IEA Bioenergy
Technology Collaboration Programme

Environmental Impacts of Waste Management Strategies

Case studies compilation

IEA Bioenergy: Task 36

March 2025

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Case studies compilation

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Preface

This report provides case studies of waste management strategies employed in two Task 36 countries, Ireland and the US. The case study report considers waste management strategies applied to tackle particular waste challenges in each location, and the technical and environmental aspects of the strategies in relation to energy valorisation within the framework of IEA Bioenergy Task 36. The cases covered in this report were selected due to their relevance in the field of waste management and waste-to-energy, addressing waste management challenges in a regional context.

IEA Bioenergy Task 36, working on the topic '*Material and Energy Valorisation of Waste in a Circular Economy*', seeks to raise public awareness of sustainable energy generation from biomass residues and waste fractions including municipal solid waste (MSW) as well as to increase technical information dissemination. As outlined in the 3-year work programme, Task 36 seeks to understand what role waste-to-energy and material recycling can have in a circular economy and identify technical and non-technical barriers and opportunities needed to achieve this vision.

See Task 36 | Material and Energy valorisation of waste in a Circular Economy for links to the work performed by IEA Bioenergy Task 36.

Summary

Regional approaches are taken to develop waste management strategies. The environmental impacts of waste management strategies vary significantly ranging from waste prevention to disposal, and the existing waste management strategy which is being upgraded. This report provides a case study compilation of waste management strategies employed in two Task 36 countries, Ireland, an EU member state, and the U.S. The case study report considers waste management strategies, applied to tackle particular waste challenges in each location, and the technical and environmental aspects of the strategies in relation to energy valorisation within the framework of IEA Bioenergy Task 36. Each case study begins with an overview of relevant regional policies for waste management which provides context for each waste management strategy employed in the case studies.

The case studies included in this compilation are:

Waste-to-Energy facility (Indaver Ltd.) in Meath, Ireland: The Meath Waste-to-Energy (WtE) facility is a grate incinerator located near Duleek in County Meath. The incinerator was the first of its kind to operate in Ireland and it opened its gates in August 2011. The waste-to-energy facility has capacity to divert up to 235,000 tonnes of municipal waste from landfill per year and generates 18MW of electricity with 41.5% considered renewable due to combustion of waste of biological origin. Further environmental benefits arise as due to the avoided production of electricity generated at the average grid mix. Further, metals sent for recovery are assumed to displace the virgin production of such metals, hence the CO_2 emissions from production are considered to be avoided.

Renewable Energy & Urban Agriculture Campus (Green Era) in Illinois: The Green Era Renewable Energy & Urban Agriculture Campus is a local hub for renewable energy generation, urban farming, and community programming and education in the Auburn-Gresham neighbourhood of Chicago's South Side in Illinois. The campus' anaerobic digester system can process approximately 80,000 tons of food waste per year. The food waste is collected from restaurants, food companies, manufacturers, and residents, providing an alternative to the current practice of landfilling and prevents 42,500 tons of CO_2-equivalent emissions every year. Further social benefits arise from the community focus, for example by providing an onsite Education Center which will offer workshops and trainings across a variety of topics led by community practitioners.

Background

Selecting efficient waste management strategies is key for minimizing the environmental impact and resource conservation while bringing value to the communities where they are developed. Factors that need to be considered in the decision-making process include the nature and amount of the waste to be handled, resources and technology availability, current and future policy, and environmental, societal and economic aspects. In other words, decision-makers need to take a regional approach when developing waste management strategies. An important premise is that local conditions are important and no one-size-fits-all exists.

If we put the focus on policy and legislation, robust policy measurements can act as facilitator for the development of efficient waste management and circularity strategies while decreasing the environmental impact. Policies might differ considerably depending on the region. In the EU, the Waste Framework Directive (EU, 2008) and The Green Deal (EU, 2019) have set the ground for the development of the waste management strategies of the state members. The waste hierarchy, landfill directive, waste reduction & recycling targets are among the "tools" that are used to reduce the impact of waste handling while embracing the circular models in the EU. While in the U.S. there is no waste legislation at a national level. As an example, in Illinois and Chicago, the Illinois Solid Waste Management Act [1] is the main legislative act used to develop waste management strategies.

Both approaches mentioned above promote, in order of preference, waste prevention at the source, reuse, recycling (material recovery), energy recovery and finally disposal via landfill. We cannot overlook the fact that, depending on the approach chosen, ranging from waste prevention to disposal, and the waste management strategy being upgraded, the environmental impacts vary significantly.

