



Abstract

An exploration of the benefits of using Industry 4.0 technologies to optimize the recycled element of domestic waste collection.

The purpose of this document is to identify and evaluate potential uses of Industry 4.0 technologies to optimize the collection and recycling of municipal waste collected by Conwy County Borough Council (CCBC) via kerbside collections.

Operating a sustainable Municipal Waste management system is a key factor in the drive to achieve urban sustainability and a developing the circular economy by recycling materials and recovering energy from waste. Consumer engagement is a serious factor that can impact upon net zero.

The UK, like most developed nations, produces more waste than it can process at home: 230m tonnes a year – about 1.1kg per person per day.

['Plastic recycling is a myth': what really happens to your rubbish? | Recycling | The Guardian](#)

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Assignment 2 - Introduction to Industry 4.0 (Jaymie Phillips)

Nick Palmer

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1.0 Introduction

Conwy County Borough Council are one of the leading organizations in municipal waste management in Wales and the wider UK. (statswales.gov.wales, 2022) This essay will outline technologies, processes and systems that support the organization in achieving minimal use of landfill, as a waste management solution whilst maximizing recycling and the development of the circular economy. It will explore politics, policy, and potential opportunities to improve waste by using Industry 4.0 technology.

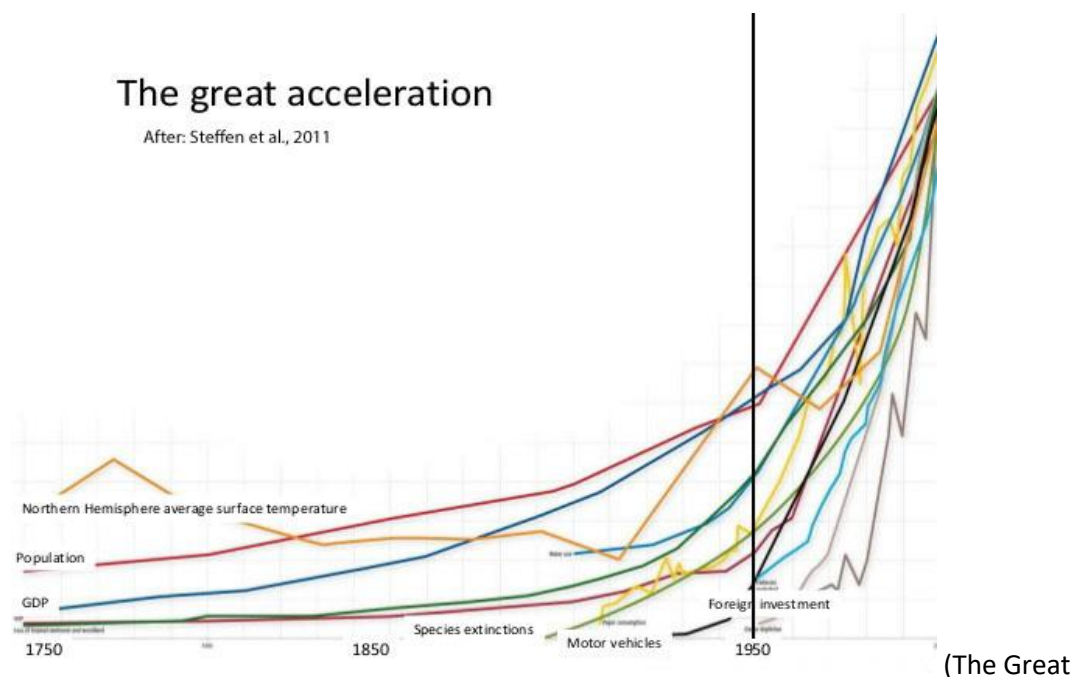
2.0 Climate Considerations

According to Will Steffen former Executive Director of the International Geosphere-Biosphere Program (IGBP) there has been “synchronous acceleration of trends from the 1950s to the present day – over a single human lifetime – with little sign of abatement. These trends are known as the Great Acceleration” (The Great Acceleration, 2016)

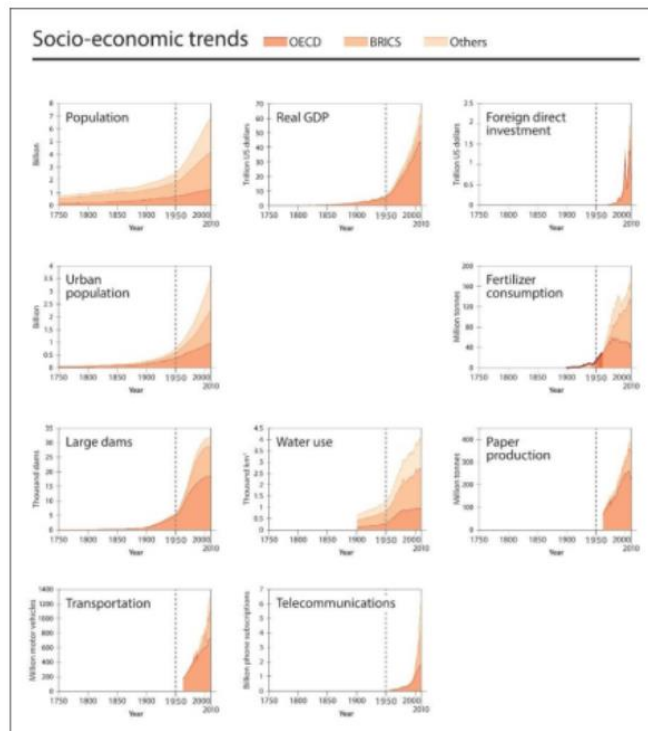
First published by Steffen in 2004 and updated in 2015 using 24 graphs to illustrate 12 Socio-economic and 12 Earth system trends from 1750 to 2010, presenting strong evidence that the Earth System has entered a new state. (The Great Acceleration, 2016)

Paul Crutzen a Nobel prize-winning atmospheric geochemist suggested to the British Geographic Survey that planet earth may have entered a new geographical epoch titled the Anthropocene. (Anthropocene, 2022)

Identified by changes in human production and consumption and illustrated by Steffen’s Great Acceleration graphs showing gross domestic product, direct foreign investment, energy consumption and telecommunications, are reflected in changes in the Earth’s natural systems: climate (greenhouse gas levels, global temperature), ocean acidification, terrestrial biosphere degradation and fish capture. (The Great Acceleration, 2016)

