual waste mostly contains inorganic non-recyclable waste components which have a single use only. The quantity in general should not be more than 10% of total waste generated from project/ city. It will reflect the efficiency of overall solid waste management of township/ smart cities.  
1. These wastes shall be sent to the nearby landfill site for further treatment/ processing and final disposal.  
2. It is recommended in guidelines that these waste should be transported in GPS enabled closed trucks. The GPS will guide the trucks and help in real time |
Sr. No. | Types of Waste | Categories of Waste | Recommended Planning for Waste Management
--- | --- | --- | ---
 |  |  | analysis and in optimal route selection so as to reduce fuel consumption.

![Schematic Layout of AWC System (Waste Management)](image)

**Figure -1:** Schematic Layout of AWC System (Waste Management)

**Norms/ Standards for Quantification of Waste:**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Source of waste</th>
<th>CPHEEO/ CPCB/ NEERI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential Population</td>
<td>0.5 kg/cap/day</td>
</tr>
<tr>
<td>2. a)</td>
<td>Commercial Population</td>
<td>0.2 kg/cap/day</td>
</tr>
<tr>
<td>2. b)</td>
<td>Hotel (200 Beds)</td>
<td>1 kg/bed/day</td>
</tr>
<tr>
<td>3</td>
<td>Industrial Workforce</td>
<td>0.2 kg/cap/day</td>
</tr>
<tr>
<td>4</td>
<td>Institutional (School under PSP)</td>
<td>0.2 kg/cap/day</td>
</tr>
<tr>
<td>5</td>
<td>Roads</td>
<td>0.05 kg/cap/day</td>
</tr>
<tr>
<td>6</td>
<td>Garden (kg/ sqm/ day)</td>
<td>0.0037 kg/sqm/day</td>
</tr>
<tr>
<td>7</td>
<td>STP sludge</td>
<td>300 Kg/ MLD</td>
</tr>
<tr>
<td>8</td>
<td>Hospital/ Biomedical Waste</td>
<td>0.5 kg/bed/day</td>
</tr>
<tr>
<td>9</td>
<td>E-Waste (%)</td>
<td>7% kg/cap/day</td>
</tr>
<tr>
<td>10</td>
<td>Construction Waste</td>
<td>1.07 kg/cap/day</td>
</tr>
</tbody>
</table>
BEST PRACTICES

Sustainable Waste Management: While one of the key measures of a society's advance is the degree to which it can distance itself from its trash, waste is increasingly viewed as a strategic resource. In developed economies, tightening regulations around the disposal of waste and the increasing cost of land-filling are driving demand for innovative solutions across the municipal solid waste (MSW) value chain. In developing economies, the focus is on building out basic infrastructure in the face of rapid urbanization and rising levels of affluence. In all cases, emerging smart technologies offer the opportunity to enhance MSW collection, generate renewable energy, and optimize the environmental performance of landfills.

The trend analyses the global market for smart MSW technologies, with a focus on four segments: smart collection, smart processing, smart energy recovery, and smart disposal. Global market forecasts for the volume of MSW generated and managed globally and the revenue generated from the deployment of smart waste technologies, segmented by geography and smart waste segment, extend through next future. This report also examines key stakeholder initiatives, regulatory issues, market drivers, challenges, and technology developments and profiles the major stakeholders across the MSW value chain.

Key Performance Indicators (KPIs) for Sustainable Waste Management & Infrastructure: Smart Sustainable Cities need indicators to measure their performance for improving quality of life and sustainability globally; ISO 37120 has listed out key indicators for evaluating a city's service delivery and quality of life are given below:

<table>
<thead>
<tr>
<th>Services</th>
<th>ISO: 37120:2014 Sustainable Development for Communities: Indicators for City Services &amp; Quality of Life</th>
<th>Government of India Smart Cities Concept Note List of Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Waste Management</td>
<td>% population with solid waste collection</td>
<td>100% households with daily door-step collection</td>
</tr>
<tr>
<td></td>
<td>Total collected solid waste per capita</td>
<td>100% collection of municipal solid waste</td>
</tr>
<tr>
<td></td>
<td>% solid waste recycled</td>
<td>100% segregation of waste at source, i.e. bio-degradable and non-degradable waste</td>
</tr>
<tr>
<td></td>
<td>% solid waste disposed (landfill, incinerator, burned openly, other)</td>
<td>100% recycling of solid waste</td>
</tr>
<tr>
<td></td>
<td>Hazardous Waste generation and % waste recycled</td>
<td></td>
</tr>
</tbody>
</table>