This case study compilation begins with a brief overview of the major environmental impacts associated with various waste management strategies and continues with two cases studies which consider different waste management strategies in Ireland and the U.S. The Irish case study considers Waste-to-Energy (WtE) based on incineration to reduce reliance on landfill. The use of incineration in Ireland is influenced by the EU Waste Framework Directive which prioritises energy recovery above disposal by landfill. The U.S. case study considers anaerobic digestion of food waste collected from restaurants, food companies, manufacturers, and residents, providing an alternative to the current practice of landfilling food. Both strategies valorise recovery – material or energy - above landfilling, however it is important to consider waste strategies in the environmental, societal and economic context to ensure their suitability in achieving sustainability goals.

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[1] See Illinois Solid Waste Management Act. Available at https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=1588#:~:text=(b)%20It%20is%20the%20purpose,solid%20waste%20planning%20and%20management.

Waste Management Strategies

This section provides an overview of potential waste management strategies for valorisation of waste, along with consideration of the associated environmental impacts; and a context to the case studies in terms of the approaches that could be used to manage the waste.

Waste Prevention and Reduction

Waste prevention and reduction is the most preferred waste management strategy and has significant environmental benefits. Many countries are adopting circular economy models, keeping the value of products and materials in the economy for longer, to replace linear production which generates significant volumes of waste (Fraser, 2022). The circular economy models can reduce and prevent excessive waste generation and extend the life cycle of resources and products, (UNEP, 2024). Reducing waste can result in reduced resource extraction, reducing the need for raw materials and can decrease greenhouse gas (GHG) emissions from production and waste processing. Further, energy demand from manufacturing and transport can be reduced, resulting in significant environmental benefits. For example, a minimisation strategy for wasted food showed the best environmental performance, reducing GHG emissions, eutrophication and acidification potential impacts when compared to business-as-usual treatment of landfilling and composting (Oldfield et al., 2016). Similarly, a study carried out in Southern Sweden found that food waste prevention yields far greater reductions in GHG emissions when compared to both incineration and anaerobic digestion (Bernstad Saraiva Schott and Andersson, 2015).

Reuse and Recycling

Reuse and recycling are high up in the waste hierarchy preferences and are key strategies in the circular economy. Keeping products and materials in the economy for as long as it is safe to reused/reprocessed them can extend their lives, reducing the need for extraction of virgin resources. Recycling can help countries reduce pollution and GHG emissions by displacing primary raw materials. For example, a study found recycling the steel, nonferrous metal, plastic, and paper wastes components of 2186.3 Mt of solid waste over the period 2005 to 2017 in China avoided 3743.3 Mtoe (megatonne of coal equivalent) of energy and reduced CO_2 emissions by 4765.9 billion kg (Cudjoe et al., 2021). Taking the example of recycling of plastic waste, chemical recycling (specifically pyrolysis and gasification) are meant to play an important role in handling mixed plastic waste, provided that the main challenges to scale up plants for chemical recycling are overcome and, therefore, it is considered now as complementary to the existing mechanical recycling that is a relatively established process for mixed plastic waste treatment (Edo, 2024). Chemical recycling by pyrolysis involves converting plastic waste into its constituent building blocks, or monomers, which can be utilized in the production of new, high-quality plastics (Theofanidis et al., 2025). In the case of chemical recycling of plastic waste by pyrolysis, it causes significantly lower GHG emissions than the equivalent made from virgin fossil resources (−0.45 vs 1.89 t CO_2-eq./t plastic) (Jeswani et al., 2021). The same study found that GHG emissions are similar to mechanical recycling when quality of the recyclate is taken into consideration. However, pyrolysis has higher impacts (including on acidification, eutrophication, photochemical and ozone formation), than for mechanical recycling and energy recovery due to the high energy demand in the pyrolysis and purification processes. It should be noted that the geographical region, its energy mix, carbon conversion and efficiency of pyrolysis and recyclate quality can affect the estimation of environmental impacts.

Energy recovery

When we talk about energy recovery, we refer to several processes designed to convert waste/residues into energy or energy products. The most common are (a) the thermal processes and primarily direct combustion of waste, most often on a (moving) grate, to generate heat/electricity. Other thermal processes (much less common as of today) include pyrolysis to produce a carbon-rich solid material and/or bio-oil (depending on the technology) and gasification focused on turning waste into syngas that can be further used for methanol, ethanol or synthetic fuels production; (b) biological conversion processes such as anaerobic digestion for biogas (and digestate) production; and (c) landfilling with energy recovery (via collection and utilisation of landfill gas) usually associated with developing economies.