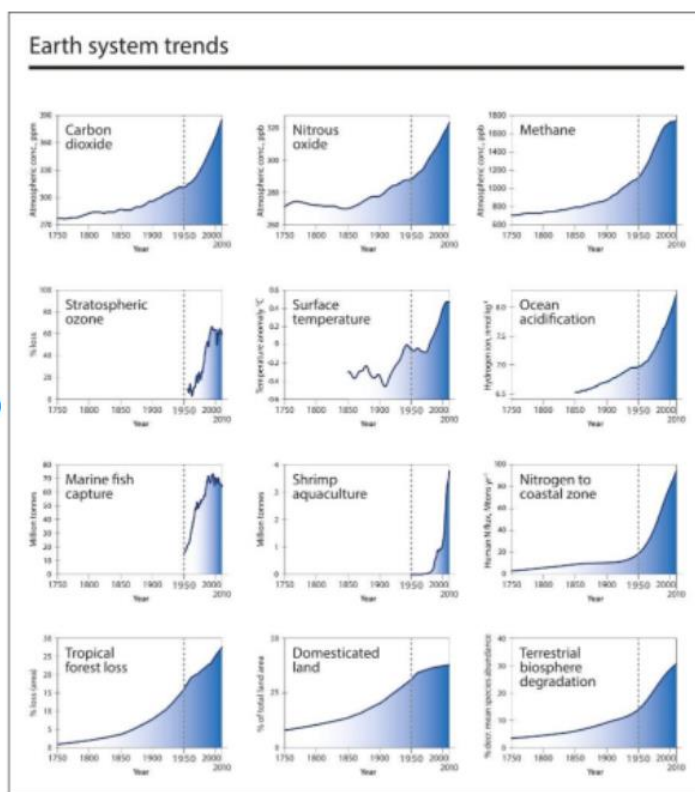


Socio Economic Trends



OECD and BRICS Socio-Economic Trends. Source: Steffen et al. (2015).

Earth System Trends



Earth System Trends. Source: Steffen et al. (2015).

It is now a globally accepted fact that earth has a finite supply of natural resources and mankind cannot continue with current rates of extraction and use. (The Great Acceleration, 2016)

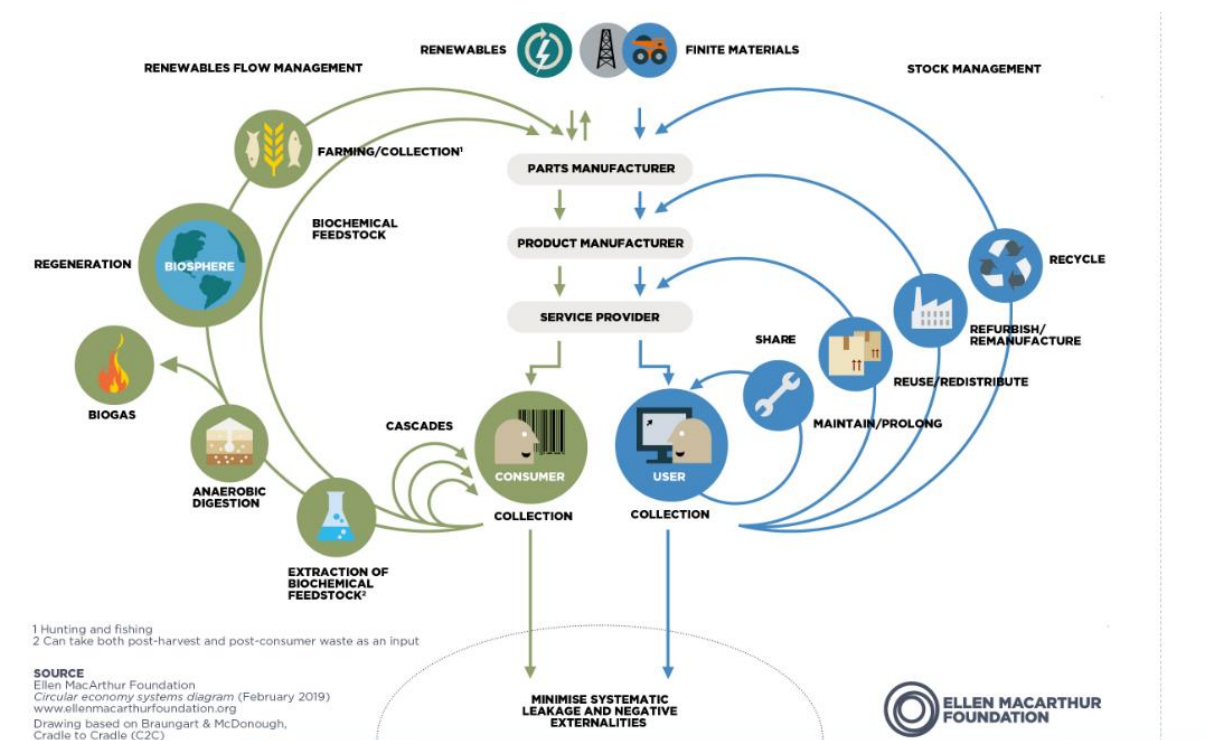
(United Nations Conference on Sustainable Development, Rio+20, 2012)

3. Linear to Circular Waste

The Ellen MacArthur Foundation suggests an alternative solution to linear waste systems, through the Butterfly model. (Ellen MaCarthur Foundation, 2022)

The diagram represents how in a circular economy there is potential to eliminate waste and pollution, circulate products and materials, and regenerate nature. (Ellen MaCarthur Foundation, 2022)

The model shows how the waste cascades at the consumer point.



(Ellen MaCarthur Foundation, 2022)

4. Policies and Pledges

Numerous world leading organizations and governments have developed pledges, policies, and legislation to pursue a sustainable agenda involving waste management. policies are one thing, action is another and either requires legislation, education or reward.

United Nations

At the United Nations Conference on sustainable development (Rio+20) June 2012, 178 countries agreed to develop a set of Sustainable Development Goals (SDGs) to building upon the Millennium Development Goals (MDG) looking to improve human lives and to protect the environment.