Focus on Sustainable Solid Waste Management:

- Encouragement of Waste Segregation at Source
- Efficient Collection of Waste using robust system
- Heavy trucks shall be avoided inside the project area
- Aesthetic View of Surrounding
- Focus on No open Littering
- Optimal Recycling of Waste through Authorized vendors
- Construction Waste for Embankment and filling-up of Low lying areas
- Treatment of Bio-degradable waste using state-of-art modern technologies for optimal utilization of Methane Gas
- Manure as By-Product of shall be utilized for internal greeneries
- Reduction of Greenhouse Gas emission (reduction in carbon footprint)
**Best Practices for Municipal Waste Management across the Globe:**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Stage of Waste Handling</th>
<th>Best Waste Management Strategies being Practiced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Waste Quantification</td>
<td>The waste quantification shall be done on the basis of national/ state laws and after studying trend of waste generation from different sectors</td>
</tr>
<tr>
<td>2</td>
<td>Waste Segregation at Source</td>
<td>In developed nations, waste management is people driven. The local people shall be encouraged for waste segregation at source. Basic study reveals that people in Singapore and other developed nations have adopted waste segregation at source and are focussed on waste reuse practices.</td>
</tr>
<tr>
<td>3</td>
<td>Waste Reduction</td>
<td>The resident shall be encouraged to focus on waste reduction by different measures such as “Think before Throw”, optimal use of product and by Donating clothes and other products which may be useful for Economically weaker sections</td>
</tr>
</tbody>
</table>
| 4       | Waste Collection from Source to Intermediate Centrally Located Waste Facility (Transfer Stations) | There are different collection processes being used by different nations. The aim of a robust collection system is to collect 100% of waste from source without any ambiguity. There are two prominent waste collection system as explained below, both have pros and cons as per the requirement:  
1. **Door-to-Door Collection:** It is a conventional method to collect waste from each and every individual household. The main alteration in this system is the application of RFID and GIS, so as to have real time data/ information of town at a central location. The kerbside bins are equipped with RFID unique system and have a central control. These bins are smart bins which send signals to the control centre using ICT services and thus making operation easy and hassle free.  
2. **Automated Waste Collection System:** This system is a pneumatic based system. The waste from source through dedicated chutes (Wet or Dry) used to get transported directly to the Transfer stations through underground pipelines. This system also encourage individual to practice source segregation. |
| 5       | Waste Segregation at Transfer Station | 1. It is seen that the collected waste at CLWF are being segregated using modern technologies like metal separators. Also, in some countries, application of microbes has been seen to separate organic and inorganic waste.  
2. Mostly, the inorganic and organic wastes are segregated followed by other wastes like recyclable and non-recyclable wastes.  
3. The segregated waste then transported to different locations as per their characteristics like recyclable wastes to recycling centres and inert/ residual waste |
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Stage of Waste Handling</th>
<th>Best Waste Management Strategies being Practiced</th>
</tr>
</thead>
</table>
| 6      | Recycling of Waste                   | 1. It is one of the major pillar of 4Rs and a key for sustainable waste management. Every nation in today's scenario is focussed on waste recycling to its maximum extent.  
2. The segregated recyclable waste used to get transported in a closed GPS enabled trucks to material recovery centre. These waste then further segregated into different components vis-a-vis paper, plastic, glass, metals etc.  
3. These waste shall be processed and transformed to some useful products |
| 7      | Transportation of Inert/ Residual waste | 1. After a thorough segregation of waste at Transfer station, about 6-8% of waste would be left out as residual in nature. It is because these wastes have no second use and can also not be degraded easily.  
2. An optimal route shall be chosen to transport these inert wastes to its final processing-cum-landfill site.  
3. It is recommended to use closed trucks and shall be equipped with GPS to have a real time tracking.  
4. The routes on GIS and GPS of trucks shall be integrated with ICT central control centre. The main aim of central control centre is to guide trucks to choose optimal routes so as to cut down fuel consumption and increase in efficiency of the overall system. |
| 8      | Waste Disposal/ Treatment            | 1. It depends on the quantity of waste generated from city. If there would be high volume of waste, then it is preferable to install a Waste-to-Energy (WTE) plant within the project premises.  
2. It is optimal and efficient to plan WTE if waste generation would be in range of 150 or more.  
3. The WTE can be based on Refused-Derived Fuel/ Pyrolysis/ Incineration etc.  
4. It is recommended to treat organic waste separately using any compost based technology if the size of waste is on lower side and other inert waste to be sent to nearby Landfill site if there would be any.  
5. These inert wastes are to be processed further and can be used as a raw feed for WTE installed at Landfill site itself.  
6. The other waste which would have no use and have no adverse impact on land as well as on groundwater can be disposed off in a sanitary Landfill. |
<p>| a)     | Waste-to-Energy                      | 1. It is a best method to reduce and reclaim the waste, which have no use and over |</p>
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Stage of Waste Handling</th>
<th>Best Waste Management Strategies being Practiced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>burdening the Landfill.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. It will reduce the waste and in same time would generate energy which can be used in electricity generation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. It is recommended that the waste quantity for WTE should be more enough to sustain the plant and generate the energy at same time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. If the waste is on lower side, it would not be economically viable to invest huge capital on WTE.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. It would be best to utilize nearby Landfill site (for low waste quantity), if available with installed WTE plant.</td>
</tr>
<tr>
<td>b)</td>
<td>Waste Disposal (Landfill)</td>
<td>Land disposal is the final stage of any nation for dealing with waste management.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. It is recommended to verify and quantify of waste being sent to landfill site for disposal so as to have trends and records of waste being dumped. This would also help in checking the efficiency of overall waste management.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. The waste which even can have no or minimal impact on environment, shall be dumped in a sanitary landfill only. This will ensure 100% efficiency of system and also control leachate mixing with groundwater.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. A dedicated leachate treatment shall be installed within the landfill site so as to collect and treat the leachate generated beneath the ground due to anaerobic reaction in solid waste.</td>
</tr>
</tbody>
</table>

