THE VALUE OF BIN SENSORS FOR THE EFFICIENCY AND EFFECTIVENESS OF PUBLIC PLACE WASTE MANAGEMENT

Prepared for:

City of Canada Bay
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Glossary

Abbreviation	Meaning	Explanation
2G	Second generation of cellular technology	A cellular communications network system that allowed text messages, picture messages, and MMS (multimedia messages). Text and phone conversations are digitally encrypted, allowing the transfer of data so that only the intended receiver can receive and read it.
2.5G	Second and a half generation of cellular technology	2G systems that have a packet-switched domain in addition to the circuit-switched domain.
3G	Third generation of cellular technology	Faster than 2G and can be used for wireless voice calls, mobile Internet access, fixed wireless Internet access, video calls and mobile television.
3GPP	3rd Generation Partnership Project	A standards organisation made up of the following regional telecommunications associations - Association of Radio Industries and Businesses (Japan), Alliance for Telecommunications Industry Solutions (USA), China Communications Standards Association (China), European Telecommunications Standards Institute (Europe), Telecommunications Standards Development Society (India), Telecommunications Technology Association (South Korea) and Telecommunication Technology Committee (Japan).
4G	Fourth generation of cellular technology	Higher capacity and speed than 3G and can be used for mobile web access, IP telephony, gaming services, high-definition mobile television, video conferencing and 3D television.
5G	Fifth generation of cellular technology	Uses higher frequencies than 4G. These frequencies are between 1 and 300 GHz up to 100 times faster than 4G.
6G	Sixth generation of cellular technology	In development. Reportedly up to 5000 times faster than 5G.
API	Application programming interface	An application programming interface is an interface or communication protocol between different parts of a computer program intended to simplify the implementation and maintenance of software
ATM	Automatic Teller Machine	A machine operated by customers that dispenses cash and performs other banking tasks. ATMs are typically located in areas of public access and are available 24 hours a day.
CAT-M1	Category M1 also known as LTE-M	New cellular technology, specifically designed for the needs of applications targeting the Internet of Things or machine-to-machine communications.
CCTV	Closed Circuit Television	A system of connected video cameras that transmit images to a specific limited number of displays or monitors on the same network or circuit
CDMA	Code Division Multiple Access	Developed during World War II a method to prevent radio signals being jammed, CDMA grants users full access to the entire spectrum of bands, allowing more users to connect at any given time, but also encodes each user's individual conversation allowing only those participating in the phone call to receive data. CDMA phones do not have to use SIM cards. Instead each phone is built specifically to work on a particular carrier's network.
CDMA2000		The 3G evolution of CDMA
DECT	Digital Enhanced Cordless Telecommunications	A standard mainly used by cordless telephone systems. It is the universal standard in Europe, Australia, most countries in Asia and South America. US radio frequency regulations delayed its adoption in North America where a variation, called DECT 6.0, operates and uses a slightly different frequency range which makes North American units incompatible with those in other areas.
Digital AMPS or D-AMPS	Digital Advanced Mobile Phone System	2G mobile phone systems developed from the North American 1G mobile system. This system is now obsolete, and networks have mostly been replaced by GSM, GPRS or CDMA2000 technologies.
EDGE	Enhanced Data Rates for GSM Evolution	A type of digital cellular technology
EV-DO	Evolution-Data Optimized	A 3G wireless radio broadband data standard that enables faster speeds than are available on CDMA networks or other 2G services, such as GPRS or EDGE.
Fitbit		Fitbit is a US company that makes wireless-enabled wearable devices. The name has become genericized to some extent and is now used to refer to all wearable computing devices, particularly bands worn on the wrist and designed to track physical activity, regardless of the manufacturer.
GPRS	General Packet Radio Service	A packet oriented mobile data standard on the 2G and 3G cellular network established by European Telecommunications Standards Institute and now maintained by the 3GPP.
GSM	Global System for Mobile Communications	A type of digital cellular technology standard developed by the European Telecommunications Standards Institute for 2G networks. It became a global standard for mobile communications.

Abbreviation	Meaning	Explanation
HSPA	High Speed Packet Access	An amalgamation of the High Speed Downlink Packet Access and High Speed Uplink Packet Access protocols. HSPA extends and improves 3G network performance using WCDMA protocols. Evolved High Speed Packet Access, also known as HSPA+ was adopted worldwide in 2010, and allows faster bit-rates.
HTTPS	Hypertext Transfer Protocol Secure	An extension of the Hypertext Transfer Protocol (HTTP) used for secure communication over a computer network
ICT Standard Protocols	Information and Communication Technology Standard Protocols	The most common practice in use in for electronic communication systems
iDEN	Integrated Digital Enhanced Network	A mobile telecommunications technology developed by Motorola. By using speech compression and TDMA, iDEN allows more users on a given channel compared to analogue cellular and two-way radio systems.
IoT	Internet of things	A system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction
IP	Internet protocol	The main set of rules for transmitting data across a network. An IP allows packets of data to be transmitted from the source host to the destination host solely based on IP addresses.
ISO 27001		The ISO/IEC 27000 family of standards covers information security management systems and compliance. It helps organisations keep information assets secure such as financial information, intellectual property, employee details or information entrusted by third parties. ISO/IEC 27001:2013 is the best-known standard and provides requirements for an information security management system. It specifies the requirements for establishing, implementing, maintaining and continually improving an information security management system in the context of an organisation. It also includes requirements for the assessment and treatment of information security risks tailored to the needs of an organisation. The requirements set out in ISO/IEC 27001:2013 are generic and are intended to be applicable to all organisations, regardless of type, size or nature.
JSON	JavaScript Object Notation	A lightweight format for storing and transporting data
LCD	Liquid Crystal Display	A type of flat panel display
LED	Light-emitting diode	A light source that emits light when current flows through it. Comes in many different colours
LoRa	Long Range	A type of wireless communication which is used in LoRaWAN
LoRaWAN	Long range wide area network	A type of LPWAN
LPWA	Low power wide area	A term used to describe wireless communications technology functioning at a low bit rate across a long range.
LPWAN	Low power wide area network	A type of wireless telecommunication wide area network designed to allow long-range communications at a low bit rate among connected objects such as battery-operated sensors. The low power, low bit rate and intended use distinguish this type of network from a wireless wide area network that is designed to connect users or businesses, and carry more data, using more power. The LPWAN data rate ranges from 0.3 Kbit/s to 50 Kbit/s per channel.
LTE	Long term evolution	A type of digital cellular technology
LTE-M	Also known as Category M1	A type of LPWAN
NB-IoT	Narrowband Internet of things	A type of LPWAN
NIDD	Non-IP data delivery	A technology that enables data to be transmitted to IoT devices without allocating an IP address. By not using an Internet protocol in transmission, the risk of a malicious attack on an IoT device is low, making it possible to build a highly secure network
PDC	Personal Digital Cellular	A second-generation technology used exclusively in digital cellular telephone communication in Japan. It uses a variation of TDMA to increase the amount of data that can be carried.
REST API	Representational State Transfer Application Programming Interface	A way for two computer systems to communicate over HTTP
SSL	Secure Sockets Layer	An encryption-based Internet security protocol that aims to ensure privacy, authentication, and data integrity in Internet communications

Abbreviation	Meaning	Explanation
TDMA	Time-division multiple access	TDMA, allows several users to share the same frequency channel by dividing the signal into different time slots. Users transmit in rapid succession, one after the other, each using its own time slot. Used extensively in satellite communications, TDMA is also used in 2G cellular systems such as GSM, IS-136, PDC and iDEN and also DECT for cordless phones.
UMTS	Universal Mobile Telecommunications System	A type of digital cellular technology
WCDMA	Wideband Code Division Multiple Access	A type of 3G cellular technology
Wi-Fi		Wireless networking technology that enables communications with Wi-Fi-enabled wireless devices

EXECUTIVE SUMMARY

This report provides an overview of the current bin sensing technologies in Australia and their associated wireless networks and legal requirements. Analyses of the most suitable wireless networks and of six case studies of bin sensing technologies are provided.

The methods used to compile this report include market analysis, legal document reviews, Internet searches for reported case studies, consultation with companies providing bin sensor technologies and councils participating in bin sensor technology trials, a SWOT analysis and a weighted assessment. A copy of the market analysis is provided in Appendix A.

This report has determined cellular and LPWAN networks are the main connection types used for bin sensor technologies. Cellular networks are distributed over areas of land called 'cells', each containing a base station. A mobile device will connect to a base station to distribute messages over data networks to the Internet. LPWAN networks are used for Internet of things (IoT) devices and have a long range but a low bandwidth so can send only small packets of data. This means large data files, such as photographs, cannot be sent over LPWAN networks. For many IoT devices, such as bin sensors, which don't send a lot of data, LPWANs are a cheaper alternative.

The six case studies included Christchurch City Council, the City and County of San Francisco, City of Canada Bay, City of Melbourne, Randwick City Council and Waverley Council. All councils except Melbourne found the technology positively influenced the number and placement of bins and found the cost and time involved with the technology to be beneficial. The City of Melbourne's negative experience was attributed to choosing a sensor not suited for the high traffic needs of the Melbourne central business district. The City and County of San Francisco, City of Canada Bay, Randwick City Council and Waverley Council had the most positive experiences with their bin sensor technology and received high scores in the final weighted scores table.

Councils considering bin sensor technology should:

- Use an integrated smart bin, such as BigBelly or eCube labs, with a compactor to increase bin capacity
- Consider cellular networks for integrated bins
- Consider either cellular networks or cellular or non-cellular LPWANs for bin sensors
- Pilot test LPWANs to determine their connectivity and ability to transmit information
- Use a system with integrated collection prediction software to reduce collection time
- Choose a system that allows the bin fullness alert to be adjusted to suit operator response times
- Use sensors that transmit daily in low traffic areas. Do not use in high-traffic areas
- Place bins in pairs, one for general waste and one for recyclables, to increase collection of recyclables and reduce contamination
- Collect bins before they overflow
- Use bin enclosures that lock to prevent overflowing bins and minimise litter and vermin
- Collect bins during off-peak periods to improve public amenity and traffic safety
- Clean and service bins and sensors to improve transmission quality

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- Choose a system that has a vibration sensor feature if bins are prone to damage or vandalism
- Choose a system that can be trialled on a smaller scale and a supplier that will allow it
- Choose a supplier that provides comprehensive training and support and
- Collaborate with contractors and staff early in the testing and acquisition process to implement bins more effectively.

This report is limited by the availability of information. Where the market analysis was unable to provide results and consultation was not possible, information such as cost, security, advantages and disadvantages may be limited.

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1 Introduction

A typical public place collection service involves a collection vehicle visiting each bin to empty it. As a result, bins are visited even though they may not be full enough to require emptying. To achieve savings in time and resources for collection staff, management, vehicles and fuel, councils are investigating bin sensor technologies so that only bins that need to be emptied are visited.

A number of companies have developed devices that can be fitted to bins which, using ultrasonic sound or other methods, measure how full a bin is and advise an operator by wireless technology, such as the mobile telephone system, when it needs to be emptied. Even though there is a cost to installing and operating bin sensors, the potential savings in service time and resources could be greater. In addition, bin sensors can provide data on public place bin use that may enable councils, and others, to better provide, position and service public place bins.

In broad terms, there are two kinds of systems. The first is one in which a whole purpose-designed bin system uses integrated sensors to measure bin fullness and advise operators. Associated routing software can then calculate the most efficient route to only visit and collect from those bins that require servicing. The other is where individual bins sensors, performing similar tasks, are fitted to existing bins.

This report will address the following:

- Information on the types of wireless connections and systems that are being used, or could be used for transmitting information from bin sensors, provided in Section 2
- Details of a range of smart bins and bin sensor manufacturers and providers resulting from research undertaken by SLR, provided in Section 3
- A review of the legalities associated with use of bin sensors, particularly privacy and the transmission and ownership of data, provided in Section 4
- Details of case studies where organisations have installed, sometimes as a trial, smart bins and/or bin sensors and the results of those installations, provided in Section 5, and
- An evaluation of the case studies that ranks the bin sensors systems in order of preference according to certain criteria, provided in Section 6.

2 Connection Types

2.1 Internet of Things

Research into the different connection platforms was prepared as part of this study. It provides information on which types of connections are used by the Internet of Things (IoT). The IoT refers to devices that collect and transmit data via the Internet. These include ATMs, Fitbits, cars, smart phones and computers among others. Sensors and smart bins are also IoT devices.

The main networks IoT devices use to connect are:

- Cellular
- Cellular LPWAN (low power wide area networks), and
- Non-cellular LPWANs.

Cellular wireless networks and cellular LPWAN networks operate using licensed frequencies while non-cellular LPWAN networks operate on non-licensed frequencies.

Licensed frequencies are radio frequencies for which an organisation pays to obtain exclusive rights to use in an area. This prevents other wireless operators from using the same frequency and interrupting each other's signals. Unlicensed frequencies aren't paid for and can be used by anyone. Because these signals are used for transmitting over very short distances, such as between a wireless keyboard and a computer, it is not always cost effective to buy a license.

LPWANs are network alternatives that have been built to connect IoT products. They have a long range, but a low bandwidth so can send only small packets of data. This means large data files, such as photographs, cannot be sent over LPWAN networks. For many IoT devices, such as bin sensors, which don't send a lot of data, LPWANs are a cheaper alternative to traditional mobile networks.

2.2 Cellular Network

2.2.1 Overview

A cellular network is a network distributed over areas of land called 'cells'. Each cell features a base station or mobile phone tower which sends and receives messages. A mobile device will connect to the nearest or least congested base station. The base stations are connected to a digital exchange where messages are sent to other telephone or data networks.

The number of users in large towns and cities means that cells in those areas are often smaller in size. Higher the population density requires more base stations.