Seventeen Sustainable Development Goals (SDGs) were adopted at a summit in New York during 2015 as part of the 2030 Agenda for Sustainable Development. (United Nations Conference on Sustainable Development, Rio+20, 2022)

Examples of Sustainable Development Goals:

SDG11 Make cities and human settlements inclusive, safe, resilient, and sustainable <i>Target 11.6:</i> States by 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
SDG 12 Ensure sustainable consumption and production patterns <i>Target 12.1.1</i> Number of countries developing, adopting, or implementing policy instruments aimed at supporting the shift to sustainable consumption and production <i>Target 12.2.1</i> Material footprint, material footprint per capita, and material footprint per GDP (Tier II*) <i>Target 12.2.2</i> Domestic material consumption (DMC) and DMC per capita, per GDP <i>Target 12.3.1(b)</i> Food waste index (Tier II) <i>Target 12.4.1</i> Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement (Tier I) <i>Target 12.4.2</i> (a) Hazardous waste generated per capita; and (b) proportion of hazardous waste treated, by type of treatment (Tier II) <i>Target 12.5.1</i> National recycling rate, tons of material recycled (Tier II)

(Why do sustainability goals matter, 2022)

European Union

Ambitious targets were set by the EU for recycling, packaging waste and landfill in 2018, with a view to improving waste management and a move away from using landfill and incineration.

In a press release dated 03.02.2021 about the circular economy and echoing previous commitments to recycling the European Parliament said “If we keep on exploiting resources as we do now, by 2050 we would need the resources of three earths. Finite resources and climate issues require moving from a ‘take-make-dispose’ society to a carbon-neutral, environmentally sustainable, toxic-free, and fully circular economy by 2050”

In February 2021 the European Parliament introduced a further resolution, with a Circular Economy action plan demanding additional measures looking to develop a fully circular economy by 2050, with tighter recycling rules and binding targets for materials use and consumption by 2030. (New Circular Economy Action Plan, 2020)

(Waste Framework Directive, 2022) One target set for municipal waste was for members to achieve a minimum criterion of reuse and recycling of:

55% of total weight of municipal waste by 2025

60% of total weight of municipal waste by 2030

65% of total weight of municipal waste by 2035 (Waste Framework Directive, 2022)

UK Government

In the UK, in keeping with most industrialized nations waste collection is split into Domestic and Non-Domestic waste. (household waste collection in England and Wales, 2019)

Non-Domestic waste originates from commercial waste collections and has become highly legislated to meet with EU legislation to combat, using Landfill Tax to financially encourage business to manage waste through improved management process or recycling through a charging mechanism based on the volume of waste sent to landfill

Domestic waste has also been legislated but has been more difficult to implement change due to the nature of traditional management of waste collection and charging systems linked to the Domestic rates charged local council. (Gov.Wales, 2022)

Welsh Government strategy

The Welsh Government has developed its own statutory targets for municipal waste collection and recycling and has produced a strategy document developing recycling and linking it to a circular economy strategy. (Gov.Wales, 2022)

5. Overview of Industry 4.0 Technology and IOT, Cloud and Data

Some people refer to Industry 4.0 as the internet of everything. The industrial internet of things includes disciplines of energy, production, manufacturing, agriculture, healthcare, retail, transportation, logistics, aviation, space travel and more. (Gilchrist, 2016)

This includes the use of technologies containing: Sensors, devices, apps, telematics, data and cloud software and connectivity. (Gilchrist, 2016)

IOT covers a broader concept to include consumer, commercial and industrial forms of the internet. (Gilchrist, 2016)

Strategies involving Industry 4.0 and IOT must consider Technology, people and processes for success.

Gathering large amounts of data that is available through IOT also has to consider GDPR and cyber security for both individuals and industry.

Cloud Technology – Cyber Security

As technology use grows, so does the risk of cyber-attacks, more than 85% of attacks start with the human factor. (so-safeawareness.com, 2022)

Cloud software can help secure consumer data, but companies, governments or authorities collecting data should mitigate risk through policies, training and secure cloud software to manage the process. Industry standards can help support this. (so-safeawareness.com, 2022)

6. Critical Evaluation of Industry 4.0 technologies in use in the waste industry

Currently the use of industry 4.0 techniques in municipal waste collection appears to be in its infancy.

In 2021 a pilot scheme was conducted in a small area of Conwy to test consumer interaction with products displaying a QR code. (Ecosurety.com, 2022)

When conducting trials of any kind it is important to consider consumer engagement as a key part of delivery.

Consumers have a major part to play

‘Circularity is the key to long term sustainability of plastics and needs to be at the forefront of any plastic strategy. Simply put, without the participation of consumers, there will not be enough material to drive an effective circular economy for plastics. (Sustainability.com, 2022)

‘Despite the very high profile of plastic issues, this increased awareness is not translating into consumer action, and for many of us, it has not fundamentally changed the way we behave. Changing behaviors at scale is extremely difficult, with studies showing that consumers need help to move from intention to action. (Sustainability.com, 2022)’

Pilots

‘The Conwy pilot leveraged Wales-based start-up Polytag’s digital DRS ‘tag and trace’ technology. The innovative recycling platform enables brands to describe the packaging, then to ‘tag’ their packaging at the point of manufacture and with the help of consumers ‘trace’ it, so it can be isolated from the existing recycling waste stream and reprocessed in an optimal way to retain high value plastics and minimize downcycling. All consumers are required to do is scan a small QR-type code on a product’s packaging.’ (Ecosurety.com, 2022)

Another pilot involved:



(polytag.co.uk, 2022)

This pilot used: Digital Deposit Return Scheme and involved kerbside collection. (Ecosurety.com, 2022)

- A welcome pack
- Participant code and app to register
- Of 365 (H) Households – sent welcome packs/ 271 (H) registered/263 (H) engaged in at least 1 bottle scanned.
- 90% scanned at least 4 bottles.

Of the households sent the welcome pack, the report does not show reasons for 54 households who did not engage, this would be the interesting data.

Challenges, that could impede engagement could include:

- Lack of digital device or ability to use
- Inability to use app technology
- Lack of interest in recycling
- Recycled as normal in household waste

Follow ups could have included the use of IOT – to complete digital surveys to see how easy and time consuming the pilot was.

Interestingly, of the households that registered, only 8 did not scan a bottle. Why?