Combustion of waste and recovery of energy in the form of electricity and heat is usually referred to as waste incineration or Waste-to-Energy (WtE). Incineration of waste has been implemented worldwide with benefits including reducing solid volume by up to 90%, recovery of energy (heat and power), removal/destruction of contaminants/pollutants, avoidance of CH_4 emission (compared to landfills) and mitigation of soil and water contamination (Gu et al., 2019). The implementation of the circular economy will require waste-to-energy systems to transcend the traditional areas of waste, heat, and power, to keep molecules in use for longer (Johansson et al., 2023). Carbon Capture and Storage and/or Use (CCUS) could also change WtE's role in a circular economy perspective.

Biogas and biomethane production via anaerobic digestion (AD), is a multi-functional process for treatment of waste, protection of the environment, conversion of low-value material to higher-value material, for the production of electricity, heat, gaseous biofuel and digestate (Fagerström et al., 2018). The digestate material remaining after AD can be used as a fertiliser(providing that the local regulated requirements are fulfilled) (Scarlat et al., 2018), returning nutrients to the field in a circular way, thus keeping molecules in use for longer. In Europe, the EU Commission stipulates that if the digestate can be used on soils and farmlands, then AD can be considered as recycling and counts towards meeting recycling targets.

Both incineration and AD have environmental impacts. Although lower than landfilling, burning waste releases fossil CO_2 mainly from plastic waste. For AD, emissions arise from methane leakage and from digestate application (Beausang et al., 2021). A study assessing the environmental impacts of treatment strategies for the organic fraction of municipal solid waste found that anaerobic digestion had lower levels of environmental impacts compared to incineration (Mayer et al., 2020). However, WtE has the advantage of being able to handle complex, heterogeneous, as received waste mixtures.

By prioritising sustainable waste management strategies, governments and industries can significantly mitigate environmental impacts, leading to healthier ecosystems and reduced contributions to climate change.

Case Studies

This section presents the selected case studies for Ireland and the US. Each case study begins with an overview of relevant regional policies for waste management which provides context for each waste management strategy.

Ireland Case Study

Waste Management Policy in the EU

In 2008, the Waste Framework Directive (EU, 2008) was implemented into European Union Legislation as a general framework for waste management requirements and definitions for member states (EU, 2008). By reducing waste production and setting ambitious recovery targets, this would slow down the need for natural resources thus a reduction in habitat disruption, biodiversity loss, and greenhouse gas emissions.

Figure 1: Waste Hierarchy (EU, 2008)

The Waste Framework Directive (EU, 2008) involves a set of different directives for the treatment of different waste types;

1. Directive 86/278/EEC: Regulates sewage sludge use in agriculture.
2. Directive 94/62/EC: Targets packaging waste recovery and recycling.
3. Directive 1999/31/EC: Landfill Directive - Sets landfill operation requirements and conditioning plans, including requiring biodegradable waste diversion from landfill
4. Directive 2000/76/EC: Waste Incineration Directive - Reduces harmful effects of waste incineration through technical standards and emission limits.

The Waste Framework Directive establishes a “waste hierarchy” that is the foundation of the

EU waste management[2]. In other words, an order of preference for managing and disposing of waste strategies is established, being prevention the most preferred strategy, and disposal the least preferred.

In 2019, EU launched the Green Deal. Green Deal is Europe's roadmap that provides a number of actions (EU, 2019) to make the EU climate-neutral by 2050 while developing a competitive economy based on resource-efficient and is expected to be completed by May 2020. The Circular Economy Action is one of the main blocks of the European Green Deal. The aim of the plan is to strength EU's economy while fitting it in a "green future" and protecting the environment. The plan focuses on the design and production for a circular economy ensuring that that the resources are kept in the EU material closed loop for as long as possible. In other words, provide actions that will transform the way products are manufactured and encourage consumers to make sustainable choices by facilitating them the access to detailed information of the products they buy.

By 2025, the EU has set a target for municipal waste recycling to exceed 55% and packaging waste recycling to exceed 65% of waste produced. Additionally, the EU has set a target to reduce the rate of landfill to less than 10% of waste produced. Following the most recent assessment of member states progress towards the EU waste management goals, the European Commission categorised member states according to their risk of not meeting the 2025 and 2035 targets (EC, 2023), based on data from 2020. Out of the EU's 27 member states, nine member states are on track and eighteen member states are at risk, meaning they are either at risk of not meeting one or more targets (EC Directorate-General for Environment, 2023).