Communication over a mobile network can be made by voice, data, images and text messages. A standard Internet protocol (IP) is used to package the message so it is not scrambled or corrupted during transmission. These data packets travel from the Internet through the base station to mobile devices.

Each cell is served by at least one fixed-location base station, but more often by three stations. The base stations receive signals by cable and transmit them by radio making the last link in the network wireless.

The typical mobile phone network includes:

- A network of base stations
- The core circuit switched network for handling voice calls and text
- A packet switched network for handling mobile data, and
- The public switched telephone network to connect subscribers to the wider telephony network.

There are a number of different digital cellular technologies. These include:

- Global System for Mobile Communications (GSM)
- General Packet Radio Service (GPRS)
- cdmaOne
- CDMA2000
- Evolution-Data Optimized (EV-DO)
- Enhanced Data Rates for GSM Evolution (EDGE)
- Universal Mobile Telecommunications System (UMTS)
- Digital Enhanced Cordless Telecommunications (DECT), and
- Digital AMPS (IS-136/TDMA) and Integrated Digital Enhanced Network (iDEN).

The transition from analogue to a digital standard resulted in multiple digital standards surfacing in the USA, while in Europe and many other countries, including Australia, the global system for mobile communications (GSM) standard was preferred. The GSM standard is now obsolete and there are no GSM networks still operating in Australia.

Current cellular connection has guaranteed connectivity because it is a continuous network. Bins with integrated sensors and bin sensor devices with frequent transmissions often rely on cellular connection due to the amount of information they collect.

Because there is a cost for each sensor to transmit to the base station, some manufacturers use a 'slave-master' system. Slave sensors transmit signals to the master sensors, which then transmits all the signals to the base station. In this case, rather than multiple devices transmitting to the base station, one device is the go-between.

2.2.2 Network Protocols

The network protocol is the system that defines how devices communicate with each another on the network. Driven by the need to transmit more data, over time, service providers (also known as carriers or operators) upgrade their networks to allow more tasks to be done. Service providers invest in the hardware and software needed to make each generation of communications possible. These generations of upgrades are numbered - 2G, 3G, 4G and now 5G.

2.2.2.1 2G

2G only enabled the transmission of phone calls and text messages, as these have relatively low data consumption. It had a global roaming range but was slower and had a limited ability to communicate. 2G systems used the GSM standard which some countries in Europe still support.

All three of Australia's service providers, Optus, Telstra and Vodafone, had shut down their 2G networks by the end of 2018.

2.2.2.2 GPRS

GPRS stands for 'general packet radio service' and was used to upgrade 2G networks to 2.5G. 3G and 4G networks outperform GPRS in both speed and reliability. GPRS is often still used in rural areas in other countries, but this network was discontinued in Australia when Optus, Telstra and Vodafone closed their 2G networks at the end of 2018.

2.2.2.3 3G

3G enabled the transmission of more data and allowed music, videos and web browser pages to be transmitted more quickly. 3G is generally slow compared to a home broadband (high-speed) connection, but faster than 2G. Common 3G cellular technologies include:

- WCDMA
- CDMA2000
- HSPA
- 3G LTE
- EV-DO Revision B
- DO Advanced, and
- Mobile WiMAX.

Australia's three service providers, Optus, Telstra and Vodafone still operate 3G networks.

2.2.2.4 4G

4G was developed to provide an even faster service than 3G. Its advantages include:

- Higher capacity – it supports more users on the network at a given time
- Higher data rates – it allows more data-demanding services, for example videos work more smoothly
- Reduced delay from the time an input is made to the time it takes to receive the result, and
- Processing more data per second.

Initially 4G didn't have set standards, so any network faster than 3G could claim to be 4G. However, connection speeds must now have a peak of 100 megabits per second to be classified as 4G. The most common frequency used is 700 MHz.

Australia's three service providers, Optus, Telstra and Vodafone operate 4G networks.

2.2.2.5 LTE

LTE stands for 'long term evolution'. LTE is easy to scale up for greater capacity and performance and it is widely considered a good long-term option, which accounts for its name. It does not function with 3G systems.

With LTE, devices can transmit and receive simultaneously because they use different frequencies for these tasks. One way this is done it using OFDM (orthogonal frequency division multiplexing) which divides a signal into parallel data streams that travel on radio sub-channels. The signal is pieced together by processors at the other end. Another method is also used called MIMO (multiple input multiple output). MIMO relies on multiple antennas and transmitters in both the phone and base station and enables simultaneous upload and download transmission.

Australia's three service providers, Optus, Telstra and Vodafone operate LTE frequencies.

2.2.2.6 5G

5G is up to 100 times faster than 4G. It includes the following advantages:

- Increased speed – it supports more Internet activity at one time
- Lower latency – it loads pages and responds to tasks quicker, and
- Better performance and efficiency.

5G operates in the same way as the other cellular networks but uses higher frequencies, between 1 and 300 GHz.

This service has already been released in some major Australian cities but will not be reach the rest of Australia at substantial speeds until after 2020. Current 5G speeds are lower than Australia's 4G speeds and use a band frequency of 3.5 GHz. This frequency is much higher than 4G.

Once service providers obtain access to higher bands, 5G services will be able to carry more data. However, higher frequencies have a shorter range. To compensate for this, micro-cells are installed throughout an area to boost connection. Microcells are similar to the cell towers or base stations used today, but, instead, the device is the size of a small box which is fitted to an existing object such as a streetlight or power pole. The service signal can be affected by anything between the microcell and the receiver including trees, wires and buildings. Many, many microcells will be required to provide adequate coverage.

Because it can keep up with high traffic demand, 5G will be able to support connections for even more IoT products and IoT products which record and transmit a lot of data. Because of IoT's potential future on 5G, security must be increased to manage possible threats.

2.2.2.7 Cellular LPWAN

2.2.2.7.1 LTE-M/CAT-M1

CAT-M1 stands for 'Category M1'. Also known as LTE-M, CAT-M1 is one of two technologies which have the support of the 3rd Generation Partnership Project (3GPP). The 3GPP also endorses NB-IoT (see Section 2.2.2.7.2) and both systems are expected to become the de-facto connectivity solutions for IoT products.

CAT-M1 is a type of cellular connection released over the 4G LTE network. It has nationwide coverage in the US. It is a low power wide area (LPWA) interface that is designed for devices with long battery lives and works best for devices which can sleep and enter a low power mode between connections.

Its other advantages include:

- Allowing LTE networks to support devices which emit lower rates of data in a cost-effective way
- Providing security as it operates over a licensed, private network
- Significantly smaller bandwidth than other cellular services which is more than enough for most IoT applications
- Connecting remotely located sensors or any devices powered by batteries as it has very low power requirements
- International roaming capability and suited for roaming devices
- Switching easily between base stations, like a phone
- Extended range and deep penetration in buildings and basements, and
- Cheap modems with all the advantages of the LTE network. This is especially useful when installing many devices on a limited budget.

Two of Australia's service providers, Vodafone and Telstra, offer CAT-M1.

2.2.2.7.2 NB-IoT/CAT-M2

NB-IoT stands for 'narrowband Internet of things'. This technology also has the support of the 3GPP (see Section 2.2.2.7.1) and is being pursued aggressively to become the de-facto connectivity solution for IoT products. It is a type of cellular connection built from the ground up. This means it is not distributed over pre-existing LTE networks like CAT-M1.

In most network connections, sensor data is transmitted to a gateway which transmits the data to a server. However, NB-IoT data is sent directly to the server through the service provider and a gateway is not needed.

NB-IoT has a narrow bandwidth, so it can't transmit as much data at once as CAT-M1. This means it is more suited to lower data applications than CAT-M1 such as a basic, static bin sensor with fewer data demands. It is designed for devices with long battery lives and works best for devices which can sleep and enter a low power mode between connections.

Some advantages include:

- Considered more cost effective than LTE-M
- Extra security is possible as NB-IoT can communicate using non-IP data delivery (NIDD), and

- Its primary design is for massive networks of sensors, although these aren't commonplace today. As such, it has the potential to be the vehicle for much larger scale IoT works in the future. It is a key component of 5G standardisation for IoT.

NB-IoT is the preferred connection for bin sensor provider, SmartSensor. Cellular connections have guaranteed connectivity as the cellular network is continuous. Only cellular networks can support BigBelly Bins.

Two of Australia's service providers, Vodafone and Telstra, offer NB-IoT.

2.2.2.8 6G

Research into 6G technology has begun in Canada. 6G is not predicted to be available until 2030 but could be up to 5000 times faster than 5G.

2.3 Wi-Fi

Wi-Fi uses radio waves, much like cellular, to send and receive information; however, Wi-Fi requires hardware to create the connection and uses an unlicensed network. The computer, telephone or other device contains a wireless adapter that will send and receive data in the form of a radio signal. The radio wave is sent through an antenna in the device to a router. The router is the device that mobile devices on the same Wi-Fi network connect to. It collects all the signals from the connecting devices and routes them through to the modem using an ethernet cable. The modem is the device that links the signals to the Internet service provider. The Internet service provider then connects to the Internet. The modem is connected by another ethernet cable to the Internet connection built into a building.

Sometimes, Wi-Fi connections use a gateway rather than a modem and router. A gateway has the functions of both technologies in one device.

Data transmission speeds are usually 2.4 GHz (slow) or 5 GHz (faster). High frequency radio waves have a shorter range than low frequency. The high frequency of Wi-Fi connections means they cannot transmit over large areas. Wi-Fi connections have a range of a few meters and are often localised to an area such as a home or building. For larger areas, Wi-Fi extenders are used to increase range. If Wi-Fi is to be used for bin sensors, it would function best an area where the hardware can be protected, Wi-Fi extenders can be installed, and the hardware can be connected to ethernet connections.

Wi-Fi can be obtained from Australia's three service providers, Optus, Telstra and Vodafone.

2.4 Non-cellular LPWAN

2.4.1 LoRaWAN

LoRaWAN stands for long range wide area network and is a type of LPWAN using an unlicensed frequency. LoRaWAN is also expected to take over IoT solutions in the future.

LoRaWAN uses a very simple technique called LoRa to encode a message in 'chirps'. Chirps are very short increases (up-chirps) and decreases (down-chirps) in frequency and combine to carry a message. The LoRa technique allows LoRaWAN to have a range of up to 10 km, which is much further than Wi-Fi, for a lower price than traditional cellular connections.

A node, for example a bin sensor, connected via LoRaWAN emits a signal which is picked up by a gateway. One gateway can handle thousands of nodes in its range. Any signal could be picked up by any gateway in range, so to avoid collisions on the network the server tells the gateways which one will pick up the signal, and which ones will ignore it. The signal is sent from the gateway to the client's server by the LoRaWAN provider.

Unlicensed networks have the potential for message collisions or interruptions. Where it is possible to control, there should be no other connections in the area on that frequency. It would function best in an area where the hardware can be protected and connect to the Internet.

However, like all LPWANs, LoRaWAN can only transmit small packets of information at once, so cannot handle the information that originates from a solar bin. Relying on LoRaWAN also increases the risk of temporary connection drops. With LoRaWAN, there is a risk that if the network is down, the sensor can't connect to anything so can't pass the data on to the customer. This doesn't happen with cellular which is a continuous network.

Low, constant signals such as those from bin sensors can be sent, depending on what data the bin sensor collects.

Service providers in Australia which operate LoRaWAN networks include Proximvo, GeoWAN, Meshed and soon Connected Country.

2.4.2 SigFox

SigFox is an Internet service provider which has a reach in approximately 40 countries. Based in France, the company has had great success in Europe, but has stagnated in the US. The company is the exclusive seller of products with its radio transmission method and doesn't partner with many other companies. As a result, to obtain SigFox transmission technology, customers must often deal directly with SigFox itself.

Devices on a SigFox network transmit their data to SigFox base stations and from there to SigFox's cloud and to the platform on which clients will read the device's data.

SigFox's transmission is designed to work with sensors which send small, infrequent bursts of data rather than a constant stream of information. However, only one SigFox network can run in a given area.

SigFox's partner Thinxtra is the service provider in Australia.

2.5 Recommendations for solar bins

The connection type chosen by a council should reflect the technology, amount of data and frequency of transmission.

Integrated bin sensors require continuous connection and transmit large quantities of data. LPWA networks do not have the capability to transmit large quantities of data frequently. Only cellular networks should be considered for integrated bins.

Bin sensors can use either cellular networks or either cellular or non-cellular LPWA networks. The most appropriate connection of these two will depend on how much data is being transmitted and how frequently. For bin sensors where continuous connection is important and data is transmitted in high volumes and/or in frequent intervals, such as hourly intervals, cellular connection is recommended. For bin sensors where small quantities of data are transmitted and/or which transmit data infrequently, for example, once a day, LPWANs are recommended. LPWAN networks should be first tested to determine their connectivity and ability to transmit information.

Due to the short range of Wi-Fi, the need for Wi-Fi extenders and an ethernet connection to a building, Wi-Fi is unlikely to be a useful option for bin sensors.

Councils should consider the long-term changes likely for these networks, including that cellular connections could become obsolete in the future, the range of future cellular networks and the issues associated with unlicensed LPWANs.

3 Overview of bin sensor technologies

3.1 SmartSensor Australia

3.1.1 Where is it from and where is it used?

SmartSensor Technologies distributes the SmartSensor Ultrasonic Waste Sensor 2.0 in Australia. The sensors are available as stand-alone products but are also used by some street furniture manufacturers in their own products including Street Furniture Australia, Escola eBin, Spark Furniture's iLEVEL bin, Gossi Park Furniture and Street and Garden.

Figure 1 Smartsensor Technologies bin sensor

3.1.2 How does it work?

SmartSensor is an ultrasonic, dual optical laser sensing unit attached to bins. It operates on a cloud-hosted service, requiring no additional software and is designed to provide clients with information on the fullness of waste bins, collection efficiency, critical zones, alerts and savings. Sensors can be installed in high- or low-use bins.