Prior to the trial it would have been interesting to carry out a focus group or survey to identify interest and digital ability, to include age ranges. This would have involved the use of GDPR. GDPR is the means by which consumers can be confident their data is used lawfully in accordance with policies they have signed. (UK Government, 2022)

When evaluating the pilots, it would be interesting to know what consumer methodology was used and whether Design thinking frameworks were applied.

7. Design Thinking, process

Understanding the target customer is key to motivating them to get on board with circular waste processes.



Having a policy or ideal is one think, influencing the audience is another.

Understanding:

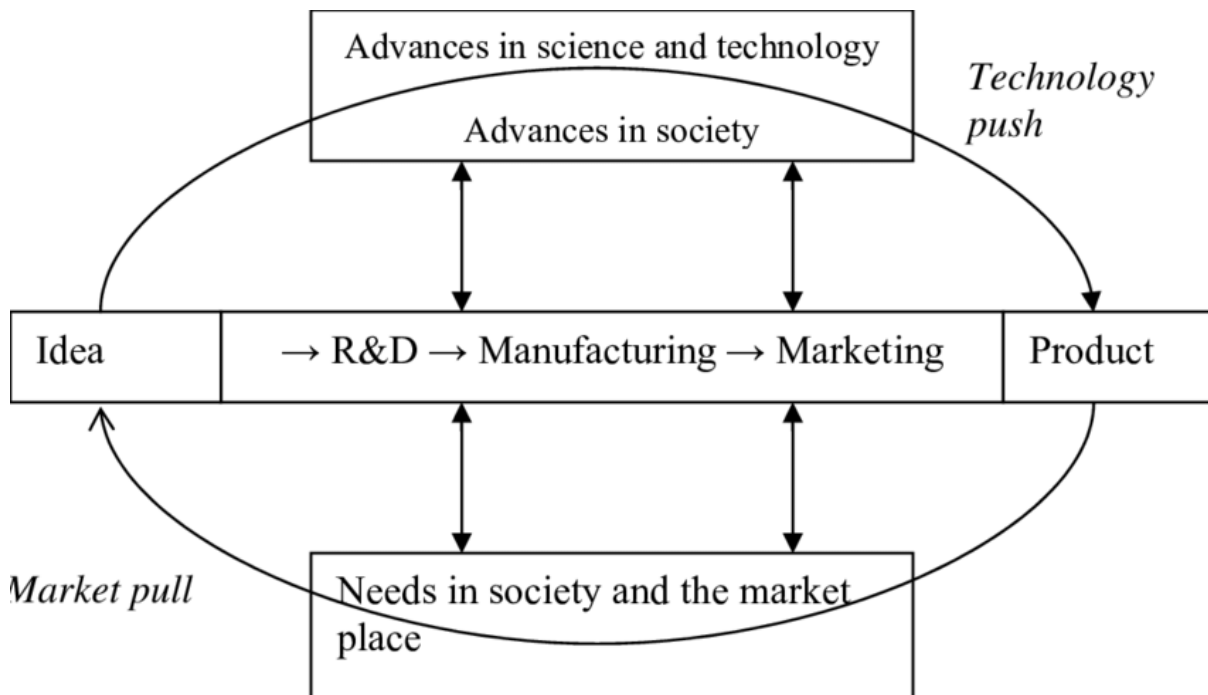
1. What matters to the consumer?
2. Creating processes that fits their needs. (Easy to use). QR?
3. Inclusion of their ideas.
4. Creating trials/prototypes
5. Providing feedback to those involved.

Are processes that include the consumer and are more likely to gain their desire to get involved.

Technology applications can support collection of knowledge and data through: Online surveys, focus groups, PR campaigns, social media - educational content.

Community engagement meetings could also be relevant to targets over 54, as this age group are shown to be less fluent with QR applications used in some of the trials.

Applying a service model to understand, educate and influence the customer to engage for societal benefit requires technology inclusion and frameworks and process management to support it.



(Reserachgate.net, 2022)

8. Technological Enablement

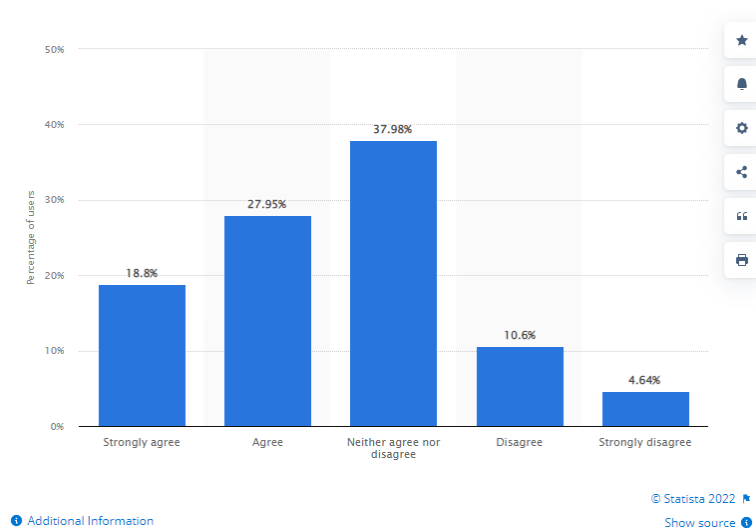
Another factor is that, of consumer familiarity and ability to use technology involved in the trials. Without consumer inclusion at the concept idea of the pilot, this would be unknown and could mitigate the success of the pilots/trials.

Consumer Technology use for QR codes (involved in pilots)



QR Codes - Quick Response codes are a matrix barcode optical labels, which contains information about the item it relates to. Commonly used to link to websites or payment systems or to explain more about the product.