Policy Context in Ireland

In 1998, Ireland introduced the Changing Our Ways Policy (Environmental Protection Agency, 1998), aiming to reduce waste generation of waste and reliance on landfill, while considering incineration (waste-to-energy) as a viable alternative.

The 2002 Preventing and Recycling Waste Strategy (Environmental Protection Agency, 2002) introduced the Waste Hierarchy, mirroring the EU Waste Hierarchy (see Figure 1), prioritising waste prevention, reuse, recycling, and biological treatment, followed by energy recovery (incineration) with landfill as the least preferred treatment. This strategy was reinforced by subsequent policies, moving away from reliance of landfill as a waste management strategy, to focus on more sustainable waste management strategies including waste-to-energy. Policies include:

- The 2004 Waste Management – Taking Stock and Moving Forward report (Environmental Protection Agency, 2004).
- The 2006 National Strategy on Biodegradable Waste (Department of the Environment, Heritage and Local Government, 2006).

- The 2007 National Climate Change Strategy (Department of the Environment, Heritage and Local Government, 2007).
- The 2012 A Resource Opportunity- Waste Management Policy in Ireland (Department of Environment, Community and Local Government, 2012).
- The 2020 Waste Action Plan for a Circular Economy (Department of Environment Climate and Communications, 2020).

In an effort to reach these targets for 2025 on a national level, Ireland implemented a Waste Action Plan for a Circular Economy (Department of Environment Climate and Communications, 2020). This is a national waste policy which shifts the focus of waste management from disposal to the preservation of resources to create a circular economy. Covering the period 2020 to 2035 it follows the ambition of the European Green Deal (EC, 2019) following a range of actions to promote circularity and sustainability. The Waste Action Plan for a Circular Economy categorizes targets by the type of waste and waste treatment. The key targets under the plan are categorised by households and businesses; food waste; plastic, packaging, and single use plastic (SUP); extended producer responsibility (EPR); construction and demolition waste; textiles; treatment; enforcement; and government leadership on circular economy.

According to the European Commission, Ireland is currently at risk of not meeting the 2025 target for the preparation for re-use and recycling of municipal waste (EC Directorate-General for Environment, 2023).

Processes, infrastructure and types of waste

In 2022, 43% of municipal waste in Ireland was treated by energy recovery, 26% by material recycling, 15% by composting and AD, 14% landfilled, and 1% was unmanaged (Environmental Protection Agency, 2022).

Ireland Case Study: Waste-to-energy plant in Meath

The Meath Waste-to-Energy facility is a grate incinerator run by Indaver Ireland Ltd. It is located near Duleek in County Meath. The incinerator was the first of its kind to operate in Ireland and it opened its gates in August 2011. The waste-to-energy facility has capacity to treat up to 235,000 tonnes of municipal waste per year (see streams below), and generates 18MW of electricity, enough to power more than 42,000 homes. Small quantities of waste are occasionally imported via Transfrontier shipment (TFS) of waste from Northern Ireland.

Waste Streams

Both hazardous and non-hazardous municipal waste are treated at the facility. In 2023, 225,929 tonnes of non-hazardous waste and 8,751 tonnes of hazardous waste were treated at the facility with a total material and energy recovery rate of 98.9% for the non-hazardous and 100% for the hazardous waste (Environmental Protection Agency, 2024). Waste streams treated include (Indaver, 2024a):

- Residual non-recyclable waste from domestic & commercial/industrial kerbside collection
- Combustible residual waste from recycling processes also known as reject fractions
- Refuse derived fuel (RDF)
- Residual combustible skip waste (non-bulky)
- Contaminated packaging / clothing / PPE / liners
- Off-specification / redundant products
- Aqueous liquids e.g. wash waters from the pharmaceutical industry
- Wastewater treatment sludge

Technology

The Waste-to-Energy operations include the acceptance and incineration of waste, recovery of energy through steam generation, export of energy generated by the burning of the waste, recovery of ferrous and non-ferrous metals from the non-hazardous ash created during the burning of the waste, and the pretreatment of the hazardous ash and flue gas residues. The incinerator itself is a moving grate incinerator.

Recovered Materials

The boiler ash and flue gas residues collected after combustion are sent for recovery to a salt mine in Northern Ireland.

Performance metrics - including environmental impacts

The products of the WtE plant are electricity (used both on-site and exported), heat (not recovered for electricity production), metals (recovered), and boiler ash and flue gas residues (for disposal by backfilling).