C cell batteries from supplier Saft are used. Battery longevity depends on the connection method the SmartSensor is using.

- On 3G/4G, it lasts 12 months based on one-hour heartbeats.
- On LoRaWAN battery life is between 24-36 months based on one-hour heartbeats.
- On NB-IoT, the battery life is 24-48 months, based on one-hour call ins.

The SmartSensor will notify the customer when battery life ends. It is easy to open the device and change the battery when required.

3.1.3 What data is collected and how is it transmitted?

The sensors collect and transmit the following data:

- Fullness levels
- Temperature alerts, and
- Maintenance alerts.

From this information, the analytics system can:

- Identify potential issues before they become critical
- Calculate collection efficiency
- Identify critical zones
- Calculate savings, and
- Show reports and predictions.

The sensor transmits data over 3G and 4G networks, LoRaWAN, NB-IoT, CAT-M1 or SigFox. SmartSensor prefers cellular networks are used because there is always connectivity. The SmartSensor also has a complete REST API library so it may connect to data on any other cloud or platform.

Clients can view data on tablets, smartphones, or any device which connects to the Internet, and is presented on platforms such as SmartSensor Dashboard, SmartSensor App and SmartSensor Voyager. Users can specify at which fill levels the alert will trigger. The platforms monitor, report and predict when the bin will be full, enabling control of bin collection frequency. This data is then used to determine the most efficient route to collect bins, presented on the SmartSensor Dynamic Routing platform. Routes and collection schedules are based on live collection levels, critical time requirements or defined schedule collections. The GPS-enabled system connects the full containers from collection point, the collection vehicle, the waste depot and refuse station all on a single map.

The sensors send up-to-the-minute reports and directions to drivers. Contractors get their own login details. Contractors using this technology include Cleanaway and Citywide. Some contractors present this as an innovative product to councils in their tender submissions.

3.1.4 Security

The client owns all their data which is hosted in Australia. Currently, there are no known issues with data breaches.

3.1.5 How much does it cost?

Clients buy the sensors outright and pay a monthly subscription that includes connectivity and software.

The cost per 100 units differs based on the situation, connectivity types and requested inclusions. On average, costs are:

- $305 per sensor for outright purchase, and
- $10 per sensor per month for connectivity and software. SmartSensor provides phone and email support between 9am-5pm Monday-Friday GMT.

Alternatively, the sensors can be leased for $16.95 per month per sensor on orders of 100 or more. A 12-month warranty is provided and 4-year warranty, with extensions, is offered for sale. Devices 'dead on arrival' will be replaced, as will batteries once they are depleted.

SmartSensor is Australian-based and works very closely with its customers. It offers onsite support in metropolitan areas for installation, bin placement, set up and training. This is also convenient for maintenance. SmartSensor provides one hour of online training for each new customer for training and an overview of the SmartSensor platform. This includes zones, assets, inventory, reports, locations and custom settings.

3.1.6 Advantages

- Reduces need for weekend collections
- Reduces instances of overflowing bins
- Provides bin use data
- Claims save up to 50% on collection costs and wasted collection trips.
- With the benefit of two-years of data, customer will know exactly what it wants the contractor to do. Councils will know if bins are being picked up and how often. They will also have data to negotiate contracts.

- The dual optical sensor avoids issues faced by single ultrasonic sensors
- Wide range of current connection types, and
- Compatible with existing client software.

3.1.7 Disadvantages

- Vague security details
- Data is not reported in real time, and
- Does not function as a Wi-Fi hotspot.

Figure 2 SmartBin bin sensor

3.2 SmartBin

3.2.1 Where is it from and where is it used?

SmartBin is a bin sensor distributor operating in Germany, Portugal, Israel and the USA. It currently has no Australian distributor. SmartBin sensors have been used in Portugal by several recycling and waste disposal companies, including Goodwill, Aaronoil Company Inc. and Cascais Ambiente.

3.2.2 How does it work?

SmartBin uses ultrasonic IoT sensors which have a non-corrosive shell and can measure bins up to three metres deep. The sensors can be used to monitor all waste streams, including liquid wastes. SmartBin sensors are easily installed using a drill and two screws.

Information is sent from the sensor to SmartBin Live, the waste management software. This sends the ideal bin collection routes to the operators who use a tablet or smartphone to receive and monitor their collection movements. The data is analysed on the cloud management software where performance can be tracked over time. The collected information is consolidated into a report for future waste planning.

Batteries are estimated to have a lifespan of more than three years.

3.2.3 What data is collected and how is it transmitted?

The sensors collect information on temperature, bin fullness and geographic locations of the bins. Data is transmitted over cellular networks.

3.2.4 Security

No security information available.

3.2.5 How much does it cost?

No training is provided, and cost is not known. No maintenance contract is offered but SmartBin offers 24-hour support for all clients and can be contacted for support on sensor installations or account configurations.

3.2.6 Advantages

- Reduces need for weekend collections
- Reduces instances of overflowing bins

- Provides bin use data
- Cuts service costs up to 50%
- 24-hour client support
- Reportedly easy to attach, and
- KPI reports available on the collected data.

3.2.7 Disadvantages

- No training provided
- Relatively short battery life
- Does not have an Australian distributor
- Collects less data than other smart bins
- Only uses an ultrasonic sensor which can be easily triggered by small but tall wastes in the bins and falsely indicate fullness
- Does not function as a Wi-Fi hotspot
- Uses cellular networks which may incur more costs than other LPWAN networks, and
- No data security details.

3.3 netBin

3.3.1 Where is it from and where is it used?

netBin is a UK based company which sells waste collection sensors and monitoring devices. Products are distributed in Australia by Draffin Street Furniture. netBin has been used frequently overseas by BIU Group in the UK, the Government of Macao, Nathans Wastesavers group in the UK and councils in northern England and in Toronto, Canada.

Figure 3 netBin bin sensor

3.3.2 How does it work?

netBin has three products which are purchased separately.
The nPod is a bin sensor with two ultrasonic sensors for improved accuracy. It is attached to the bin wall instead of the underside of the lid and the sensor tilts to get an accurate reading. Unexpected behaviour in the network is logged as alerts which are transmitted by e-mail, a HUB notification and text message.

Sensors can be retrofitted to most bins but have limited effectiveness when a bin liner is used. A common issue with the sensor is poor quality data from incorrect installation.

The other two products are nTag and nLok. The nTag is a notification tag which pairs with netBin's INSPECTOR app to record real time collection of the bins. nTag records the location of the bin and the time the operator is at the bin. When bins have not been collected at the required frequency, netBin HUB alerts account managers.

The nLok is a locking mechanism which is attached to the nPod. The device locks the bin at all times and releases when someone with the nLok app and a Bluetooth connection approaches the bin. This verifies access and the opening mechanism is released.

The netBin HUB displays this information and allows access from an account manager and its sub users. Analytics for each metric are also provided for individual bins. In HUB, the full bins can be selected and the app will automatically optimise the order and estimate trip duration, costs and distance. Routes can then be scheduled and assigned to drivers for completion.

If for any reason a bin cannot be serviced, netBin's cloud system will be notified by the bin operator's smartphone app that a bin has been missed so that a solution can be worked out by the network manager.

The netBin COLLECT app must be on the smartphones of the drivers who collect the client's waste as they receive the collection route through this application. While completing jobs the driver can report information back to headquarters.

3.3.3 What data is collected and how is it transmitted?

The nPod transmits bin fullness, GPS position, temperature and tilt sensing. To conserve battery life, the sensors faculties are only powered when they are required. Data is then logged to a cloud-based server, where changes are tracked. The raw data can also be accessed, analysed and reported in Microsoft Excel through the netBin ANALYSER app.

Data is transmitted over GPRS, 3G, NB-IoT or LTE-M/CAT-M1. It is crucial to have Bluetooth connected devices. Data can also be transmitted to outside programs using netBin's API.

3.3.4 Security

Head bolts increase the unit's resistance against vandalism and impact, however, the sensor's black matte finish and discrete installation means most people aren't aware of its presence. Bins have tight physical security if an nLok is installed, as only an operator with the nLok app will be able to access the bin. Bins with nLok have complete traceability of access. The site has tight SSL access to the user interface and all communications between the nPod and the cloud are encrypted.

3.3.5 How much does it cost?

The upfront cost to set up the sensors is $660. The optional GPS module, which allows automated location of the nPod to the HUB, is $39.60.

The cost of netBin products can differ if bought direct or through a reseller. Similarly, the products can be bought for an upfront full purchase price or a split purchase price. Through Draffin Street Furniture, the full purchase model authorises the use of netBin for either 24 or 36 months through one payment. Once the initial contract has ended, a small monthly charge applies per sensor. The split purchase model is for contracts of 24 months, 36 months or 60 months. An initial upfront cost is paid, followed by small monthly payments for the contract duration.

Where netBin systems have less than 100 nPods, a small system charge of $110 will be required for setup and monthly use. If the total number of nPods increases to 100 or more, the ongoing maintenance fee will be removed.

A 10-year warranty is also provided for products if paid monthly. A maintenance and support service is also provided to customers for technical support and to order replacements for faulty hardware.

3.3.6 Advantages

- Innovative physical security and tight data security
- Compatible with other cloud systems

- 10-year warranty period
- Independent bin collection tracking app
- Platform for bin operators to report issues
- Overcomes ultrasonic sensors problems with dual ultrasonic sensors
- Data analysed in ANALYSER app
- Compatible with client software
- Reduces need for weekend collections
- Reduces instances of overflowing bins, and
- Provides bin use data.

3.3.7 Disadvantages

- Bin monitoring is split across three devices when other systems consolidate these features into one product
- Conducts less analysis than other smart technologies
- Incompatible with bins with bin liners
- Minimum purchase period is 24 months, and
- Additional long-term cost for purchases of less than 100 nPods.

3.4 Nordsense

3.4.1 Where is it from and where is it used?

Nordsense is a company based in the USA and Denmark which distributes standalone IoT sensors. Currently Nordsense has no Australian distributor but the team in Denmark is very responsive and keen to work with Australian clients. The company is known for systems installed in San Francisco, Copenhagen, Ramla and Netanya.

Figure 4 Nordsense bin sensor

3.4.2 How does it work?

Nordsense sells two products, the NS Pod Tall and NS Pod Flat. These are ultrasonic sensors which can detect waste within 30 cm of the sensor. They can be placed in any container regardless of shape, size or contents. They are especially effective in small containers. The sensor is optical and detects a 256-pixel resolution that enables it to produce 3D depth maps of a bin's content. The 3D map of the waste lets the sensor detect fullness more accurately and prevent false fullness readings.

After installation, a waste study during the trial period determines the best system for the client. A report is prepared to show over- or under-servicing, how to improve waste handling efficiency and recommends bin locations based on traffic activity.

The batteries in the devices are claimed to last between five and 10-years.

3.4.3 What data is collected and how is it transmitted?

Data from each bin is collected every 15 minutes and reported once a day to the NS Platform, Nordsense's waste management cloud software. Accessible from any Internet-connected device, the platform lets clients organise collection vehicles broadly or in zones for small scale management. Sensor data is provided in tables, figures and graphs. If streets are blocked, the management software can be told to avoid and route around certain areas to provide the best route for the conditions. Clients can also order an 'empty now' option which adds certain bins to the collector's route and sends returns a notification when the bin is emptied.

The operator receives their routes via the NS Navigator app. The app indicates when a job is ready and the jobs are sent to the nearest driver. Rerouting occurs automatically should the route change due to a sudden on-demand pick up or when new containers become full.

Interactive online monitoring, maintenance tools and status maps show:

- Station location
- Bin fullness and content through the 3D depth map
- Movement and orientation, and
- Collection routes.

Resulting data includes:

- The activity level of each container
- The rate at which they fill
- History of capacity
- Emptying events
- Drover routes and
- Predicted time until full.

The data is collected over 2G, 3G, NB-IoT or LTE-M/CAT-M1 systems. Nordsense will recommend the most appropriate connection for clients.

3.4.4 Security

Nordsense claims to have high quality customer data protection. All platforms are housed in Amazon Web Services (AWS). AWS maintains controls over security and provides assurances to meet AWS's commitments and system requirements including:

- The system is protected against unauthorized access, use, or modification
- The system is available for operation and use.

The system is ISO 27001 compliant. The only data stored are measurements taken by the sensors.

3.4.5 How much does it cost?

Nordsense's products and software are distributed on a 'software as a service' model. This means software is distributed to clients but centrally hosted at Nordsense's data centre. This comes with a flat monthly subscription fee to cover device-related costs and the software platform and apps. The subscription cost is €12 (A$23). This cost is per sensor and does not include shipment, installation or input duties. Outright purchasing is also an option which comes with a smaller monthly maintenance fee.

Nordsense offers to help install sensors by sending out technicians or offers training for clients on how to install the sensors themselves.

Nordsense sells minimum of 100 sensors to clients, depending on the case. Prices can be decreased for large scale implementation.

3.4.6 Advantages

- Overcomes the issue of ultrasonic sensors by producing a high-resolution 3D topographic map of the waste
- Offers training
- Collects a large amount of data
- Can prevent overpaying for waste services
- Costs for waste operations will drop by 50%
- Reduce the number of collections by up to 90%
- Reduce the number of public complaints by up to 95%
- Reduce capital expenditure and carbon footprint
- System can give audible directions to the bins to avoid distracting the driver
- Routes are sent to the nearest driver for efficient servicing
- Undertakes waste study during trials to determine how client is performing, and
- High degree of client assistance.

3.4.7 Disadvantages

- No Australian distributor
- Minimum purchase of 100 sensors, depending on the case, and
- Data is not reported in real time.

3.5 PiP IoT

3.5.1 Where is it from and where is it used?

PiP IoT is a company based in New Zealand specialising in IoT devices. Its stand-alone 'LevelSense' bin sensors are deployed across New Zealand, including with Christchurch City Council.