QR Codes are a common sight now. Thanks to the increase in global smartphone penetration that went from 59.01% in 2017 to 78.05% in 2020. And access to high-speed mobile internet increased from 48.8% in 2014 to 62.5% in Jan 2022. In addition to this, internet users have grown by 4% from Jan 2021 to Jan 2022. Here, 92.1% of device ownership belongs to mobile phone users. (Scanova.io, 2022)



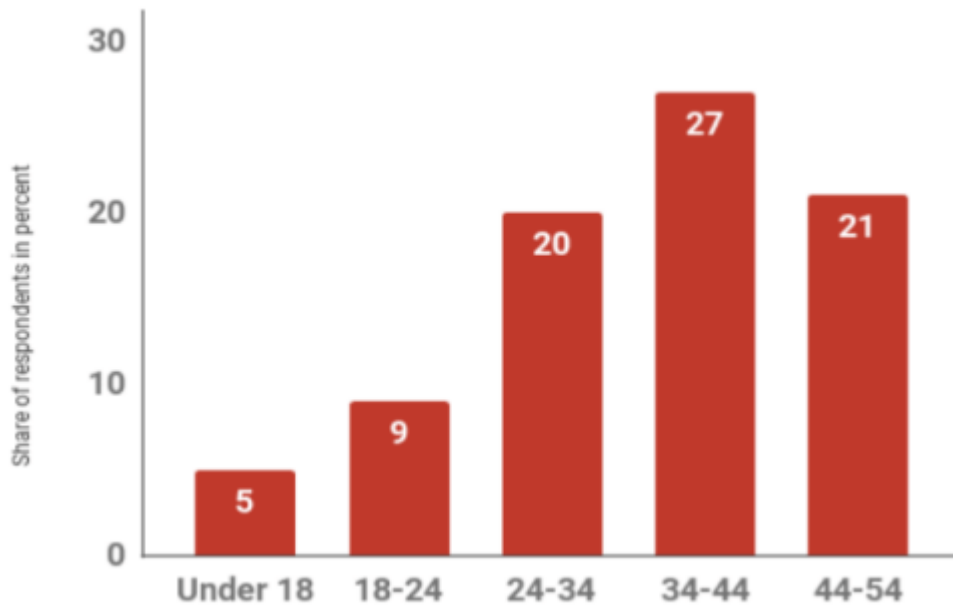
Covid 19 has supported the growth in QR code use. Shown in a survey by Statista.com

'A September 2020 survey found that 18.8 percent of consumers in the United States and United Kingdom strongly agreed that they had noticed an increase of QR code use since the begin of COVID-19 related shelter-in-place orders in March 2020.'

(Statista.com, 2022)

But while QR codes use is increasing, it is important to consider age when it comes to waste incentives and education, from a targeting perspective.

Currently use age is predominantly between 24 to 54 years of age. (Scanova.io, 2022). This will offer a challenge, to recycling trials.



(Scanova.io, 2022)

9. Comparison of a Consumer-focused Model

In Sweden, the Pant system offers consumers a deposit system for cans and bottles, paying financial rewards for recycling cans and PET bottles. (Pantamera.nu, 2022)

Sweden, have a goal of 90% percent of all cans and PET bottles to be recycled. They are achieving slightly below that number but are still one of the best in the world. (Pantamera.nu, 2022)

Recycling in percent in 2021:

Cans: 89%
 PET total: 86,4%
Total: 88,2%*

(Pantamera.nu, 2022)

Engagement and surveying seem key to their success, though this has challenges with GDPR and Cyber security, from a trust and risk of identify fraud perspective.

Trust and knowledge seem to be significant factors in achieving success. Which could mean IOT systems offer opportunity for organizations and governments, when inserting pilots or trials.

Focus Groups, Surveys and CRMs for demographic data and improved targeting can be collected using cloud storage. Collecting big data provides opportunity to build a big picture. Subject to GDPR permissions and cyber controls.

Swedish data shows:

- 83 per cent of Swedes stating that they have high or very high confidence in the system.
- 8 out of 10 Swedes feel that they are doing something for the environment when using the deposit system for their cans and bottles.
- Young men and women are the group that sticks out somewhat in the survey. They state that they are slightly less likely to use the deposit system than the population as a whole.

- Young women are also the group that claims to have the greatest confidence in the Swedish deposit system, with as many as 87 per cent stating they have high or very high confidence.
- Returpack has collaborated with the Youth Barometer. Their analyses clearly show that young people today are more value driven.
- In 2020, Returpack is placing additional focus on meeting young people's needs and increasing accessibility for this group. As a first step, Returpack is conducting youth focus groups in collaboration with the Youth Barometer.
- They identify with their leisure interests, what they spend their money on and the accounts they follow on social media. (Pantamera.nu, 2022)

This incentive shows the value of collecting data, and how people feel they are contributing to the environment by taking part – showing it is not just reward schemes that incentivize people. Including and informing people of progress via IOT and Social media channels. Suggests inclusion and trust are other factors that affect success.

10. Current System - Conwy Municipal Waste System – How it works now.

Conwy County Borough Council are responsible for the collection of Municipal waste within the county of Conwy.

There are numerous terms for Municipal Waste including Municipal Solid Waste (MSW), Solid Waste (United Nation Environment Program) (United Nations Department of Economic and Social Affairs, 2022) Local Authority Collected Municipal Waste (LACMW) used by the UK government.

With no customer facing Industry 4.0 technologies, in Conwy, it currently operates the following system for municipal waste collection:

Weekly multi-stream kerbside recycling collection in a three-box stackable system, the Trolibocs. The system comprises: a 45-litre top box for paper and card; a 55-litre middle box for plastic bottles and containers, drink cartons and cans, which are collected simultaneously and later sorted; and a 55-litre bottom box for glass and cardboard, which are sorted at the kerbside.

If Trolibocs are not practical, a small number of households have retained the old recycling system involving a bag for plastic and cans, a sack for paper and a box for glass and cardboard.

Food waste is also collected weekly from a separate 7-litre caddy, which is emptied into the same resource recovery vehicles. (Gov.Wales, 2022)

Conwy also offers one free bulky household waste collection service (furniture, large WEEE, carpets and beds) for one item a year, with an additional five items collected for £5 each at the same time. For additional collections, residents can pay £25 for up to six items.

A garden waste collection service operates fortnightly, costing £35 for a 12-month subscription. This includes one 240-litre wheeled bin, and residents can pay for a maximum of three extra bins for £20 each. Two 120-litre garden waste bags fit into each bin. (Gov.Wales, 2022)

On the same day as garden waste collection, textiles can be put out for collection in a purple sack, while small electronics are collected in pink bags and batteries in a reusable white bag. The council also provides a collection service for nappies and absorbent hygiene products, which residents can register for on the council website.

Residual waste is collected every four weeks in a 240-litre wheelie-bin.

There are also two household waste recycling centres across the county.