Table 1: Data Inventory for Waste-to-Energy plant in Meath, Ireland for 2023 (Indaver, 2024a)

	Parameter	Quantity	Unit
Inputs	Amount of waste treated in 2023	234,660	tonnes
	Biogenic fraction of waste	41.5	weight %
	Heating oil (fuel)	92	tonnes
	Electricity	17,358	MWh
	Quicklime	3,788	tonnes
	Hydrated lime	1,561	tonnes
	Absorbent for dioxins and heavy metals	77	tonnes
	Expanded clay	254	tonnes
	DeNOx reagent	209	tonnes
	Ground water	86024	m3
Outputs	Flue gas	1,344,010,286	Nm3
	Energy recovery	1,957,957	GJ

	Parameter	Quantity	Unit
	Waste water	0	m3
	Bottom ash	37,877	tonnes
	Boiler ash	18	tonnes
	Ferrous metals recovered	2,677	tonnes
	Non-ferrous metals recovered	624	tonnes
	Flue gas cleaning residue	4047	tonnes
	Fly ash	10,948	tonnes
Emissions	Total CO_2 (fossil and biogenic)	210,212	tonnes
	Biogenic CO_2	128,427	tonnes
	Dust (particulates)	0.12	tonnes
	CO	6.61	tonnes
	TOC*	0.55	tonnes
	HCl	1.54	tonnes

	Parameter	Quantity	Unit
	SO_2	50.73	tonnes
	NO_x	193.21	tonnes
	Cd, Tl	0.0002	tonnes
	Hg	0.0009	tonnes
	Heavy Metals	0.1600	tonnes

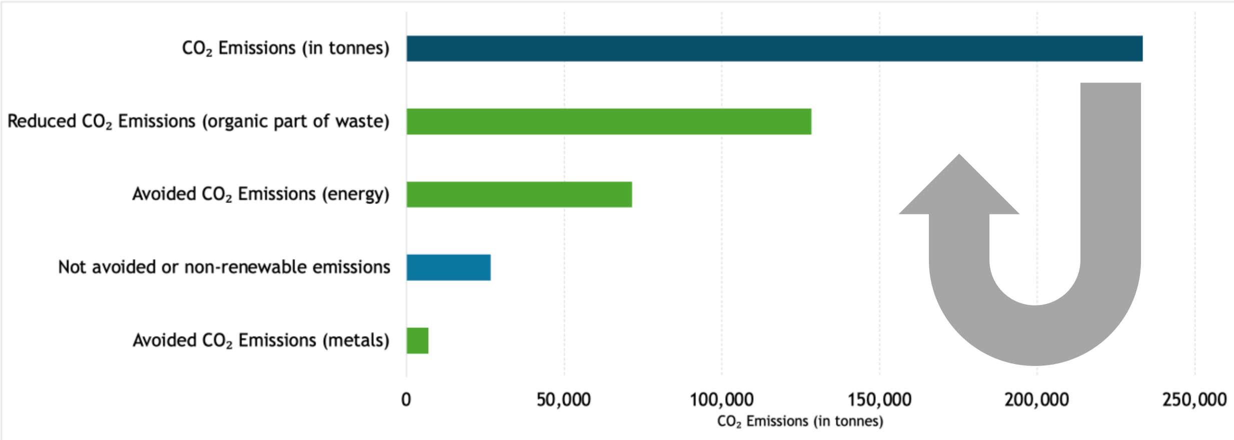
**TOC: total organic content Source:* Indaver (2024b)

The CO_2 emissions associated with operation of this Waste-to-Energy plant are outlined in Figure 2. However, as 41.5% of the waste incinerated is of a biological origin and is considered renewable, the CO_2 emissions from incineration of this portion of the MSW (128,427 tonnes CO_2) are considered to be biogenic and renewable. In addition, the Waste-to-Energy facility generates electricity, some of which is used on-site, with the remainder fed into the national grid. Therefore, it is assumed that this electricity displaces/avoids electricity generated at the average grid mix. Further, metals sent for recovery are assumed to displace the virgin production of such metals, hence the CO_2 emissions from production are considered to be avoided.

Indaver's general carbon management plan (Indaver, 2023) focuses on the following priorities:

- Avoid CO_2 from being emitted by keeping carbon in chemicals via recycling.
- Reduce use of primary energy sources in waste management including fossil fuels and electricity from the grid.
- Recover of materials including wood, plastics, metals, granulate, precious metals and water.
- Increase energy recovery.
- Consider Carbon Capture and Storage (CCS) and Carbon Capture and Usage (CCU) as a last resort for non-avoidable emissions when it is considered best available technology for the sector.