Figure 5 PiP IoT bin sensor

3.5.2 How does it work?

PiP IoT sells one bin sensing solution called the LevelSense. This device attaches to the underside of bin lids using adhesive pads. The design of the device protects it from dust, water, sand or other particles. It can be used both indoors and outdoors.

The device uses multiple sonar sensors to read bin fullness level and other bin data. The LevelSense devices are programmed to trigger an alert when bin fullness reaches a chosen capacity. The bin data and alerts are transmitted over the SigFox network to the PiP Services platform. This platform allows users to monitor and manage sensor battery settings, configuration and device health. Users can also monitor bin fullness levels and sensor capacity triggers. Bin operators use a web browser, mobile device or other device with Internet connection to view the bins requiring collection.

The battery is estimated to last up to five years.

3.5.3 What data is collected and how is it transmitted?

The LevelSense collects data on bin fullness, temperature, GPS location and three-axis orientation. SigFox data is collected in selected intervals and reported to the PiP Services platform.

3.5.4 Security

No security information is available.

3.5.5 How much does it cost?

PiP IoT has a standard pricing scheme where the price per sensor is based on the quantity of sensors ordered. Ordering between one and 99 sensors has the highest cost per sensor of NZD$330.52 (A$324.84). Ordering more than 1,000 sensors is the cheapest option at NZD$219.56 (A$215.79) per sensor.

An additional cost applies for use of the PiP IoT API, which is required to use the system. This is a subscription fee with a base cost of NZD$7.20 (A$7.08) per unit per year. Optional additional costs include access to the SigFox Network and the PiP IoT sensor monitoring dashboard, which are similarly charged per unit per year. No training to use the systems is provided but the sensors come with a one-year warranty.

PiP IoT has a standardised labour rate per hour for technician callouts.

3.5.6 Advantages

- Costs for waste operations will drop by 50%, and
- Tight data security.

3.5.7 Disadvantages

- Only operates over SigFox
- Conducts less analysis than other smart technologies
- No training provided
- Does not have an Australian distributor
- Does not function as a Wi-Fi hotspot, and
- Data is not reported in real time.

3.6 BioEnable

3.6.1 Where is it from and where is it used?

BioEnable is a standalone sensor distribution company based in India. Currently it does not have any Australian distributor.

3.6.2 How does it work?

BioEnable's Smart Bin Sensors are ultrasonic sensors which monitor the fill level of a bin in real time. They come in two models, Compact Black and Longer Battery Life, which collect different types of data. The Longer Battery Life model contains a dual ultrasonic sensor which obtains a more accurate reading.

The battery life for the Compact Black sensor is between two and five years and 10 years for the Longer Battery Life sensor.

Figure 6 BioEnable bin sensor

3.6.3 What data is collected and how is it transmitted?

Both sensors collect fill level and geographic location. The Longer Battery Life sensor also provides temperature sensing data.

The sensors transmit data on bin capacity to the cloud service and waste analytics program provided by ECUBELabs. The cloud service estimates when containers will become full and uses predictive analytics to generate the best collection routes to service the full bins. These routes are sent to the bin operators. Clients are able to access this from a smartphone or desktop to observe bin fullness levels for each bin and a map to track bin placement.

The sensors use 2G and 3G networks, but the Longer Battery Life sensor can connect to Wi-Fi or LoRaWAN.

3.6.4 Security

No security information is available.

3.6.5 How much does it cost?

Cost is not known. No training to use or install is provided.

3.6.6 Advantages

- Provides data in real time
- Longer Battery Life uses a dual sensor for a more accurate reading
- Reduces need for weekend collections
- Reduces instances of overflowing bins, and
- Provides bin use data.

3.6.7 Disadvantages

- Compact Black model only uses an ultrasonic sensor which can be easily triggered by small but tall wastes in the bins to falsely indicate fullness

- Collects little data in comparison to some smart waste technologies
- Cannot work on many modern connection technologies
- No Australian distributor, and
- No data security details.

3.7 BrighterBins

3.7.1 Where is it from and where is it used?

BrighterBins is a Pakistan- and Belgium-based bin sensor company. Sensors were developed by the Belgian company SmartEnds. There is no known Australian distributor, but the technology is used in Australia as well as in Belgium, Greece, Estonia, India, Sweden, the UK, Ireland, Switzerland and Oman.

Figure 7 BrighterBins bin sensor

3.7.2 How does it work?

The BrighterBin sensor unit is attached to the internal wall or roof of a bin unit with an adhesive. It is effective for almost any bin or stream except small bins. It can also collect incorrect data if the structure of the bin is complex. BrighterBins staff examine bins to which the sensors will be attached and then provide advice on optimal placement. The product comes with an installation guide and installation tools.

Batteries are non-rechargeable but easily replaced. The estimated life expectancy of the battery is up to eight years. The device is expected to operate for five to ten years.

3.7.3 What data is collected and how is it transmitted?

The sensor sends data to a cloud platform run by BrighterBins, where it can link to customer systems. Alternatively, the devices can connect to a cloud service the client already uses. Clients can read the catalogued information on their smartphones, desktop or Internet-connected devices.

When the bins are ready to be collected, the most efficient bin collection routes are sent to the operators through an app. The Dynamic Route Planning creates the best pick up routes and optimises them in real time. Skip Planning uses the same route but lets the driver skip bins that do not need to be collected. The app also allows drivers to enter inputs such as the status of a bin or a reason for missing a collection.

The cloud software reports the data on bin collection to councils and partners twice a year to assist in better urban planning.

The sensors record information on location, fire and bin fill levels. This is extrapolated over time to track additional details, including:

- Planned collections
- Missed collections
- When uncollected bins are likely to overflow
- Unscheduled collections
- Average bins fill levels, and
- Bin fill rates.

The sensor does not collect much information, so it can transmit its data over LoRaWAN, SigFox and NB-IoT. The wireless connection range varies with the urban density of the area. On average, the technologies have a connection range of 1.5 km to 5 km.

3.7.4 Security

The system's security complies with IoT standards.

3.7.5 How much does it cost?

Cost is not known. The devices can be purchased individually if the client has an existing waste management system into which it can integrate the units. Alternatively, the devices can be purchased with the waste management hub software. No training to use the systems is provided but the sensors come with a one-year warranty.

3.7.6 Advantages

- Savings per bin are claimed to be €350 (A$570)
- Sensor are claimed to fits 90% of bins
- Bin data is reported to inform urban planning
- Reduces need for weekend collections
- Reduces instances of overflowing bins
- Collects bin use data
- Compatible with client software
- Standard security, and
- Client assistance during installation.

3.7.7 Disadvantages

- No known Australian distributor, and
- No information on the type of sensor.

3.8 EYEfi Smart Sensors

3.8.1 Where is it from and where is it used?

EYEfi is a smart sensor distribution company based in Melbourne. It is being used by the City of Melbourne.

3.8.2 How does it work?

The EYEfi sensor is an ultrasonic sensor powered by either solar cells or portable batteries. A camera was expected to be integrated in models released in the fourth quarter of 2019.

Figure 8 EYEfi nPod bin sensor

3.8.3 What data is collected and how is it transmitted?

Once the data is collected, it is sent to the EYEfi Cloud. Here, capability plugins perform analytics. One of these plugins provides data on bin fullness levels and sends collection routes to the bin operators once the system registers bins are ready to be collected.

The sensor collects information on the following:

- Bin fullness
- Battery temperature
- Ambient temperature
- Appearance of the waste through the camera, and
- Other customisable sensor input and output options to make the sensor applicable to many uses.

Currently, the sensor operates on 3G and LTE networks. EYEfi plans to expand this to include LPWAN networks such as NB-IoT, LoRaWAN and SigFox. The system's API will allow it to merge with third party systems or other cloud software and customer systems.

3.8.4 Security

No security information is available.

3.8.5 How much does it cost?

The cost is unknown. No training is provided.

3.8.6 Advantages

- Sensor measurement options are customisable to the client's needs
- Solar powered or battery powered
- Compatible with client's software
- Reduces need for weekend collections
- Reduces instances of overflowing bins, and
- Provides bin use data.

3.8.7 Disadvantages

- Has plans to be on LPWAN networks and release a camera but currently lacks this capability
- Only uses an ultrasonic sensor which can be easily triggered by small but tall wastes in the bins and falsely indicate fullness, and
- No data security details.

3.9 Enevo

3.9.1 Where is it from and where is it used?

Enevo is a company based in the USA which distributes standalone IoT sensors. Products are distributed in Australia through Smarter Technology Solutions. Enevo has provided sensor technology to McDonalds and a doughnut franchise. Some councils in Australia are also reported to use Enevo sensors.

Figure 8 Enevo bin sensor

3.9.2 How does it work?

Enevo produces ultrasonic sensors which are used by both waste companies and councils. They require minimal maintenance.

The sensor monitors when collections are scheduled to occur and alerts the system when they are missed. The most cost-effective route is refined over time as the system collects data on which bins need collection. This process is called 'right sizing'.

The data is also used to track seasonal variations and create a season-based waste collection schedule. If a high quantity of a particular type of waste is being collected, Enevo will also arrange a special program to manage this. An example is the collection of donated excess food by food companies.

3.9.3 What data is collected and how is it transmitted?

The sensors detect bin locations, fill levels and when collections are taking place. The data collected by the sensor is sent to the customer portal platform which is accessed by an Internet-connected device. The platform shows a general waste overview, bin sites, bin fill levels, past collections, scheduled pick up times and a live map of the collection fleet and its pick-ups. When bins are ready to collect, collection routes are sent to the drivers. Over time, it tracks the history of collections and provides right-sizing suggestions.

No information on the networks used to transmit the data has been provided.

3.9.4 Security

No security information is available.

3.9.5 How much does it cost?

Cost is not known.

3.9.6 Advantages

- System makes recommendations on how to manage excessive amounts of individual streams
- Adjusts billing to reflect actual collections, and
- Can build up a database of likely seasonal collections.

3.9.7 Disadvantages

- Only uses an ultrasonic sensor which can be easily triggered by small but tall wastes in the bins and falsely indicate fullness

- Collects less data compared to other smart solutions, and
- No data security details.

3.10 Sensoneo

3.10.1 Where is it from and where is it used?

Sensoneo is a sensor distribution company based in the UK and Europe. Currently, there is no Australian distributor. Its standalone sensors operate in hospitals, Natur-Pack and Tesco retailers in Central Europe, the City of Prague, the City of Sofia in Bulgaria, road operator Granvia Operations and in waste management operations in the United Arab Emirates.

Figure 9 Sensoneo bin sensor

3.10.2 How does it work?

The Sensoneo sensor comes in two forms: the single sensor which uses one ultrasonic beam and the quattro sensor which uses four ultrasonic beams.

The sensors are retrofitted onto other bins but cannot work on small bins or large skips. The bins must have a cover or lid. No installation training is provided, and it requires screws and nails to install. Sensoneo recommends that the units work best on underground or partially underground bins rather than small street containers.

The sensor batteries are replaceable and expected to last up to seven years. The life expectancy of the sensor unit is between 10 and 15 years.

3.10.3 What data is collected and how is it transmitted?

The sensors collect the following data:

- Bin capacity
- Waste type
- Temperature
- GPS position
- Battery status, and
- Overturn or collection recognition.

Information extracted from this data includes:

- Filling cycles for an individual bin
- Measurement history
- Bin fullness prediction last measurement, and
- Missed collections.

The system used by Sensoneo features an unusual but cost-effective network mesh topology. Single sensors are designated as 'slave' sensors and quattro sensors are 'master' or 'slave' sensors. The sensors designated as 'slaves' send their information to the 'master' sensor. The master sensor reports the information to the analytics and storage software. Using one sensor to connect to the system saves costs.

The data collected is sent to the cloud-based platform where the information can be accessed by clients. Clients can monitor, control and plan waste management activities. Bin data is displayed on a digital map and routes for collections are made through a Smart Route Planning page. The routes account for the waste type being collected and the facility it is being discharged to. Clients can also compare the planned route against the actual route taken.

Sensoneo also offers a Citizen App. This app discloses all the bins monitored by Sensoneo and guides members of the public to the nearest bin which has space for their waste. Members of the public can also use the app to report issues with a bin.

This data is transmitted over 4G, LTE, NB-IoT, LoRaWAN, GSM, SigFox or CAT-M1, making it very versatile in connection options.

3.10.4 Security

Microsoft Azure is used to safeguard the data. Payload and network communication are encrypted on two levels.

3.10.5 How much does it cost?

Outright costs are not known. The cost is determined by how many sensors are purchased and of what type. Sensoneo offers samples to test their products on a small scale before customers need to commit to a contract.

If clients have existing cloud software, clients can buy the devices themselves. Otherwise, the products are sold with both sensor and software. The devices will come with an upfront cost and the software will be paid for monthly as a subscription. Clients can also pay monthly for both the hardware and the software without an upfront price.

Sensors come with a two-year warranty.

3.10.6 Advantages

- Space for customer feedback on the system.

3.10.7 Disadvantages

- The single sensor may take inaccurate measurements because single ultrasonic sensors can be easily triggered by small but tall wastes in bins and falsely indicate fullness.

3.11 BigBelly Solar

3.11.1 Where is it from and where is it used?

BigBelly Solar is an integrated bin system from the USA distributed in Australia by Smartsensor Technologies (See Section 3.1). BigBelly bins are possibly the most commonly used bin system that incorporates sensors. BigBelly bins are used in a number of Australian local government areas including City of Melbourne, City of Canada Bay, Hume City Council, Waverley Council, Townsville City Council as well as Darling Harbour in Sydney and Crown Casino in Melbourne.

Figure 10 BigBelly integrated bin

3.11.2 How does it work?

The bins consist of a solar panel on the top which powers its features, most notably a compactor which compresses the contents when the sensor detects the bin is filling. The solar panel operates even in cloudy conditions. Bins can be used for different waste streams, including garbage and recyclables. When the bin is 85% full, it sends a text message and email to the operator to let them know. Compactor bins are recommended for high traffic areas.