11. Current performance

According to figures published by the Welsh Government on 18th November 2021, CCBC was on one of four local authorities to already successfully achieved the 2024/25 target of recycling 70% of MW. (Gov.Wales, 2022)

During 2020/2021 from a total of 53,375,000 tonnes of waste collected, only 37,474,000 tonnes was recycled, most of the waste not recycled was incinerated with energy recovery – this represents nearly 30% of the total waste collected. (Gov.Wales, 2022)

This shortfall represents an opportunity for Industry 4.0 technologies to reduce this figure to help achieve the Welsh Government target of Zero Waste by 2050.

The Welsh Sustainability Action plans states an intention through their second emission plan to use the Carbon Budget 2 (2021-2025) to set the foundations to make Wales net Zero by 2050. (Gov.Wales, 2022)

On average every resident of Conwy Borough Council produces 452 Kg of waste annually, of which 135kg is not recycled. (statswales.gov.wales, 2022)

On a positive note, Conwy is one of the leading councils in Wales with the management of municipal waste. Improving over the course of the last 9 years 56.4% to 70.2% recycling rate. Reducing its landfill tonnage from 29,000 in 2012/13 to 123 tonnes in 2020/21

Area (Conwy)									
Area Code Area									
Year									
Measure	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Total Municipal Waste Collected/Generated	66,812	63,898	64,333	63,523	62,560	60,054	55,959	54,568	53,375
Total Waste Reused/Recycled/Composted (Statutory Target)	37,712	35,948	37,998	37,908	39,149	38,227	36,327	37,826	37,474
Waste sent for other recovery	21	0	0	0	0	255	289	291	4
Waste Incinerated with Energy Recovery	0	1	5,824	5,673	5,438	6,048	6,262	11,131	15,943
Waste Incinerated without Energy Recovery	67	69	62	37	0	0	0	0	0
Waste Landfilled	29,010	27,885	20,349	19,737	17,813	15,538	13,058	5,127	123
Percentage of Waste Reused/Recycled/Composted (Statutory Target)	56.4	56.3	59.1	59.7	62.6	63.7	64.9	69.3	70.2

(statswales.gov.wales, 2022)

12. Evaluation of different Industry 4.0 technologies that offer potential for use for Conwy.

Waste collection and processing systems and Systems that influence and engage the customer both offer opportunities to change the waste trajectory.

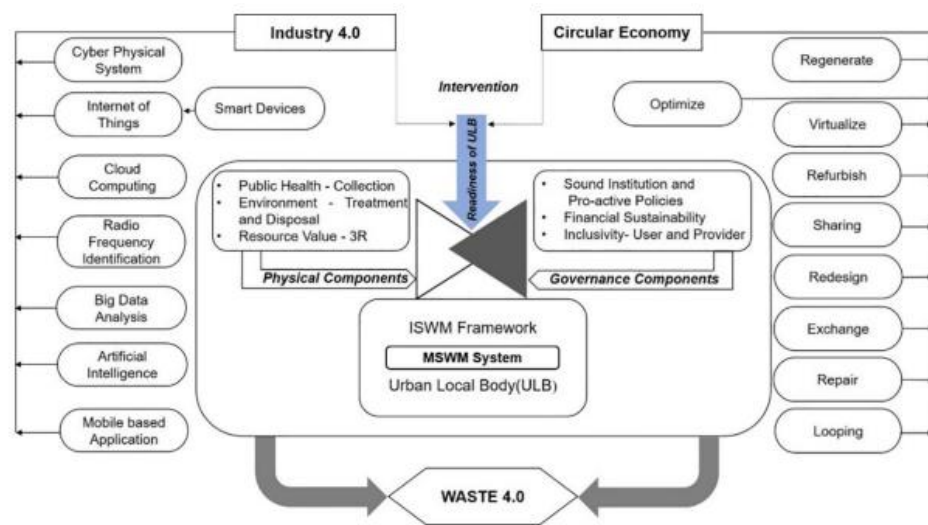


Figure 1. Components of Waste 4.0.

ISWM: integrated solid waste management; MSWM: municipal solid waste management.

Systems and Processes - SMART Technologies

‘Smart waste management refers to any system that uses technology to make trash collection more efficient, cost-effective and environmentally friendly. Most of these systems are equipped with the Internet of Things (IoT), a monitoring technology that collects and tracks real-time data, to help optimize waste collection and spur future innovation’. (Bigrentz, 2021)

The following technologies combine IOT data analytics and innovative systems:

- Smart Bins - uses artificial intelligence-based object recognition to automatically sort recyclables into separate compartments. After sorting, the machine compresses the waste and monitors how full each bin is.
Smart waste bins take human error out of the initial sorting process, making material processing faster and easier for recycling facilities. This can [lower waste management costs](#) by as much as 80% and drastically improve employee efficiency. (Bigrentz, 2021)
- Waste Level Sensor – Can be used to measure and record waste to scope the frequency of domestic wasted collections. (Bigrentz, 2021)
- A.I. Sorting Robots – Can improve efficiencies at recycling centres and reduce the need for human sorting, but this can have an impact on labour and jobs.
- Recycling Apps - Can improve education and knowledge about what to recycle, gaining human engagement. E.g., RecycleNation and iRecycle (Bigrentz, 2021)

Smart Cities are on the rise, and they offer innovative solutions to change how waste is collected, moving away from traditional models.

E.g. Songdo, South Korea was one of the first cities to implement a [truck-free waste management system](#). It achieved this by installing bins connected to a series of underground pneumatic waste pipes that transport trash to a waste processing facility, where waste is automatically sorted and either recycled, buried or burned for energy. Songdo’s system was the first to eliminate the need for

collection trucks by connecting every building in the city to the underground pipe system. This not only cut down on carbon emissions but also saved the city money. By 2014, the system only required seven workers to operate.

Although, this would probably not be viable, in established towns and cities, due to cost and existing architecture.

Consumer Behaviour – IOT and Industry 4.0

Using Technology and IOT to educate consumers and encourage positive behaviours has potential.

When considering other industries/sectors e.g., Tesco Clubcard was one of the first innovative loyalty systems used to collect large amount of data surrounding human behaviours, this was then used to feed back to consumers, promotions and advertisement, that influenced their spending habits.