Figure 2: CO_2 emissions avoided, reduced and non-renewable



Note: Adapted from Indaver (2024b)

Indaver are considering several approaches to improve the sustainability of the Waste-to-Energy facility in Ireland. They are exploring the possibility to buffer the plant's renewable energy in batteries which can then be discharged when wind or solar systems are not generating. In 2019, Indaver provided an electric delivery truck for all on-site transport, installing a charging point to supply the delivery truck with electricity.

Indaver has a focus on maintaining biodiversity at their sites. The Waste-to-Energy facility in Meath promotes biodiversity by laying lawns, flower meadows, bushes and hedges, and reducing the use of pesticides. The site feature beehives and a small pond. Further, the horizon-line of the facility follows the undulations of the landscape.

US Case Study

Policy Context in the U.S.

This section provides an overview of waste management policies relevant to the U.S. case study. In the United States, waste management policies consist of those made at the federal level, state laws, and local initiatives. There is no national law in the United States that mandates recycling. State and local governments often introduce their own recycling requirements. Individual agencies and governments have implemented measures to address challenges in waste management and environmental concerns.

National Level Policy - The U.S. 2030 Food Loss and Waste Reduction Goal

In 2015, the U.S. Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) announced the *U.S. 2030 Food Loss and Waste Reduction goal*, with the goal to reduce food loss and waste by half by the year 2030. A Federal Interagency Collaboration between the EPA, the USDA, and the Food and Drug Administration (FDA), will work with relevant stakeholders such as communities, organisations and businesses, to take action to achieve the goal.

To measure progress to achieving the *Food Loss and Waste Reduction Goal*, the following baselines have been set for:

- **Food waste in the U.S.:** In 2016, 328 pounds (149 kg) of food waste per person was sent to landfill, controlled combustion, sewer, co/anaerobic digestion, compost, aerobic digestion, and land application. The 2030 goal aims to reduce this food waste by 50 percent to 164 pounds per person (75 kg).
- **Food loss in the U.S.:** Currently, EPA and USDA do not have a baseline for food loss, which occurs in production and up to the retail level.

State-Level Waste Management Policies in Illinois and Chicago

The approach to waste management in Illinois is guided by several key policies:

1. **The Environmental Protection Act (1970)**
   This Act ensures the protection and restoration of the environment, regulating waste disposal and the operation of waste facilities. It also mandates permits for waste management activities, imposes fees on retail and landfill operations, and includes amendments prohibiting the disposal of specific hazardous items such as lead-acid batteries and used oil through landfilling (Illinois General Assembly, 1970).

2. **The Illinois Solid Waste Management Act (1986)**[3]
   This act established a waste management hierarchy in descending order of preference, as State policy (Illinois General Assembly, 1986):

   i. volume reduction at the source;
   ii. recycling and reuse;
   iii. combustion with energy recovery;
   iv. combustion for volume reduction;
   v. disposal in landfill facilities.

   The Act also sets out requirement for purchase of items made from recycled material and also requires state-supported colleges to create waste management plans.

3. **The Solid Waste Planning and Recycling Act (1988)**[4]
   This Act required all Illinois counties, and the City of Chicago, to develop waste management plans which were to be updated and reviewed every 5 years. This Act reinforces recycling requirements and the state's commitment to sustainable waste practices, for example by mandating provisions to be made for the implementation of

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[3] See the Illinois Solid Waste Management Acthttps://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=1588#:~:text=(b)%20It%20is%20the%20purpose,solid%20waste%20planning%20and%20management.
[4] See Solid Waste Planning and Recycling Act. Available at https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=1587&ChapterID=36

a recycling program to recycle 25% of the municipal waste generated in each jurisdiction.

Chicago's Comprehensive Waste Strategy

In 2021, the City of Chicago published a comprehensive waste and materials management plan with the overarching goal of reducing waste disposal. The 2021 *City of Chicago Waste Strategy* (City of Chicago, 2021) consists multiple reports and assessments; Materials Management Strategies, Existing Conditions Report, Peer City Analysis, and the University of Illinois Chicago Waste Characterization and Generation Update report.

Key objectives of the plan are to:

- Minimize waste disposal and decrease the associated environmental impact.
- Enhance cost-effectiveness and operational efficiency.
- Maximize economic growth and workforce opportunities.
- Address social and environmental justice disparities.