### Categories of Wastes

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Waste Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>Bio-Degradable</td>
<td>44-45%</td>
</tr>
<tr>
<td>1(b)</td>
<td>Recyclable</td>
<td>20-22%</td>
</tr>
<tr>
<td>1(c)</td>
<td>Non-Biodegradable</td>
<td>33-35%</td>
</tr>
<tr>
<td>2</td>
<td>Hazardous/Bio-Medical</td>
<td>0.1%</td>
</tr>
<tr>
<td>3</td>
<td>E-Waste</td>
<td>7% of MSW</td>
</tr>
<tr>
<td>4</td>
<td>Construction Waste (Tentative)</td>
<td>@ 1.07 TPD</td>
</tr>
</tbody>
</table>
### Different Treatment Technologies of Waste to Energy:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bio-Methanation</td>
<td>- Generation of gaseous fuel; &lt;br&gt;- Can be done on a small-scale; &lt;br&gt;- No external power requirement unlike aerobic treatment; &lt;br&gt;- Enclosed system enables all the gas produced to be collected for use. Green house gases &lt;br&gt;- Emission to the atmosphere is avoided; &lt;br&gt;- Free from bad odour, rodent and fly menace, visible pollution and social resistance; &lt;br&gt;- Modular construction of plant and closed treatment needs less land area; and &lt;br&gt;- Production of biogas and high grade soil conditioner.</td>
<td>- In case of digesters operated under mesophilic temperatures, destruction of pathogenic organisms may be less than that in Aerobic Composting. However, several digester systems operated at high thermophilic temperatures are also available; &lt;br&gt;- It is more capital intensive compared to composting and landfill; and &lt;br&gt;- Not suitable for wastes containing less biodegradable matter.</td>
<td>The costs of the projects especially based on biomethanation technology are high as critical equipment for a project is required to be imported.</td>
</tr>
<tr>
<td>2.</td>
<td>Refuse-Derived Fuel</td>
<td>- It is more homogeneous fuel with higher heat content than unprocessed waste. &lt;br&gt;- RDF may be burned as a supplemental fuel in an existing coal-fired boiler. &lt;br&gt;- An RDF waste processing system offers potential for increased material recovery. &lt;br&gt;- Removal of inert, non combustibles results in fewer operational problems in combustor (for example, explosions, grate jams, and slagging) &lt;br&gt;- The potential exists for reduction in air emissions and ash generation &lt;br&gt;- Reduce greenhouse gases &lt;br&gt;- Huge reduction in amount of material sent for dumping &lt;br&gt;- Use of RDF in industrial processes offers more flexibility than the simple incineration of waste. Its use permits to reduce the emission of CO₂ since the plants can partially replace the use of fossil fuel.</td>
<td>- One of the disadvantages is the fact that a cost is associated with the front-end processing to recover the fuel fraction. &lt;br&gt;- Another disadvantage is that the unit yield of energy i.e., kJ per kg of MSW. &lt;br&gt;- Processing equipment is energy intensive and requires frequent maintenance. &lt;br&gt;- Recyclable recovered during RDF processing are more contaminated and therefore more difficult to market, then recyclable separated at source of generation. &lt;br&gt;- In order to avoid constructing a boiler dedicated to burning only RDF, a suitable and long term market for RDF must be found. &lt;br&gt;- High speed shredders, which are</td>
<td>In terms of applications, RDF has been used in industrialised countries as a fuel supplement for coal-fired utility boilers and as the sole fuel for firing in dedicated boilers.</td>
</tr>
</tbody>
</table>
Collection of Waste, In-House Transportation of Waste:

**Automated Waste Collection System (AWCS):** After reviewing various similar projects all over the globe and analysing the feasibility & viability of this system, AWC system is being recommended for Indian cities. This system as can be depicted from above schematic layout, basically works on suction and pressure difference mechanism.

![Schematic Layout of AWC System (Waste Management)](image)

**Figure -1:** Schematic Layout of AWC System (Waste Management)

![Waste Collection Bins (integrated with AWC system)](image)

**Figure -2:** Waste Collection Bins (integrated with AWC system)
Figure 3: Integrated Approach for internal and external waste collection

Figure 4: Waste Collection from Public Areas
The system would be capable for:

- Collection of waste from various primary and secondary locations
- Chutes and bins are connected through this system
- It also helps in partial segregation of waste at source
- It transport waste from different locations to a centrally located processing facility unit (Transfer Station), thus no requirement of external waste transportation within the township.
- It will help in sorting of waste, thus with minimum human intervention, waste can easily be sorted into various categories.
- It would help in minimization of waste related nuisance within the township as this system is running 24 X 7 under the surface.

How this system works:

- Chutes are used to feed waste into the system
- Storage section holds the waste between transport cycles
- Primary air inlet creates an active high speed air path in the pipe network
- Discharge valves are periodically opened to allow movement of waste into the active air path
- Transport pipes form the waste path between the storage chambers and the Central Waste Handling Facility (CWHF)
- Outdoor load stations that may also feed smaller quantities of waste material into the system

Proposal for Processing and Treatment of Waste:

a) Biodegradable Waste: The Biodegradable waste may be treated within the project boundary (at Transfer Station) using modern state-of-the-art technology like Bio-Methanation or vermi-composting process.

The by-product shall be reused as manure for internal gardening and greeneries. Extra if any, shall be sold out to external agencies after framing a policy. The Bio-Methanation technology is based on principle of self-sustainable Waste-to-Energy concept.

b) Recyclable Waste: It is proposed to recycle waste to maximum extent. The recyclable waste would be sold out to authorized vendors.

c) Residual Waste: The household waste after segregation for composting and recycling from the township would be very low (about 6-8% of Non-Biodegradable waste) and thus it is not viable to install any packaged treatment plant for its processing. It is recommended to transport the residual/inert waste to the Landfill site (based on any modern state-of-art technology) so as to process it further and to utilize same as raw feed for generation of energy.

An optimal route shall be selected for transportation of these wastes from Transfer station to Landfill site. An optimal route is one that results in the most efficient use of labour and equipment.

Collection and Transfer of inert waste from Transfer Station to Landfill site shall be done using modern specialized compaction closed trucks. These trucks shall be equipped with GPS to have a track, on its in-out and collection efficiency.
It is noteworthy that the packaged plant for treatment of such a low quantity of waste would have high implication on capital investment and thus not recommended to adopt and plan separate treatment plant for residual waste.

d) **Bio-Medical Waste:** As per MoEF guidelines, authorized vendors shall be responsible to handle for processing/ collection and treatment at an appropriate site using modern technology.

e) **E-Waste:** As per applicable by-laws in India, E-Waste shall be handled and treated/ processed by authorized vendors only. Thus industries shall be responsible to collect E-Waste at a specific point and vendor shall collect from the same location. Transportation and other processing shall be done by vendors only.

f) It is also recommended to formulate a policy to select authorized vendors (*for Bio-Medical, E-Waste and other Industrial Hazardous Waste*) and make them a part of City Development group by signing a tripartite agreement so as to have better and long term control on their operations.