Bins can also be fitted with illuminated panels, powered by the solar cell, which can carry advertising or community messages.

3.11.3 What data is collected and how is it transmitted?

Bin volume and other data related to when waste needs to be collected is monitored, reported and communicated to the cloud. Clients can view real time bin capacity on the network. Data is stored and transmitted to the client constantly through interactive online monitoring and maintenance tools and status maps showing:

- Station location
- Bin type
- Fullness level, and
- Operational state.

Information that can be extracted from the data includes:

- Real time status statistics per station over time
- Daily collection activities and analysis
- Logging of critical station errors, including open door, low battery, communication errors, alert history
- Collection history
- Collection amounts
- Collection frequency

- To the minute collection time, and
- Heat maps of utilisation and collection trends.

Because bins are releasing multiple and different types of information at once, they communicate with operators on cellular networks and cannot run on other networks. LoRaWAN systems can only handle small packets of information at a time and so are unsuitable for this application.

Data communication is reliable and traceable. Data shows the exact place and time particular bins were used. If a bin is breached, operators are alerted by text or email.

3.11.4 Additional features

Additional features may be added to the bin including ash trays, security shields, side panels, wraps and labels.

3.11.5 Security

For security, BigBelly bins feature the CLEAN Management Console's Security Management Module. The module enables the following functions:

- Event Creation – Create and easily add or delete stations from a security event.
- Event Scheduling – Stations are automatically placed into and removed from Secure Mode based on the specified event start and end time.
- Security Notifications – Security Notifications can be sent to any staff or law enforcement personnel.
- Security Dashboard – Easily monitor and manage security events.
- Security Plates – Security Plates can be installed during special events to prevent access to bins.

3.11.6 Wi-Fi

Bins can also be made into a Wi-Fi hotspot. Wi-Fi installed in two nearby bins allows that area to have public Wi-Fi. Bins can also permit access to a Wi-Fi network controlled by the client. From the website, the Wi-Fi feature enables the following:

- Full control over how users access the network
- Ability to offer free or paid access or a mixture of both
- Ability to fully customise the splash page branding and appearance
- Ability to capture user information in exchange for Wi-Fi access through splash page
- Ability to track advertising statistics on views and clicks
- Access to management portal where all devices and access detailed reporting can be monitored
- Support seven days a week by telephone, email and online chat, and
- 24 hours a day equipment monitoring. Clients will be notified if an access point goes offline.

3.11.7 How much does it cost?

Units can be purchased under a leasing program. The cost per bin is $6,500. Additional features increase the cost. Software and connectivity is $195 per bin per year. Maintenance can be undertaken for $40 per bin per month, however, maintenance is rarely required. Most bins can be left for many years unattended. Bin components can be replaced which means the whole bin doesn't have to be replaced.

The typical purchase program is a small number of bins installed for testing followed by large scale acquisition. The bin reorder rate is approximately 95%.

Solar Bins Australia runs 'how to' workshops for contractors involved and waste management, operations and environmental teams. Training sessions and workshops show how to use the cloud system CLEAN, where the data is accessed.

3.11.8 Advantages

- Reduces the number of collection trips by 80%
- Reduces need for street collections by 86%
- Compacts waste for extra capacity
- Long life, low maintenance
- Secure waste management platform
- Provides bin use data
- Prevents access by birds and vermin
- Reduces need for weekend collections
- Reduces instances of overflowing bins, and
- Provides data in real time.

3.11.9 Disadvantages

- Internal bin is a unique design, not compatible with standard wheelie bins.

3.12 Escola ebin

3.12.1 Where is it from and where is it used?

The Escola ebin is manufactured by Street Furniture Australia fitted with a Smartsensor bin sensor (See Section 3.1).

3.12.2 How does it work?

Escola ebin is a sturdy, wear-resistant bin fitted with a Smartsensor. It comes in two models for 120 L and 240 L bins. The Smartsensor hardware comes securely pre-mounted out of view on the underside of the bin roof.

Street Furniture Australia sells replacement parts.

Figure 11 Escola ebin

3.12.3 What data is collected and how is it transmitted?

Data collected includes bin capacity, temperature and fire and GPS location. This information can be viewed on the Smartsensor waste dashboard. Software allows bin network and positioning to be calculated relative to other bins. Analytical tools include map, fill levels and route planning to only full bins.

The Smartsensor is 3G-enabled and transmits over the cellular network. It is not recommended in built up areas. Clients enter into an agreement with Smartsensor and when the plan expires, access to the bin analytics dashboard ends.

3.12.4 Security

No security information is available.

3.12.5 Additional Features

The bins are customisable for colour, advertisements and bin decoration, opening size, roof angle, mounted or free standing and fitted with ashtray and/or dog poo bag dispenser.

3.12.6 How much does it cost?

The cost of the units is between $2,300 and $4,000 each. Street Furniture Australia and Smartsensor offer a 12-month trial with access to the asset management app. Customers can then stay on the system by extending the plan. When the plan expires access to the bin analytics dashboard ends.

3.12.7 Advantages

- No data provided but likely to:
  - reduce the incidents of overflowing bins
  - reduce the number of collection trips to empty bins
- Provides bin use data
- Prevents access by birds and vermin
- Reduces need for weekend collections
- Reduces instances of overflowing bins
- Uses standard 120 L and 240 L bins
- Bin features can be personalised, and
- Uses a Smartsensor Technologies sensor which does not have the issues experienced by single ultrasonic sensors.

3.12.8 Disadvantages

- No compaction
- Not that much cheaper than more sophisticated solar bins
- Analyses less data than other smart technologies
- Does not function as a Wi-Fi hotspot, and
- No data security details.

3.13 SPARK

3.13.1 Where is it from and where is it used?

Spark furniture is an Australian street furniture manufacturer. Its iLEVEL bin enclosure is equipped with a sensor provided by Smartsensor (see Section 3.1).

3.13.2 How does it work?

The iLEVEL is an enclosure designed to be retrofitted around older bins. It reduces the risk of bin contents spilling and overflowing and prevents access by birds and other vermin. The concealed sensor measures bin fullness levels and reports to the customers' dashboard. Once bins are full, it can also map the most economical route to empty bins that need attention.

Figure 12 SPARK bin enclosure

3.13.3 What data is collected and how is it transmitted?

The system measures and records bin volume, temperature, network maintenance requirements and reports data to the customers' dashboard. It also categorises bins by regularity of use and can identify hotspots for future infrastructure installation.

3.13.4 Security

No security information is available.

3.13.5 Additional Features

The iLEVEL enclosure can be custom designed to the client's specification or retrofitted in a standard design.

3.13.6 How much does it cost?

Costs are not known.

3.13.7 Advantages

- Categorises bins by regularity of use and reduces emptying costs
- The cowl design reduces vermin and weather ingress
- Provides bin use data
- Reduces need for weekend collections
- Reduces instances of overflowing bins
- Compatible with existing bins, and
- Uses a Smartsensor Technologies sensor which does not have the issues experienced by single ultrasonic sensors.

3.13.8 Disadvantages

- Analyses less data than other smart technologies

- Does not function as a Wi-Fi hotspot
- No compaction, and
- No data security details.

3.14 Yindi Smart Bin

3.14.1 Where is it from and where is it used?

Yindi is a Sydney-based solar bin manufacturer. It makes the:

- Yindi 120
- Yindi 120 Twin
- 120 L Smart Module
- Yindi 240
- 240 L Smart Module.

Its bins are used by Northern Beaches Council, Fairfield City Council and by Manly Council at Shelley Beach, in Sydney and City of Yarra in Melbourne.

Figure 13 Yindi integrated bin

3.14.2 How does it work?

The bins can connect to mains electrical power supply or use the inbuilt solar panels to provide power. Both an ultrasonic sensor and an infrared sensor are used to measure bin fullness to avoid false readings. A smart module can be fitted into the bin which turns it into a compaction bin. This allows capacity to be increased by up to six times. The bins are designed to house standard 120 L, 140 L and 240 L wheelie bins and contain a safety shield to ensure safety of cleaning staff and public.

An LED light on the bin indicates the current fullness and bins over 80% full are highlighted on the app. The app can be used on a smart phone or access can be obtained with a web browser. The operator can visit the bins on a route and observe the LEDs and decide if they need emptying or download the app to see bin data. The app's detection parameters can be altered so operators can see bins with a different level of fullness, or only see bins within a certain distance. This process uses Google Maps.

Bins can be used anywhere and can be designed for high- or low-traffic areas. Bins in high-traffic areas can be collected immediately but bins in low-traffic or remote areas can be delayed or rescheduled for a better time.

3.14.3 What data is collected and how is it transmitted?

The sensors relay information about bin capacity once per hour. They also collect data on GPS location, error detection and use photoelectric sensors. A camera takes photos and transmits information to show contamination.

The collected data is logged to the company's vStream cloud service. The bin will continue to communicate with the vStream cloud management software to log when it is ready for pick up and to log service conditions. The system can also be configured to communicate with the client's existing cloud system or other systems with its open API.

The system uses Wi-Fi, 3G and 4G through an installed sim card. Wi-Fi and cellular are also used to transmit software updates to the bins. For increased battery longevity, LoRaWAN or SigFox is used at all other times.

3.14.4 Security

The system complies with ICT Standard Protocols by using HTTPS. This makes the system as secure as online bank log-in systems.

3.14.5 Additional Features

The design of the bins can be highly customised. Some bins are transparent and allow pedestrians and others to see the contents and the action of the compactor. This is a novelty public attraction and people nearby will often stop to watch the process. Others are designed to client specifications. One beachfront-based client obtained bins with a timber slab finish to match the aesthetic of the area.

3.14.6 How much does it cost?

Each bin costs between $3000 and $4000 for a base product although some customers have paid up to $8000 for special designs. Each bin can be bought outright with or without the compactor or can also be leased daily, monthly or yearly. Alternatively, Yindi Smart Bins offers a six-month free trial. No training is provided.

Bins come with a 24-month warranty. Malfunctioning compactors can be returned for $500 and will be replaced. The smart module compactor can be unplugged and returned to Yindi for repair or service. When the compactor is not working or missing the bin will function as a conventional bin. When the compactor returns, it comes with a new warranty.

3.14.7 Advantages

- Compatible with standard wheeled bins
- Compatible with other cloud systems
- Overcomes issues experienced by standard ultrasonic sensors by also using an infrared sensor for an accurate reading
- Positive public reception
- Functions in built-up areas
- Older models had the same compaction system as a competitor and there were issues with this compaction system breaking due to a flawed design. The City of Melbourne also reported compactor malfunctions. Yindi Smart Bin's new design relies on a patented scissor compactor system that does not break and has a longer life expectancy. This compaction system is also made of post-consumer plastic, to conserve waste.
- Secure data protection
- Conserves power by using mostly using LoRaWAN or SigFox and using cellular or Wi-Fi connections when necessary.
- Prevents access by birds and vermin by containment
- Reduces need for weekend collections
- Reduces instances of overflowing bins, and
- Bins can be personalised in design for the client.

3.14.8 Disadvantages

- Uses cellular which may incur more costs than other LPWAN networks.
- Analyses less data than other smart technologies
- Does not function as a Wi-Fi hotspot, and
- Transmits data once an hour, not in real time.

3.15 Guardforce

3.15.1 Where is it from and where is it used?

Guardforce is a Hong Kong-based security firm with operations in Macau, Thailand and Australia. Its Smart Waste Bin is distributed in Australia by SecureCorp. The Smart Waste bins are in used in Hong Kong.

3.15.2 How does it work?

The product is a hybrid solar powered bin with a regular wheeled bin inside. An ultrasonic fill level sensor is installed inside the bin to detect how full it is. The sensor sends data back to a cloud-based analytics platform to alert those responsible for the bin. When the waste inside the bin reaches a pre-set level, a solar-powered compactor activates to compress the waste, allowing the bin to hold up to eight times more waste.

The bins are tailored for high traffic public and private areas but can also be used in remote areas like large parks or beachside areas and campsites.

Figure 14 Guardforce integrated bin

3.15.3 What data is collected and how is it transmitted?

The sensors send fullness data to a cloud-based platform. The sensor also collects temperature data to send fire alerts to client devices. Fires are quickly extinguished by the compaction system. It also detects when a hand may be injured by the compaction system and will cease compaction immediately.

Desktop and smartphone devices can be used to access the Fleet Management Platform. The platform organises the collection route and schedules for the operators based on the real time data. The routes are then sent to the bin operators.

Details on the method of transmission are undisclosed.

3.15.4 Security

The sensor detects the presence of a human hand which will halt the crushing process.

Guardforce specialises in electronic security, facial recognition systems, retail analytics, robotic solutions, video analytics, cyber security and smart cleaning solutions. The bin is protected with a metal casing to avoid unauthorised bin access, damage or bin movement.

3.15.5 Additional Features

Lightboxes on the side of the bin may be used for advertising.

3.15.6 Wi-Fi

Some bins are being trialled as Wi-Fi hotspots.

3.15.7 How much does it cost?

Costs are not known.

3.15.8 Advantages

- Compacts waste for extra capacity, holding up to eight times more waste than a standard bin
- Reduces collection frequency by up to 80%
- Functions well in high traffic areas
- Human hands will not be caught in the compaction process
- Prevents access by birds and vermin
- Reduces need for weekend collections
- Reduces instances of overflowing bins
- Able to extinguish internal bin fires
- The sides of the bin can be used as advertising space, and
- Provides bin use data.

3.15.9 Disadvantages

- Uses cellular which may incur more costs than other LPWAN networks
- Analyses less data than other smart technologies, and
- Only uses an ultrasonic sensor which can be easily triggered by small but tall wastes in the bins and falsely indicate fullness.