For context, Chicago produced 4.13 million tons of waste in 2020, including refuse, recycling, and yard waste (Ai et al., 2021). Breakdown by source:

- Low-density residential buildings: 989,924 tons.
- High-density residential buildings: 629,735 tons.
- Institutional, commercial, and industrial sectors: 1,456,708 tons.
- Construction and demolition debris: 1,053,818 tons.

Processes, infrastructure and types of waste

Chicago's waste management processes include recycling, composting, food rescue, anaerobic digestion, and material diversion. The city utilises an extensive infrastructure network, including transfer stations, material recovery facilities, composting sites, and landfills. The city categorises waste into several streams, including municipal solid waste, hazardous household waste, electronic waste, construction debris, and pharmaceutical waste.

US Case Study: Green Era Renewable Energy & Urban Agriculture in Illinois

The Green Era Renewable Energy & Urban Agriculture Campus is a local hub for renewable energy generation, urban farming, and community programming and education. It is located on a 9-acre, former Brownfield site in the Auburn-Gresham neighbourhood of Chicago's South Side in Illinois. The Green Era Campus has taken a decade of grassroots organizing in getting the project built. The partners include: Urban Growers Collective, a Black- and women-led non-profit farm working to build a more just and equitable local food system, Green Era Educational NFP, the land owner and site developer; and Green Era Sustainability, an organization which aims to create more sustainable communities by supporting local food production through better management of biodegradable waste and access to soil, and the Greater Auburn-Gresham Development Corporation. Construction of the anaerobic digester began in Summer 2020 and was completed by Q3 2022. Final permits/approvals were issued in 2023 and work began on the Community Program Space in the same year. The Green Era Campus was launched in 2024 (Smart Cities, 2024). There is currently a lack of data on the actual operating parameters of this plant as it progresses towards full operation. The data for this case study focuses on the design phase of the Green Era Renewable Energy & Urban Agriculture Campus.

Waste Streams

The campus' anaerobic digester system is the core driver of the campus and will process approximately 80,000 tons per year or approximately 200 tons of food waste per day. The food waste is collected from restaurants, food companies, manufacturers, and residents, providing an alternative to the current practice of landfilling food.

Several sources of food waste are accepted, including;

- Solid food waste from food processors (dairies, bakeries, potato chip plants, etc.), grocery stores, and restaurants including packaged food waste.
- Source- separated bagged kitchen waste from neighbourhood curbside collection programs.
- Pumpable commercial food waste including wash/rinse water from cleaning tanks and trailers, whey, liquid ice cream mix, end of batch soups, sauces and syrups, and separated and thickened scum and solids from plant wash water.
- Fats, oils, and grease (FOG) collected from grease traps at restaurants and food processors.

Technology

The facility has been designed to receive and treat 80,000-tons per year of food waste which would have been landfilled. Most of the processes are carried out inside the processing building where the various forms of food-based waste (pumpable and non-pumpable solid food waste) are delivered, screened, and combined to form a homogenized slurry. A separation mill is used to pulp the organic waste fraction and remove contaminants (i.e., non-digestible packaging). From the separation mill, the pulped feedstock is augured into a grit separation hopper to allow for the settling of stones, sand, glass, and organic calcium (shells and bones). The pulped feedstock continues into the equalization/holding tank which serves as serve as a storage of "conditioned feedstock" before being transferred into the digester tank where the actual "in-vessel" anaerobic digestion process occurs. Within the digester tank, the food waste is heated to ~130 degrees Fahrenheit in an oxygen-free environment, and microbes break it down, producing biogas that is approximately 65% methane and 35% CO_2. The biogas is piped to the upgrading equipment where methane gas is separated from dilutant gases such as carbon dioxide and trace "contaminants" such as hydrogen sulphide and volatile organic compounds. The upgraded biomethane then injected into the natural gas distribution piping for distribution to vehicle fleets for use as a transportation fuel as well as existing natural gas customers.

Recovered Materials

At the Green Era facility, digestate and any non-digestible solids that were not removed by the separation mills or grit hopper (e.g., pieces of paper or plastic packaging) are transferred from the digester tank for screening and dewatering. The dewatered digestate creates a "cake" that is approximately 20 to 25% total solids and approximately 35 tons of digestate are produced per day. The "Finished product" cake solids are used by the Urban Growers Collective for their urban farming operations on the Green Era Campus and can be directly loaded via collection conveyors onto trucks for off-site shipment and use by other regional composters or agricultural entities. All water removed during the dewatering process is discharged to the municipal combined sewer system. However, this liquid fraction of the digestate is also rich in nutrients and can potentially be used for land application as fertilizer. As such nutrient recovery technologies are being explored to produce more concentrated fertiliser products.