**Proposal for Control and Automation of System:**
To have better control on overall waste management system, Information and Communication Technologies (ICT) would play a very critical role. ICT plays a pivotal role in making a city more adapted to the contemporary needs of its citizens. The presence of these devices combined with wireless connectivity throughout a city facilitates a richer and more complex digital space within the city, which in turn can increase the collective embedded intelligence of a city.

ICT solutions are to be integrated for effective operation and management of the waste management system. Supporting ICT solution such as:

- Waste System Management with waste collection automation
- Waste management information and prognostics
- Centralized control
- Mobile waste collection solutions (with GIS, GPS, TCS)
- Customer information system, Waste accounting and Billing
- Mobile work force management
- Preventive maintenance and asset lifecycle management

**Involvement and Participation of Private Organization on PPP Model for Waste Management:**
Particular importance is being placed on building partnerships between the public and private sectors within these districts, as well as between the ICT and energy industries of the city.

PPP would help in investment for huge capital intensive infrastructure such as for Automated Waste Collection system, Bio-Methanation process, authorized vendors/ dealers for Bio-Medical, Hazardous and E-Waste Management. The recycled products can also be handled by private entity so as to make revenue by selling out or processing these wastes.

There will be huge capital requirement for planning and managing Transportation of residual waste to landfill site using modern well equipped with GPS trucks.
POLICY & REGULATORY FRAMEWORKS

While some cities in the world are converting bird sanctuaries into landfill areas, others are importing waste to meet the demands of energy from waste. With the ever growing increase in consumer goods the wastage also increases. Cities are finding it difficult to source, segregate different kinds of waste and make use of a product which can potentially bought back into consumer life cycle.

This challenge can be solved with source reduction, proper identification of category of waste and develop a proper use for the waste. There may be various forward-looking resolutions for converting waste into a resource and creating closed loop economies, but to enable this process we need proper and correct information and advanced technology.

**Smart waste management systems will empower**

- Implementation of a waste tracking system to monitor and control the movement of different kinds of waste.
- Sorting of waste without the operator coming into contact with it.
- To leverage technology to collect and share data from source to transportation to disposal of waste.
- To connect various smart waste management systems with local waste management service providers.

Although plans have been announced for the development of smart cities in India, there are lacunae in the regulatory framework relating to the development of smart cities. As a first step, what a smart city actually entails needs to be defined. Although there exists a broad general concept of a smart city, the actual objective features which would qualify a city as a smart city have not been crystallized. Any regulatory framework to govern their development would be possible once its subject matter is known and understood.

For their effective and efficient development, smart cities may require both, Central and State legislation, and possibly the inclusion of local regulation and codes as well.

The primary mode of development is on a PPP basis under the aegis of State made laws. However, since the development is highly driven by communication technology and availability of power through non traditional means, which fall within the purview of the Central Government's powers to varying extent, there may need to be a recognized regulatory framework for smart cities at various levels of governance.

For the integrated development of smart cities, special legislation dealing specifically with smart cities together with changes to existing laws may be required. As an example, the laws relating to SEZs are set out in Central and State laws. Further, the existing laws, including those relating to taxation, land acquisition and local land development laws, have been amended to provide for the rights and benefits attached to establishments of SEZs.

**Ambiguity in existing Framework:** A key issue with the development of smart cities appears to be financing. The Government proposes development of these smart cities through the PPP model. It appears that heavy reliance will be placed on private participation in the development of these new smart cities which may include financing the development to a large extent. There are proposals for substantial allocations in the Budget, but the ability of the private sector to fund such large scale development is a concern. It is pertinent to note that there is no Central legislation governing PPPs, although some States have legislated therefore.

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**International Regulatory Frameworks:** The steps taken by some foreign governments to implement development of cities as smart cities are briefly discussed below:

**a. Barcelona:** Currently, there are over 100 project components considered part of the smart city network in Barcelona. From 2011 the Urban Habitat, a centralized government body, acted as the umbrella to facilitate departments relating to urban development that used to work in isolation to come together. Underneath this Urban Habitat structure sits water, energy, human services and environment. Housing and urban planning are also grouped together. The city has created the Smart City PMO (Personal Management Office) in which different projects belong, and this PMO is responsible for coordinating the projects in the city under the smart city tag. Barcelona is also a forerunner in use of alternate energy. Barcelona Energy together with the City Council has implemented a sustainable energy initiative, making Barcelona the first city to require the use of solar water heaters in 2006. Barcelona, one of the pioneers of the smart city movement, recently held the Smart City Expo, which attracted more than 6,000 participants from 51 cities around the globe.