3.16 Ecube Labs

3.16.1 Where is it from and where is it used?

Ecube Labs is based in Los Angeles and Seoul and provides both a stand-alone sensor and an integrated bin along with a cloud service to manage data and a waste collection management platform. The products are distributed in Australia by Smart City Solutions.

Ecube Labs products are being used in City of Gold Coast in Queensland, City of Moonee Valley and Monash University in Melbourne, The Hills Shire Council, Randwick City Council and Campbelltown City Council in Sydney, and City of Playford and Town of Walkerville in Adelaide.

3.16.2 How does it work?

CleanCUBE is the integrated bin and CleanFLEX is a stand-alone sensor.

The integrated bin is a hybrid, solar or mains powered unit with a compactor. It has the CleanFLEX sensor fitted which uses wireless ultrasonic connection to monitor bin fill level. The CleanCUBE is compatible with 120 L and 240 L bins and can be used for different waste streams, including garbage and recyclables. Most bins between 25 cm and 4 m in depth can be retrofitted with the CleanFLEX sensor. The Ecube Labs sensors come with an installation guide to retrofit them to older bins. The compactor can reduce waste volume up to eight times. Bins can be used for general waste and recyclables and are best used in high traffic areas.

Figure 15 Ecube Labs integrated bin

The sensor unit has a life span of 3000 reporting cycles. Depending on the frequently of the cycles, the battery can last from one to eight years, although three to four years is typical. All sensors have interchangeable batteries. The solar panel should be replaced every 15 years. The CleanCUBE bin itself lasts for seven to eight years.

3.16.3 What data is collected and how is it transmitted?

The sensors monitor fill levels and have safety sensors in case of fire. Both systems track GPS locations, check battery levels and geographical location. The software can analyse collection history, overflow status, response times, fire events and the history of bin capacity and collection paths.

The collected data is sent to the CleanCityNetworks cloud management server. It can be used to manage waste management routes which can be optimised using machine learning algorithms so they will continue to get better over time. This also allows users real time monitoring of routes, analysis and asset management, including vehicle status, driver behaviour and fuel consumption. It also allows drivers access to reporting tools. This is accessible on tablets, smart phones and any device with an Internet connection.

The information from the sensor is transmitted over 3G/2G, LoRaWAN or NB-IoT networks. Bins can have an external antenna where the cellular signal is weak.

3.16.4 Security

The system uses Amazon Web Services which includes web server, database and data storage. No software is needed, users can log-in online. The system is ISO 27001 compliant.

3.16.5 Additional features

Bins have a foot pedal and can also be equipped with additional features such as LED back lights, LCD panels, graphic wraps, ash trays, mounting brackets, audio speakers and a Wi-Fi router.

3.16.6 How much does it cost?

Units can be leased or bought outright for $449 each. Leasing requires a minimum order. If bought outright there is a monthly service fee. Additional costs will be incurred for the additional features.

During the warranty period, free technical support is available. Ecube engineers can troubleshoot issues otherwise monitored is done by users. Extensive training is offered for installation and operation.

3.16.7 Advantages

- Compaction system to increase waste capacity, holding up to eight times more waste
- Reduces collection frequency by up to 80%
- The bin enables customers to increase their operational waste collection efficiency by up to 50%
- Sophisticated data protection
- Includes fire detection systems
- Machine learning algorithms to improve waste management system over time
- Compatible with other cloud systems
- Functions in built-up areas
- Prevents access by birds and vermin
- Reduces need for weekend collections
- Reduces instances of overflowing bins
- The sides of the bins can be used as advertising space
- Provides bin use data, and
- There used to be a 20-25 cm blind spot in the sensor range which meant that the sensor couldn't be placed on the side of a bins at an angle and get an accurate reading. This has been changed to solve the problem. Now there are two monitoring sensors instead of one. The sensor also has some rotation and flex so it can be placed on the side of any bin, angled to suit and still be robust and give accurate readings.

3.16.8 Disadvantages

- Uses cellular which may incur more costs than other LPWAN networks.
- Does not function as a Wi-Fi hotspot, and
- Only uses an ultrasonic sensor which can be easily triggered by small but tall wastes in the bins and falsely indicate fullness.

3.17 Victor Stanley Inc.

3.17.1 Where is it from and where is it used?

Victor Stanley is a USA-based street furniture manufacturer. It has no distributor in Australia. It makes a range of bins integrated with its Relay Sensor. These come in packages - CCS-200SCL, CCS-210SCLW, CCS-220DCL, CCS-230DCLW, CCS-300SCW, CCS-310DCW and others. It also supplies the sensor as a stand-alone product.

Its bins and sensors are use in Pittsburgh and Washington DC, in the US.

Figure 16 Victor Stanley bin enclosures

3.17.2 How does it work?

Sensors can be fitted in new and existing Victor Stanley litter bins and recycling stations. Sensors can also be fitted to most litter bins, recycling stations and bin lids, however, clients should take an inventory of the styles and brands of their bins and their conditions to see if they are compatible with a retrofitted sensor. They work with any type of waste material, garbage, mixed recyclables, paper, glass, metals and others.

They are best used in high-traffic, commercial and urban environments at street level and are designed for durability in most climates.

Bins have a self-contained power supply with an estimated life of more than six years under typical use which is to monitor once per hour and report twice a day. Battery life may vary depending on configuration, transmission frequency, wireless signal strength and temperature.

3.17.3 What data is collected and how is it transmitted?

The following data is monitored in real time:

- Fill level
- Weight
- System temperature
- GPS location, and
- Collection status.

The system continuously and automatically monitors and allows customisable alert triggers and push notifications. Configuration and software updates are made remotely by wireless.

Victor Stanley systems collect additional information, including address, fill level at collection, collection efficiency, contents, weight, signal strength, overdue collection rate, average time between collections, weight, detection and alerting of vandalism (tipping), overflows, illegal dumping, rummaging, rodents and fire.

Data is transmitted by standard cellular networks including 3G, 4G and NB-IoT due to high data requirements. Contracts for these systems are handled by Victor Stanley. Collected data can be accessed from anywhere and on any device using the Victor Stanley Relay web portal. The portal is also used by the operator.

Real-time and historical information is available to maximize collection planning, scheduling, routing and resource utilisation. Additional data access is available using APIs, JSON, CSV, Excel, XML, and others.

3.17.4 Security

The Victor Stanley Relay service and API comply with ICT Standard Protocols by using HTTPS. This uses encryption methods, protocols, and algorithms across its service and embedded devices to help provide a secure path for data. The Victor Stanley data centres are operated by Microsoft and have internal security to protect against hazards and unauthorised intrusions. Unauthorised data traffic within and to the data centres is also prevented.

The web portal has identity and access management controls. All team members sign non-disclosure agreements to protect customer information and data and have appropriate credentials and training for sensitive data management and non-technical attacks. Audits are regularly conducted to monitor the state of the system and vulnerabilities are handled in an incident response framework.

3.17.5 How much does it cost?

Customers pay a monthly, yearly or multi-yearly subscription fee of US$4.95 (A$7.30) per bin or US$59.40 (A$87.50) per year for contracts between three and five years. The bins come in different styles and each style has a different cost. Three of the most popular styles range from US$996 to $1396 (A$1468 to $2057).

3.17.6 Advantages

- Provides bin use data
- Prevents access by birds and vermin
- Reduces need for weekend collections
- Reduces instances of overflowing bins
- Eliminates inefficient fixed collection routing
- Reduced fuel costs, resource costs, and CO_2 emissions
- Efficient resource allocation saves an estimated 40-60% in collection expenses
- Data provided in real time
- Very sophisticated and audited data protection
- Collects a large variety of data
- Compatible with other cloud systems, and
- Secure system.

3.17.7 Disadvantages

- No Australian distributor
- Cannot be retrofitted in all cases
- Does not function as a Wi-Fi hotspot, and
- Uses cellular which may incur more costs than other LPWAN networks.

4 Legal requirements

4.1 Introduction

This task was undertaken by Hones Lawyers who prepared this section. It is a review of current legislation and applicable guidelines in NSW and Federally to which local councils are subject.

Before discussing the specific legislation, it is important to differentiate between two types of sensors offered. Those are ultrasonic or infrared only, and those which also include cameras. This is because the sensors which also include cameras may trigger a number of legal obligations which are not present for the sensors without cameras.

The companies whose sensors include cameras are listed as:

- EYEfi Smart Sensors, which intend to integrate cameras into models released in the fourth quarter 2019, and
- Yindi Smart Bin.

4.2 Local Government Act 1993 (NSW)

The *Local Government Act* sets out the general responsibilities, powers, and functions of councils. This includes guiding principles relating to:

- Carrying out functions in ways which provide the best possible value for residents and ratepayers
- Planning strategically to provide effective and efficient services
- Acting ethically and without bias
- Spending being responsible and sustainable, and
- Having effective financial and asset management.

We note no inconsistencies or perceived difficulties in terms of the council's responsibilities, guiding principles or obligations in the bin sensor project. Indeed, the value of bin sensors for the efficiency and effectiveness of public place waste management aligns with the local council's obligation to invest in responsible and sustainable infrastructure that will benefit the local community[1] and is appropriate to the current and future needs of the wider public.[2]

The project is also consistent with the councils' service functions under the *Local Government Act* in terms of both waste management and public place management.

We also identify no issues in terms of land classified as 'community land' under the Act, however note that in the unlikely event that any Plans of Management for community land include references to matters which may be impacted by sensors, for example, monitoring by camera, Wi-Fi, and the like, then those Plans of Management should be updated.

[1] *Local Government Act 1993* (NSW) s 8B(a).
[2] *Local Government Act 1993* (NSW) s 24.

Additionally, under s. 55 of the *Local Government* Act, councils are required to invite tenders before entering into a range of contracts, generally for amounts over $250,000. To ensure that they comply with their obligations under s. 55, and broader probity requirements, it is recommended that if the respective councils determine to proceed with acquiring bin sensors, if the overall contract value will be over, or potentially close to $250,000, that they do so through an appropriate tender process, whether this be open, or by invitation, and depending on size and scale, with a probity plan and/or probity auditor to ensure the process is not only lawful, but accords with probity requirements and community expectations.

The Act also governs how councils are funded. The councils will need to review their own records, funds and procedures to determine the funding source. However, as the bin sensors will be in public places, the funding should come from the respective consolidated funds, rather than under the annual domestic waste management charge since they will not relate to domestic waste collection services[3].

We have not located any provisions under the *Local Government Act*, or associated regulations and guidelines, which are otherwise relevant to privacy or data management and retention.

4.3 *Privacy and Personal Information Protection Act 1998* (NSW)

The primary function of the *Privacy and Personal Information Act* (PPIP Act) is to protect the personal information and privacy of individuals.

The legislation defines personal information as any information about an individual whose identity is apparent or can reasonably be attained from the information or opinion.[4] This includes particularly information which shows identifying characteristics such as name and address, driver licence number, licence plate number, and the like.

The PPIP Act applies to government agencies including councils which handle or are privy to personal information.

Under the PPIP Act, there are a number of 'Information Privacy Principles' (**Principles**) which such government agencies must follow, but which are modified by the Privacy Code of Practice, discussed below. These include principles related to the collection, storage, retention, and dissemination of personal information.

4.3.1 Ultrasonic sensors and infrared sensors only

Almost all the sensors discussed are only equipped with ultrasonic sensors, and infrared sensors. By their nature, these cannot collect or retain personal information. As such, for all sensors which comprise only ultrasonic and/or infrared sensors, we are satisfied that no obligations under the PPIP Act, Principles, or Privacy Code of Practice arise which would need to be complied with by a council.

4.3.2 Camera equipped sensors

However, we note that two of the sensors include cameras. For example, the EYEfi Smart Sensors are expected to include integrated camera models from late 2019, which can collect information including 'appearance of the waste through the camera,' and 'other customisable sensor input…'

Depending on the resolution of the camera, and the information it can record, it may possibly be able to record personal details, for example, names and addresses on envelopes thrown in the bin, or personal documents thrown into the bin. Although likely to be extremely rare, it can possibly be argued that this comprises personal information which falls within the PPIP Act.

[3] *Local Government Act 1993 (NSW)* s 496, Dictionary to the Act and *Council Rating and Revenue Raising Manual* (DLG, 2007) section 10.1
[4] *Privacy and Personal Information Protection Act 1998* (NSW) s 4(1).

A counter-argument can be raised, which is to the effect that if personal information is collected unknowingly by the cameras and recorded, does it fall within the PPIP Act? This is particularly as it may be highly impractical to discern what, if any, small amount of personal information is held within all the data gathered. Unfortunately, we cannot find any specific exclusion in the PPIP Act which would govern this situation, and as such, it must be assumed that for the small amount of personal information unwittingly gathered, the PPIP Act applies.

For such information, since it results from items willingly thrown in the bins, the personal information, being unsolicited, would not be regarded as having been 'collected' by a council under the PPIP Act. As such, the Principles relating to collection of personal information would not apply.

Only the Principles relating to retention, use and dissemination of personal information would apply, being of most relevance, in summary:

- Principle 12 – only retaining personal information for as long as necessary, and keeping it securely
- Principle 13 – undertaking reasonable steps to allow the persons to ascertain that personal information is held, and what that information is
- Principle 17 – only using the personal information for specific, authorised purposes, and
- Principle 18 – only disclosing the personal information for specific purposes or with permission.

As you will note, the above will place limits on the provision of personal information to a council's sensor partner. Therefore, a council will also need to put in place protocols with regard to the sharing of any personal information gleaned from cameras with the sensor partner or operator.

Further, we note the vague security details of some of the solutions provided, such as an online cloud-based server. We also note that networks such as Wi-Fi can be particularly vulnerable to data 'snooping'. Should cameras be utilised, a council must ensure that personal information is protected from unauthorised access, use, modification and disclosure. Accordingly, a council should ensure that appropriate measures and processes are implemented to secure the information and prevent unlawful access to servers.