Case Study: [Case Study – Tesco, Dunnhumby and the launch of Clubcard – What is Life? \(philipslambert.com\)](http://philipslambert.com)

‘How Tesco and its marketing data analytics consultancy partner Dunnhumby used Big Data to re-engineer the UK Supermarket Sector in the 1990s and 2000s. Some years before the term ‘Big Data’ first entered popular usage’. (philipslambert.com, 2021)

This does have huge implications for GDPR permissions and Cyber security and Clubcard did have a backlash, when consumers realized how their data was being used to manipulate their behaviours. This does not mean it could not have the potential to be used for good.

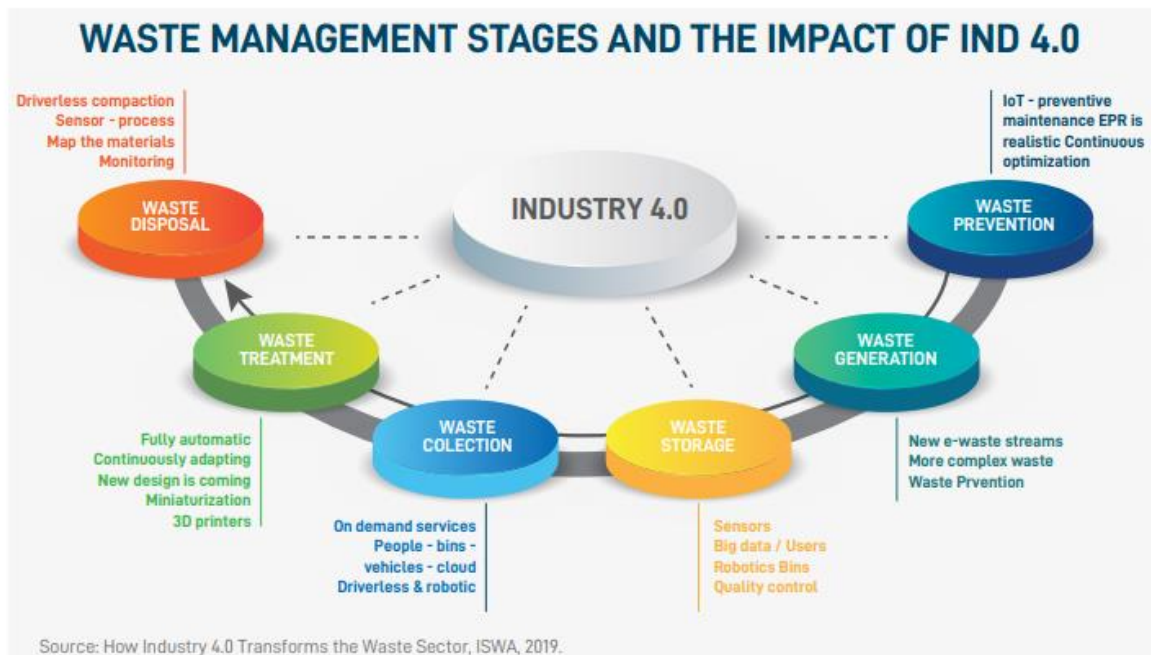
Cloud technology and security software offers protection against hackers and biotechnology uses individual thumbprints to offer the protection using bio individual identities.

Being data-driven

‘Tesco and other organizations will be clinical in keeping base-level data clean: Customer address; purchase history; purchase-location history. Based on this simple initial set of data it is relatively easy to infer additional meta-data (data about data) such as individual customer demographics (age band, income band, gender, education level etc.) and so-called event information (births, new homes etc.). But even with this information, it is no mean task to determine exactly what could and should – and should not – be done with this data’. (philipslambert.com, 2021)

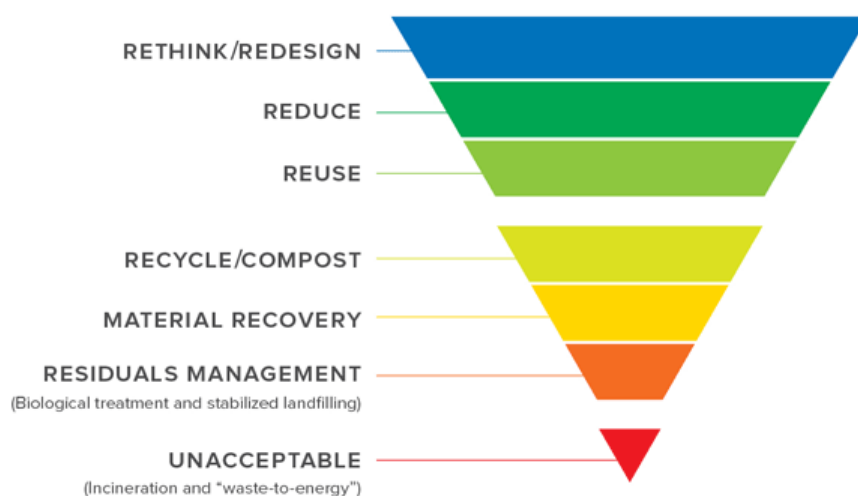
The case study does show how it is possible to use algorithms to identify engagement, through customer demographics. However, the cloud security software involved would need to be of a security standard used by government for Census or by the Police Force or NHS. Corporate and Bureaucratic systems and process differ broadly, both from a legislative perspective and modern technology investment.

13. Conclusion



When considering the goals of waste management either through climate policies and pacts or individual countries action plans and legislation, it seems that coming from a human labour force process of waste management, with virtually zero technological application, public IOT inclusion or innovation. That going forward, there will be a massive number of pilots and trials across the world. But to impact the global picture, there will need to be more data collection and knowledge sharing, to make the required impact. LMICs don't have the R & D or same resources available to them. (Blomedcentral.com, 2019)

THE ZERO WASTE HIERARCHY 7.0



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The perception is that this decade will be the period in which advances in technologies will become mainstream and profoundly change the waste industry. There is a wide trend of introducing Internet of Things (IoT) applications to waste collection practices (e.g., iPads for drivers, RFID tags on containers, etc.) as well as within transfer stations and electric vehicles. Training, measuring and monitoring use and safety will keep processes moving forwards.

The deployment and wide dissemination of Remote Monitoring & Control (RMC) for the different facilities will also follow. Cameras and sensors to manage these systems will require human intervention to interpret and act on break downs and maintenance. Will these humans be retrained and redeployed individuals or new recruits?