**b.** As early as 1998, the city of **Hong Kong** identified that ICT investment had the potential to have a positive impact on the economy. However, they were also aware that driving change in this area would bring about new challenges, and in response they developed the Digital 21 Strategy as the blueprint for Hong Kong’s ICT development. The Office of the Government Chief Information Officer (OGCIO) was established in 2004. The idea behind the OGCIO was to streamline government structure and leadership for delivering the ICT functions within the Government and to enable the Government to take a proactive, leading role in championing ICT. The Digital 21 Strategy brought together a pan-governmental ICT strategy for the first time. It contains five key action areas

(i) Facilitating a digital economy;
(ii) Promoting advanced technology and innovation;
(iii) Developing Hong Kong as a hub for technological cooperation and trade;
(iv) Enabling the next generation of public services;
(v) Building an inclusive, knowledge-based society. Today the OGCIO’s role has expanded to include running the city’s main webpage, conversion of the city of Hong Kong into a predominantly wireless city providing free wireless internet to all its citizens.

From the above it is clear that there are different models for development of smart cities – some that bring together a centralization of different functions and some that emphasize on the focused development of certain key infrastructure.

In India, for the successful implementation of the smart city structure, an integrated approach may be essential, given the plethora of regulations that would affect the actual development of a city.

**Pay-As-You Throw Program (PAYTP):** In communities with pay-as-you-throw programs (also known as unit pricing or variable-rate pricing), residents are charged for the collection of municipal solid waste—ordinary household trash—based on the amount they throw away. This creates a direct economic incentive to recycle more and to generate less waste.

Pay-As-You-throw (PAYT) breaks with tradition by treating trash services just like electricity, gas, and other utilities. Households pay a variable rate depending on the amount of service they use.

Most communities with PAYT charge residents a fee for each bag or can of waste they generate. In a small number of communities, residents are billed based on the weight of their trash. Either way, these programs are simple and fair. The fewer, individuals throw away, the less they pay.
EPA (Environment Protection Agency) supports this new approach to solid waste management because it encompasses three interrelated components that are the key to successful community programs:

1. **Environmental Sustainability** - Communities with programs in place have reported significant increases in recycling and reductions in waste, due primarily to the waste reduction incentive created by PAYT. Less waste and more recycling mean that fewer natural resources need to be extracted. In addition, greenhouse gas emissions associated with the manufacture, distribution, use, and subsequent disposal of products are reduced as a result of the increased recycling and waste reduction PAYT encourages. In this way, PAYT helps slow the build-up of greenhouse gases in the Earth's atmosphere which leads to global climate change.

2. **Economic Sustainability** - PAYT is an effective tool for communities struggling to cope with soaring municipal solid waste management expenses. Well-designed programs generate the revenues communities need to cover their solid waste costs, including the costs of such complementary programs as recycling and composting. Residents benefit, too, because they have the opportunity to take control of their trash bills.

3. **Equity** - One of the most important advantages of a variable-rate program may be its inherent fairness. When the cost of managing trash is hidden in taxes or charged at a flat rate, residents who recycle and prevent waste subsidize their neighbours' wastefulness. Under PAYT, residents pay only for what they throw away.

EPA believes that the most successful programs bring these components together through a process of careful consideration and planning.

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**Figure -5: Waste Management Hierarchy**

- **PREVENTION**: Reduce quantity and types of wastes at source is most desirable but challenging to achieve.
- **REUSE**: Putting materials and products back into use before they become waste although not everything can be reused.
- **RECYCLING**: Involves reprocessing but may be more environmentally friendly than using virgin materials. It also reduces landfilling.
- **RECOVERY**: Modern technology recovers energy, and recovery minimizes landfill use.
- **DISPOSAL**: What cannot be taken out of the waste stream needs to be landfilled.
Our 10-year Action Blueprint categorizes the decisions and actions we need to take using the waste management hierarchy for reference. Many of the actions are in fact interrelated. Better management of municipal waste will reduce greenhouse gas emissions

- The amount of municipal waste is expected to grow by 25% from 2015 to 2025.
- Increased recovery of waste, and diverting waste away from landfill play a key role in tackling the environmental impacts of increasing waste volumes.
- As recycling and incineration with energy recovery are increasingly used, net greenhouse gas emissions from municipal waste management are expected to drop considerably by 2025.
- Limiting or avoiding growth in waste volumes would further reduce greenhouse gas emissions from the waste sector and deliver other benefits to society and the environment.

**Figure -6:** Joined-up Action Agenda

*The Action Blueprint 2015-2025*