Importantly, under s. 27B of the PPIP Act, there are exceptions to the Principles if:

- The personal information is reasonably necessary for the purposes of research, or the compilation or analysis of statistics in the public interest; and
- In the case of use or disclosure – either that purpose cannot be served without disclosing the personal details, or reasonable steps are taken to de-identify the information; and
- The personal details are not published in a publicly available publication; and
- The collection, use or disclosure are in accordance with any guidelines.

As such, it may be possible for councils to (unwittingly) collect personal information via cameras, and for that information to be disseminated to a council's sensor partner in compliance with the PPIP Act, provided that it is strictly for research in the public interest, and the above requirements are complied with.

Finally, we note that under the *Privacy and Personal Information Protection Regulation 2019 (NSW)*, Councils are exempt from Principle 11 regarding collection of personal information, which requires councils to take steps to ensure information collected is relevant to the purpose, not excessive, and does not intrude unreasonably, etc, in relation to closed circuit television (CCTV), which would likely apply to outward-facing cameras.

4.3.3 Conclusion on PPIP Act

In summation – from a legal and compliance perspective, it will be far easier for councils to acquire sensors without cameras, since no issues will arise under the PPIP Act. However, if councils wish to acquire sensors with cameras, then we recommend that councils put in place protocols to either ensure (1) personal information is detected and deleted, (2) the Principles are complied with, or (3) the exception for research and analysis is strictly complied with.

4.3.4 Codes of Practice under the PPIP Act

Under the PPIP Act, privacy codes of practice regulate the collection, use and disclosure of personal information held by public sector agencies in more detail than the PPIP Act, and in some cases, modify the Principles under the PPIP Act.

The *Privacy Code of Practice for Local Government* (DLG, 2000) (**CoP**) governs council's obligations under the PPIP Act. It leaves many of the Principles in place, but slightly modifies a number of the Principles.

Most notably, Principle 10 (s. 17 PPIP Act) is modified by the CoP so that a council may use personal information for a purpose other than for which it was created where the use is in pursuance of a council's lawful and proper functions, and council is satisfied that the personal information is reasonably necessary for the exercise of such functions.

This provides an additional exception by which a council may be able to utilise the personal information collected by cameras. However, again, in practice a council would need to implement systems to ensure that, if it relies on this exception, it is not breached.

Again, as noted for the PPIP Act – it will be far more straightforward if sensors without cameras are used, since personal information will not be collected, and therefore, the CoP will not apply. But should a council choose sensors with cameras, then it will need to implement systems to ensure compliance.

We also note that the CoP is currently under review. If and when it is updated, councils will be obliged to comply with the updated CoP.

4.4 *Privacy Act 1988* (Cth)

The Commonwealth *Privacy Act* promotes the protection of privacy and ensures that it is balanced with the interests of entities in carrying out their functions and activities.

It contains significant requirements and principles related to privacy, much like the PPIP Act.

However, as the PPIP Act 'covers the field' with regard to privacy obligations of councils, the Commonwealth *Privacy Act* does not apply to councils. It will therefore have no application to the proposed sensors.

4.5 *Surveillance Devices Act 2007* (NSW)

The *Surveillance Devices Act* regulates the installation, use, maintenance and retrieval of surveillance devices across NSW and requires law enforcement officers to apply for warrants to authorise the use of such devices.

4.5.1 Sensors with cameras

Two companies included in this report have incorporated cameras into their bins, being EYEfi Smart Sensors, expected to integrate cameras into models released in the fourth quarter 2019 and Yindi Smart Bin.

The purpose of the cameras is to provide information on contamination and the visual appearance of waste levels. This implies that the cameras will be placed internally and therefore will not be able to identify or record individuals.

However, if the cameras are placed externally or are able to transmit footage of the surrounds of the bin, they may be capable of 'recording visually or observing any activity' of people, which in turn, may trigger obligations under the *Surveillance Devices Act*. This will depend on the location and specific usage of the cameras, as well as specifications such as resolution.

Broadly, the *Surveillance Devices Act* prohibits cameras to be installed, maintained or used in a place, object, vehicle, etc, unless the owner of that place, object, vehicle, etc, has given consent. Similarly, devices which record audio, or which gather or intercept data, are prohibited unless they are consented to.

Given that councils will own the bins, we do not see that the installation of cameras within or outside of the bins will breach the *Surveillance Devices Act*. Notwithstanding this, if the bins have cameras installed on or in them in such a way as to be able to record the activity of persons in the vicinity of the bin, it is recommended that the bin have an appropriate warning sign placed on or near it, such as those signs installed for other council security projects.

4.5.2 Sensors with Wi-Fi hotspots

In addition, the *Surveillance Devices Act* has a number of prohibitions in relation to tracking devices and data surveillance devices (sections 9-10), which are defined as follows:

- **Tracking device**: Any electronic device capable of being used to determine or monitor the geographical location of a person or an object
- **Data surveillance device**: Any device or program capable of being used to record or monitor the input of information into or output of information from a computer.

The *Surveillance Devices Act* prohibits the installation, use or maintaining of either a tracking device to monitor a person or object's location, or a data surveillance device to record or monitor information from a computer, without the consent of the relevant person or owner.

Some of the sensors can function as Wi-Fi hotspots. If these functions are utilised, then the council will need to ensure that the data collected by the Wi-Fi hotspot does not breach sections 9-10 of the *Surveillance Devices Act*, by unlawfully tracking or surveilling computer data. Typically, this is done by a sign-in page to use the Wi-Fi, whereby the user agrees to such data monitoring and collection. The bin sensor supplier will need to ensure that the system is compliant when set up and continues to be so as long as the Wi-Fi hotspot function is utilised.

4.6 *Workplace Surveillance Act 2007* (NSW)

The *Workplace Surveillance Act* regulates the surveillance of an employee by the employee's employer while the employee is at work for the employer.

In cases where the smart bins, or existing bins to which sensors are to be attached, are to be collected by third party contractors rather than by council employees, the requirements under the *Workplace Surveillance Act* will not technically apply to that council.

However, in circumstances where a council employee may be collecting waste and attends a smart bin or sensor-equipped bin to deposit that rubbish, and any outward-facing cameras may apply, the council needs to consider notifying its employees in writing that they may be periodically under surveillance while in the proximity of these bins,[5] and there is clear notice on the bins of the cameras[6].

We presume that councils have in place policies related to workplace surveillance, and if necessary, may already have notified employees in relation to surveillance, but in either case, if cameras will be present, then such policies and notification should be revisited.

4.7 *State Records Act 1998* (NSW)

Under the *State Records Act*, councils have a number of requirements in relation to the protection, management, retention of, and access to, council records. A 'record' is defined to mean[7] 'any document or other source of information compiled, recorded or stored in written form or on film, or by electronic process, or in any other manner or by any other means.'

As such, the data obtained by councils from bin sensors would almost certainly fall within the definition of 'records,' and hence requirements of the *State Records Act* will apply to that data. Further, as 'control' of a record is defined to include where the record is in the possession or custody of another person, or the council has entitlement to possess and have custody of the record, which means that the data obtained by sensor partners may also fall within the ambit of the Act.

Councils will therefore need to be mindful that the management of data obtained from bin sensors will need to comply with the *State Records Act*.

4.8 *Radiocommunications Act 1992* (Cth)

The *Radiocommunications Act* regulates the use of various frequencies by radiocommunication equipment via a wide range of radiocommunication technologies such as cellular networks and Wi-Fi.

Wi-Fi devices with inbuilt antennae must comply with the ACMA's Radiocommunications (Electromagnetic Radiation – Human Exposure) Standard 2014 (the Human Exposure Standard). Further, the operation of Wi-Fi devices in Australia is authorised by the Radiocommunications (Low Interference Potential Devices) Class Licence 2015 (the LIPD class licence), which must also be complied with.

We would presume that for the sensors which also provide Wi-Fi hotspots, the manufacturers would ensure that those hotspots are compliant with the above ACMA requirements, being standard across Australia. However, this should be confirmed prior to installation of Wi-Fi hotspots, if they are to be utilised.

4.9 NSW Government Policy Statement and Guidelines for the Establishment and Implementation of Closed-Circuit Television (CCTV) in Public Places

The sensors mostly do not incorporate cameras. As such, these Guidelines are not applicable to those sensors without cameras. However, should bin sensors be installed with any outward-facing cameras, then these Guidelines should be considered.

[5] *Workplace Surveillance Act 2005* (NSW) s 10(1).
[6] *Workplace Surveillance Act 2005* (NSW) s 11.
[7] *State Records Act 1998 (NSW)* s 3

These Guidelines have been developed by the NSW Government to provide a policy framework and a set of underlying principles to assist agencies considering CCTV as a possible response to local community safety concerns. The policies are not legally binding in and of themselves but provide a good guide to what would be regarded as acceptable practice from government agencies that operate CCTV.

One of the guiding principles of the Guidelines concerns community consultation (Principle 1.2) which is an important consideration for a council to bear in mind if it selects a type of smart bin that has the potential of recording footage of the immediate surrounds of the bin, as opposed to the internals of the bin only. Further, as noted above, it would be advisable for there to be a notice on the bin that a surveillance device is installed on the bin.

Most other aspects of the Guidelines are concerned with crime minimisation and are specifically tailored to wider scale security cameras and are therefore not relevant.

5 Case study summaries

5.1 Christchurch City Council

Christchurch City Council bought 100 stand-alone LevelSense bin sensors from supplier, PiP IoT. Using sonar technology, the sensors measure and record bin fullness levels as well as GPS location, bin temperature, tilt angle and vibration over the SigFox network. The bin sensors were installed in existing bins to reduce overflowing, lower CO_2 emissions, reduce noise and air pollution and prepare for expected population increases.

The sensors were useful for checking on damaged bins, improving collection and cost efficiency, co-ordinating collection vehicle deployment and improving bin placement. When sensors were not cleaned or installed properly, signals became disrupted. The data allowed Christchurch City Council to adapt to changes in servicing requirements. The bin sensors were removed after the trial. Christchurch City Council expects to engage PiP IoT again for additional sensors.

Figure 18 Public place bin fitted with LevelSense bin sensor

5.2 City and County of San Francisco

The City and County of San Francisco trialled 48 Nordsense bin sensors which were retrofitted to existing public place bins. The sensors measured 16 points inside the bin and collected real-time data on waste levels, temperature, movement, GPS location and each emptying event. This data was analysed to identify waste generation patterns in specific locations. Predictions were then made about bin use that allowed collections to be optimised to prevent overflowing.

The installation of the sensors led to an 80% decrease in overflowing bins, a 64% decrease in illegal dumping and the elimination of public complaints of overflowing bins. Analysis of waste generation patterns enabled bin placement to be optimised which was found to be more effective than increasing the number of bins. A three-year contract to install sensors in another 1,000 public bins was established after the successful pilot program.

Figure 17 Nordsense ultrasonic bin sensor

5.3 City of Canada Bay

The City of Canada Bay trialled SmartBin sensors, provided by Smartsensor Technologies, in 94 existing public place waste bins. Public place bin management places a strain on the Council's resources. The bin sensors were placed in low pedestrian use areas to assist Council's management strategy and cope with the anticipated increase in population.

There were some initial issues including connectivity problems and resistance from collection staff. Council's resources have been more efficiently distributed after staff adjusted to the new system. Collections are required less frequently, and staff have been allocated to other tasks, including vehicle maintenance and cleansing duties.

Figure 20 SmartBin sensor fitted to waste bin in Canada Bay

5.4 City of Melbourne

The City of Melbourne Council leased 50 stand-alone nPod smart sensors from the Australian company EYEfi which were retrofitted to existing public litter bins. Ultrasonic sensor technology monitored bin fullness. Bin locations, temperature and other data were recorded and transmitted once per day.

Bin data was only transmitted data once per day whereas bins in the CBD need to be collected multiple times per day. In that regard the sensors were unable to meet the City's needs. Staff also did not find the system user-friendly. The City felt that the sensors did not improve collection efficiency and the trial was not extended into acquisition. The City has since acquired solar compactor bins.

Figure 18 nPod Smart Sensor fitted to a waste bin

5.5 Randwick City Council

Randwick City Council trialled a total of 11 CleanCUBE integrated solar bins from Ecube Labs to reduce cost, improve efficiency, reduce overflowing bins and manage litter during peak summer periods. The internal bin sensor triggers a compactor when the bin reaches capacity. This allows the bin to store up to 960 L of waste before collection. Council staff found the system easy to use.

The sensor technology allowed Council to service bins as required. It has not been cost effective to integrate collection routing technology due to the small number of bins. The waste contractors have learned to predict when bins will require collection to avoid being frequently dispatched to the same location. The bin enclosure reduced litter and vermin and enabled waste contractors to schedule collections efficiently during low traffic periods.

Figure 19 Waste operators servicing a CleanCUBE bin

5.6 Waverley Council

Waverley Council installed 42 BigBelly smart solar compactor bins in 14 high-litter, high pedestrian-traffic locations. The bins were positioned in pairs, one bin for general waste and one for recyclables. Each garbage bin has a compactor that trigger automatically when the bin reaches a set fullness. This increased bin capacity to 600 L. When the bins reach 60% capacity, Council staff are alerted for monitoring, reporting and collection purposes.

Figure 20 BigBelly solar compactor bins at Bondi Beach

The overall experience by the council was positive. The bins improved public visual amenity and capacity while reducing the total number of bins, collection time and bird access to the bin contents. Council found the bins to be cost effective over a longer period.

5.7 SWOT Analysis

Based on the outcomes of the case studies above, SLR has undertaken a SWOT analysis. The results are shown in Table 1 below.