Performance Metrics

The Green Era Campus anaerobic digester prevents 42,500 tons of CO_2-equivalent emissions every year by diverting food waste from landfill. Such emissions will be reduced further by capturing CO_2 which will be used to make food grade CO_2 for bottling drinks, etc.

Diverting food waste from landfill to anaerobic digestion will extend the life of nearby landfills, reducing the need for land and expense of developing a new landfill.

There are significant community benefits. The 7-acre Urban Farm will grow 125+ varieties of produce per year, train young farmers, and support new food businesses and entrepreneurs. The farm will provide a source of fresh fruit and vegetables in a neighbourhood considered a "food desert". Much of Chicago's soil is too contaminated to support local food production, the Green Era Campus will also provide digestate to other urban farming sites.

Further, the Green Era campus has a number of other facilities which can benefit the community. There is an onsite Community Education Center which will offer workshops and trainings across a variety of topics led by community practitioners to educate and engage participants both virtually and in-person. A Retail Store and Nursery will serve as a destination for learning, gathering, and food access for an estimated 2,000 people per year, selling affordable fresh produce and plants grown on the Campus Urban Farm. The campus will host weekly community events in the Event Plaza and Amphitheater that will include over an acre of outdoor community space through the Edible Forest and Walking Trail and Community Garden Plots, providing a place for neighbours to grow food while connecting with other community members.

Concluding Remarks

This report provides two case studies of waste management strategies employed in two Task 36 countries, Ireland and the U.S. The case study report considered waste management strategies, applied to tackle particular waste challenges in each location, and the technical and environmental aspects of the strategies in relation to energy valorisation within the framework of IEA Bioenergy Task 36.

Policies in both regions favour waste management strategies which focus on waste prevention, reuse and recycling, and energy recovery above landfilling. Research has shown that a food waste minimisation strategy can have the best environmental performance when compared to treatment by composting, anaerobic digestion, incineration, and landfilling and composting. In both the Irish and U.S. case studies, alternative waste management strategies have been implemented to avoid disposal of waste by landfilling which is the last priority in the relevant policies.

The Meath Waste-to-Energy facility is a grate incinerator run by Indaver Ireland Ltd., located near Duleek in County Meath. The incinerator was the first of its kind to operate in Ireland and has capacity to treat up to 235,000 tonnes of municipal waste per year, which would have been treated by landfill. The WtE plant generates approximately 18MW of electricity, enough to power more than 42,000 homes. The combustion process causes CO_2 emissions, however as 41.5% of the waste incinerated is of a biological origin and is considered renewable, the CO_2 emissions from incineration of this portion of the MSW (128,427 tonnes CO_2) are considered to be biogenic and renewable. Further environmental benefits arise as due to the avoided production of electricity generated at the average grid mix. Further, metals sent for recovery are assumed to displace the virgin production of such metals, hence the CO_2 emissions from production are considered to be avoided.

The U.S. case Study focuses on the Green Era Renewable Energy & Urban Agriculture Campus which is a local hub for renewable energy generation, urban farming, and community programming and education in the Auburn-Gresham neighbourhood of Chicago's South Side in Illinois. The campus' anaerobic digester system is the core of the campus and can process approximately 80,000 tons per year. The food waste is collected from restaurants, food companies, manufacturers, and residents, providing an alternative to the current practice of landfilling food. The Green Era Campus anaerobic digester prevents 42,500 tons of CO_2-equivalent emissions every year by diverting food waste from landfill. Such emissions will be reduced further by capturing CO_2 which will be used to make food grade CO_2 for bottling drinks, etc. The digestate from the AD will be used to help ameliorate soil in Chicago which is too contaminated to support local food production. There are significant social benefits arising alongside the environmental benefits. The Urban Farm will grow over 125 varieties of produce per year, will train young farmers, and support new food businesses and entrepreneurs. The farm will provide a source of fresh fruit and vegetables in a neighbourhood considered a "food desert". There is an onsite Community Education Center which will offer workshops and trainings across a variety of topics led by community practitioners. The campus will host weekly community events in the Event Plaza and Amphitheater which will host weekly community events. There will be an Edible Forest and Walking Trail and Community Garden Plots, providing a place for neighbours to grow food while connecting with other community members.

Both case studies highlight the environmental benefits of waste management strategies which are implemented to avoid the current regional practice of landfilling. This case study compilation highlights that different waste management strategies can be considered as responsible waste management approaches when considering local conditions, needs, trade-offs and solutions.

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