In terms of recycling, decontamination processes will shift from low-cost material recovery solutions to specific processes for high quality recycled materials and higher value of recyclates and secondary materials. Improvements on mechanical sorting and chemical recycling will open up new opportunities to put resources to better use by including more waste streams in the recycling industry and create a resource for new products.

When dealing with organic wastes, Bio-waste treatment facilities will be operated as bioreactors in order to create and extract chemicals and novel products from AD (and to a lesser extent composting), and technologies for contaminant removal will be in place.



These systems and processes have the potential to enable change, if the people involved in use are managed, monitored and well trained. Cost of updating previously manual waste systems to Industry 4.0 will be significant.

Also, there is a likelihood that with technological enablement, through industry 4.0 processes that there will be an impact upon human resource, as robotics and automation becomes more mainstream.

A question that will need to be asked, is what happens to the humans whose roles will become increasingly redundant. What is the plan for retraining and re-deployment? In a Sector where waste impact has long been impacting the environment without plans and strategies to change, until the last hours. Will this be the same for the human resource set to be overtaken by technology or will industry and governments apply resources to retrain and redeploy the workforce?

Consumers

When it comes to the human interaction with waste and recycling, it is evident in the most successful trials that inclusion and education, gain trust and support E.g. Sweden and whilst much of this interaction is IOT based, it cannot be ignored that there is a significant quantity of the population who remain minimally IOT literate and that other supporting inclusion events such as press releases and community interest events are still relevant.

The key aspect to improving recycling rates is to maximize the volume collected, this relies on the commitment of individuals; the communication skills of the council to get their message across and ultimately the ease of use of the service.

The message is: Preventing Waste is the goal, sending waste to landfill, should be a last option.



Preventing waste is the preferred option, and sending waste to landfill should be the last resort.

Technology

With the acceleration from the 3rd industrial revolution (Computers, data, machine learning and A.I.) to the 4th revolution (Digitization and IIOT) the opportunity for progress in waste management systems and data storage and analysis that can benefit global sustainability, advancement will come as much from open innovation, R & D and sharing successes and failures across countries. This still requires human intervention and cooperation.

Appendices.1: Examples of best practice Smart Technologies for waste collection and management.

[Guidance for separate collection of municipal waste - Publications Office of the EU \(europa.eu\)](#)

4.3.4 Engaging communication

- Improper composting leads to smell, vermin and compost that is unsuitable for use in the garden. In the long run this will hamper the penetration of composting. By disseminating user-friendly instructions and providing training services such as 'compost

Good practice example⁹⁶

The app 'Too good to go' prevents food loss by connecting, in a user friendly way, restaurants that have left-over meals with citizens that are looking for a last-minute meal at a reduced price.

⁹⁶ <https://ec.europa.eu/environment/waste/studies/pdf/>

other areas with high population density

Good practice example⁹⁹

Afval Afhaal ("Waste Collection") introduced an innovative online platform in Amsterdam, the Netherlands, to connect restaurants and small enterprises that produce bio-waste with companies that can valorize the waste, e.g. the use of citrus peels for the production of soap. Via a user-friendly app street cleaners can pick up bio-waste from restaurants and deliver it to interested companies.

4.4 References and further reading

Good practice example

The city of Bergen, Norway, is a UNESCO heritage city with narrow streets and high population density complicating waste collection transportation in vehicles. Bergen has in 2017 started using an underground pipe system, Bossnettet of almost 8 km in total pipe networks length, covering more than 5.000 households (as of January 2019). Private households, plus more than 100 business customers have been connected to an increasing amount of inlets for residual waste and paper, beverage carton and plastic. Bossnettet carries waste to a collection terminal using air thereby abolishing the need for bins or waste vehicles.

The system accepts all clean plastic packaging packed in the registered bags (for the central sorting), including detergent bottles, crisp packets, coffee bags, plastic jugs, trays, plastic bags, cling film, and bubble wrap. The registered bags are available free of charge at local grocery stores and at the mobile recycling station. Any plastic that is not packaging, such as toothbrushes or pens, can be disposed of as residual waste (see chapter 2 for obligations of the new WFD: in the future, municipalities should offer their citizens the possibility to store these plastics and bring them to a CAS).

The scheme operates with a "Pay as you throw" (PAYT) system using a key chip. Residents must use the key chip every time they dispose of waste.

This innovative facility coupled with a PAYT system and intensive communication campaigns proved to be successful. In overall the waste management company BIR reports a stable reduction in general waste generation by 8.4%, an increase of separate collection by 28% for plastic and by 10% for glass and metal.

The implementation price is high (the investment is about €127 million) but over time the initial investment costs should be offset by reduced costs: manual handling results in low operating and maintenance costs; increased sustainability credentials; possibility of better use of space; and increased property values with cleaner local environments. The annual fee that the citizen has to pay to the municipality has increased around €10. The system may be an innovative niche solution for municipalities with specific constraints on transport in the centre.¹²¹

Lastly, municipal corporations and agencies must implement smart solutions for solid waste management. Smart Waste Management System is nothing but an IoT-based solution that help corporation keep cities and towns smart and clean. Smart solid waste management systems include:

i. **RFID-Enabled Door-to-door waste collection monitoring:** The local authorities can ensure daily waste collection by placing RFID tags on each property.

ii. **Bin Sensors:** Sensors are installed on public trash bins to track the bin's status in real-time. When the waste in these bins reaches a specific threshold, sensors in the bins alert the corporation's control centre. The system automatically updates nearby collection drivers which smart bin is full. The vehicle driver then quickly empties the bins, ensuring timely cleaning of bins.

iii. **GPS Vehicle Tracking System:** Garbage collectors' whole fleet of vehicles is fitted with GPS trackers. It helps municipalities and garbage collection agencies get real-time data about garbage collection vehicles and track their route. This increases vehicle productivity and reduces costs.

iv. **Attendance App:** Keeping track of the waste collector's schedule has never been easy. However, with attendance apps and smartwatches, tracking field staff's routine has become a breeze.

Convexicon India have developed IOT-based solutions to help municipal corporations and agencies manage municipal solid waste smartly across the country. A million tons of garbage are generated in India every day, making Smart Solid Waste Management solutions vital.

Consider implementing Convexicon's SMART waste management solutions to streamline the waste management operations. Doing so will go a long way to help you achieve your operational excellence!

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