Table 1 SWOT analysis of each case study

Case Studies	Strengths	Weaknesses	Opportunities	Threats
Christchurch City Council Bin Sensor - LevelSense	• Able to account for landslides due to local geography • Able to identify when the bin is being collected • Reduction in costs • Greater time efficiency • Good public reception • Collection frequency reduction • Lowers CO_2 emissions	• Does not transmit live data • Data collection experienced interference from different bin types, bin liners and waste types • Sensors must be regularly cleaned by bin operators • No collection route co-ordination software is provided with the sensors.	• Can contribute on a local scale to carbon reduction objectives. • Technology is part of smart city infrastructure • Identifies underutilised and highly utilised bins which can influence waste strategy • Allows adaptation to changes in servicing requirements over time.	• The rapid development of this industry may make this sensor obsolete in the long term • The optimised system may cause job losses • Shorter range from faster Internet cellular networks may require more infrastructure costs over time • Waste streams may change and make bins and sensors obsolete
City and County of San Francisco Bin Sensor - Nordsense	• Reduction in costs • Greater time efficiency • Ability to organise waste collection fleet at micro scale • Collection reduction • 16-point sensor eliminated errors • Reduction in overflowing bins • Reduction in illegal dumping • Fewer street cleaning requests • Bins were faster to empty • Fewer public complaints • Training operators eased integration into the smart waste system • Machine learning algorithm to improve collection frequency predictions	• Does not transmit live data • No opportunity to increase bin capacity	• Can contribute on a local scale to carbon reduction objectives. • Technology is part of smart city infrastructure • Long term partnership with strategic waste consultants • Identifies underutilised and highly utilised bins which can influence waste strategy • Allows adaptation to changes in servicing requirements over time.	• The rapid development of this industry may make this sensor obsolete in the long term. • The optimised system may cause job losses • Shorter range from faster Internet cellular networks may require more infrastructure costs over time
City of Canada Bay Bin sensor - Smartsensor Technologies	• Greater time efficiency • Collection reduction • Ultrasonic and dual optic sensor for greater accuracy • Training operators eased integration into the smart waste system • Bin management undertaken as part of Smartsensor Technologies services. • System is easy to use	• No opportunity for bin capacity increase • Initial resistance to the bin sensors • No firm cost efficiency data • Real time data caused collection route issues • Council considers routing platform costly • Connectivity issues using the LoRaWAN network	• Can contribute on a local scale to carbon reduction objectives • Technology is part of smart city infrastructure • Allows adaptation to changes in servicing requirements over time. • Identifies underutilised and highly utilised bins which can influence waste strategy	• The rapid development of this industry may make this sensor obsolete in the long term • The optimised system may cause job losses • Shorter range from faster Internet cellular networks may require more infrastructure costs over time

Case Studies	Strengths	Weaknesses	Opportunities	Threats
City of Melbourne Bin sensor - EYEfi	• Collections reduced in low traffic areas • Contractors used the bin fullness information where possible • Discussion with waste operators enabled an evaluation of the suitability of the technology • Machine learning algorithm to improve collection frequency predictions	• Does not transmit live data • No opportunity for bin capacity increase • Online waste monitoring system was not user friendly • Not suitable for high traffic areas such as the CBD • Not enough notice for waste operators before bins overflowed	• Can contribute on a local scale to carbon reduction objectives. • Technology is part of smart city infrastructure • Allows adaptation to changes in servicing requirements over time. • Identifies underutilised and highly utilised bins which can influence waste strategy	• The rapid development of this industry may make this sensor obsolete in the long term • The optimised system may cause job losses • Shorter range from faster Internet cellular networks may require more infrastructure costs over time • Sensor used 3G which is likely to be phased out in time
Randwick City Council Integrated Smart Bin - CleanCUBE by Ecube Labs	• Greater time efficiency • Increases bin capacity • Enclosure created vermin control • Enclosure created litter control • Bin management undertaken as part of Ecube Labs services. • Discussion with waste operators eased integration of the technology • Solar powered • Can install cigarette tray to target cigarette litter • Collection reduction • Timed collection to off-peak periods to reduce traffic congestion • Machine learning algorithm to improve collection frequency predictions	• Cannot be implemented into existing public waste bins and may require infrastructure removal • No firm cost efficiency data yet • No collection routing system	• Can contribute on a local scale to carbon reduction objectives. • Technology is part of smart city infrastructure • Can integrate into waste education through bin graphic wraps • Can generate income from advertising • Wi-Fi from bins provides Internet connectivity opportunities • Allows adaptation to changes in servicing requirements over time • Identifies underutilised and highly utilised bins which can influence waste strategy	• The optimised system may cause job losses • Shorter range from faster Internet cellular networks may require more infrastructure costs over time • The rapid development of this industry may make the sensor or compactor obsolete in the long term. • Changes in the type of waste placed in the bins could impact the effectiveness of compactors • Increases in recycling and/or diversion of waste streams, for example, organic waste, could reduce the need for the increased capacity of compactor bins

Case Studies	Strengths	Weaknesses	Opportunities	Threats
Waverley Council Integrated Smart Bin - BigBelly by Smartsensor Technologies.	• Reduction in costs • Greater time efficiency • Increases bin capacity • Enclosure created vermin control • Enclosure created litter control • Solar powered • Can install cigarette tray to target cigarette litter • Collection reduction • Waste operators driving by can observe the light on a bin to indicate fullness • Litter reduction • More staff free time • Reduction in litter including cigarette waste	• Cannot be implemented into existing public waste bins and may require infrastructure removal • Is insufficient for large events • Bin fullness alert level adjusted based on the time required for operators to respond	• Can contribute on a local scale to carbon reduction objectives • Technology is part of smart city infrastructure • Can integrate into waste education through bin graphic wraps • Can generate income from advertising • Wi-Fi from bins provides Internet connectivity opportunities • Allows adaptation to changes in servicing requirements over time • Identifies underutilised and highly utilised bins which can influence waste strategy • Most cost-effective solution over the long term	• The optimised system may cause job losses • Shorter range from faster Internet cellular networks may require more infrastructure costs over time • The rapid development of this industry may make the sensor or compactor obsolete in the long term. • Changes in the type of waste placed in the bins could impact the effectiveness of compactors • Increases in recycling and/or diversion of waste streams, for example, organic waste, could reduce the need for the increased capacity of compactor bins

6 Sensor technology analysis

This section provides an analysis of bin sensor technology and its contribution to the efficiency and effectiveness of each council's public waste management system.

6.1 Evaluation

6.1.1 Assessment Matrix

SLR compared the six case study systems against a set of criteria. The criteria are shown in Table 2 below.

Table 2 Evaluation Criteria

Evaluation Category	Description
Capacity	The capacity by volume the technology provides. Bin sensors received lower scores than Integrated Smart bins as the bins can compress waste up to eight times the normal volume, resulting in a much greater capacity
Contractor Collaboration	Scores whether the contractor had a good working relationship with the council and efficiently and diligently resolved problems and teething issues associated with the implementation of the technology
Connectivity	The quality of the data connection between the bins where the technology was fitted and waste collectors. Lower scores were given where there were disconnected bins or intermittent data transmittal.
Software	The quality of the software and if it was user friendly. City of Melbourne received a low score as its staff did not find the system user friendly.
Maintenance	The frequency and effort required to maintain the bin or sensor. A higher score was given if the technology required very little maintenance.
Bin or Sensor Settings	The accuracy and/or customisability of bin or sensor settings. City of Melbourne received a low score as the sensors could only be set to report once per day.
Litter Management	Measures how the implementation of the bin or sensor affected litter management in the area
Vermin Management	What impact the technology had on the control of vermin and pests normally associated with the bins where the technology was fitted
Collection Efficiency	Measures whether the council reported an improvement in collection efficiency for bins where the technology was fitted. City of Melbourne received a low score in this category as the sensors only transmitted data once per day but bins needed to be emptied multiple times per day.
Cost and Time	The effect of the systems on the costs and time required to service public place waste systems taking into account purchase and installation costs and handling and management costs
Training	Measures the quality of the training received and subsequent ease of use of the technology. City of Melbourne received a low score as staff still found the technology hard to use after training.
Informing Waste Strategy	Measures how the implementation of the technology influenced the council's waste strategy
Customer Satisfaction	Measures how happy customers were with the technology. Scores are given mostly from anecdotal data as qualitative data was not available.
Bin Numbers and Maintenance	Measures the benefits of the sensors on operations including the number and placement of bins to optimise servicing and notifications for bin maintenance and cleansing
System Integration	Measures how well the sensors integrated into other waste management systems and customer service systems for optimal data capture and reporting opportunities
Unit Life	Battery life and useful operational life

A matrix was prepared that allowed each criterium to be scored for each system. These raw scores are ranked out of three. A low score indicated the council had a negative experience with the technology and a higher score, a positive experience. The raw scores are shown in Table 3 below.

Table 3 Raw scores

	Christchurch City Council	City and County of San Francisco	City of Canada Bay	City of Melbourne	Randwick City Council	Waverley Council
Evaluation Categories	**PiP IoT LevelSense bin sensor**	**Nordsense bin sensor**	**Smartsensor Technologies bin sensor**	**EYEfi bin sensor**	**ECube Labs CleanCube bin**	**BigBelly bins**
Capacity	2	2	2	1	3	3
Contractor Collaboration	2	2	3	3	3	2
Connectivity	2	3	2	3	2	3
Software	3	3	3	1	3	3
Maintenance	2	2	3	2	3	3
Bin/Sensor Settings	3	3	2	1	3	3
Litter Management	2	3	2	2	3	3
Vermin Management	2	3	2	2	3	3
Collection Efficiency	3	3	3	1	3	3
Cost and Time	3	3	3	2	3	3
Training	2	3	3	1	2	2
Informing Waste Strategy	3	3	3	3	3	3
Customer Satisfaction	3	3	3	2	2	2
Bin Numbers and Maintenance	3	3	3	2	3	2
System Integration	1	2	2	2	3	2
Unit Life	1	2	1	3	2	3
Total	**37**	**43**	**40**	**31**	**44**	**43**

Key:	
1	Council had a negative experience
2	Council had a neutral experience
3	Council had a positive experience

Criteria are weighted to arrive at a set of final scores that rank the systems in order of preference. The weighted scores are shown in Table 4 below.

Table 4 Final weighted scores

Evaluation Categories	Weightings	PiP IoT LevelSense bin sensor	Nordsense bin sensor	City of Smartsensor Technologies bin sensor	EYEfi bin sensor	ECube Labs CleanCube bin	BigBelly bins
Capacity	4	8	8	8	4	12	12
Contractor Collaboration	4	8	8	12	12	12	8
Connectivity	4	8	12	8	12	8	12
Software	3	9	9	9	3	9	9
Maintenance	3	6	6	9	6	9	9
Bin/Sensor Settings	3	9	9	6	3	9	9
Litter Management	3	6	9	6	6	9	9
Vermin Management	1	2	3	2	2	3	3
Collection Efficiency	5	15	15	15	5	15	15
Cost and Time	5	15	15	15	10	15	15

Evaluation Categories	Weightings	PiP IoT LevelSense bin sensor	Nordsense bin sensor	City of Smartsensor Technologies bin sensor	EYEfi bin sensor	ECube Labs CleanCube bin	BigBelly bins
Training	2	4	6	6	2	4	4
Informing Waste Strategy	1	3	3	3	3	3	3
Customer Satisfaction	5	15	15	15	10	10	10
Bin Numbers and Maintenance	3	9	9	9	6	9	6
System Integration	3	3	6	6	6	9	6
Unit Life	4	4	8	4	12	8	12
Total		**108**	**118**	**114**	**78**	**118**	**118**

6.1.2 Score Explanations

The City and County of San Francisco, City of Canada Bay, Randwick City Council and Waverley Council all received high scores in the final weighted scores table due to their positive experiences with implementing their technologies.

Randwick and Waverley received high scores in the capacity category as they installed integrated smart bins which can compact waste and increase bin capacity. Canada Bay, Melbourne and Randwick did well in the contractor collaboration category as they had a positive relationship with the contractor and problems were quickly resolved or addressed. Even though Melbourne's sensors were not satisfactory, Council still had a good relationship with its contractor.

San Francisco, Melbourne and Waverley experienced little or no connectivity issues and so received the highest scores in this category. All councils except Melbourne found the software to be high-quality and user friendly. Canada Bay, Randwick and Waverley found their technologies required very little maintenance and so received higher scores. Christchurch, San Francisco, Canada Bay, Randwick and Waverley all found their technologies to be accurate and/or easily customisable.

San Francisco, Randwick and Waverley all found the technology controlled vermin and pest issues.

All councils except Melbourne found their collection efficiency dramatically increased with the implementation of the technology. This criterion was weighted equal highest. All councils except Melbourne found the cost and time involved with the technology to be beneficial. This category was weighted equal highest.

San Francisco and Canada Bay found the quality of their training to be high and so received the highest scores for this criterion. All councils found the implementation of the technology was influential in informing their waste strategy. This category was weighted lowest.

Christchurch, San Francisco and Canada Bay were all happy with their technologies. All councils except Melbourne found their technologies positively influenced the number and placement of bins and maintenance and Randwick found the sensors integrated well into its other waste management systems. Melbourne and Waverley found the expected battery and useful operational life to be best in their systems.

6.2 Specific Recommendations

Any council considering implementing bin sensors or bins with sensors should undertake their own investigations and make decisions based on their own unique circumstances. Having said that some recommendations can be made to assist councils considering these systems.

- Bins in high traffic areas will fill up more quickly than those in low traffic areas

  Recommendation – Use an integrated smart bin, such as BigBelly or eCube labs, with a compactor to increase bin capacity.

- Bins with sensors are suitable for daily use in high traffic areas but can be overwhelmed by the quantities of waste generated during public events.

  Recommendation – Do not install bins with sensors to manage waste at public events.

- LoRaWAN can only handle small packets of information at once. It is unable to handle the information that needs to be collected from a solar bin, such as BigBelly or eCube labs.

  Recommendation – Cellular networks, such as 3G and 4G should be used where large amounts of data are transmitted and a continuous network or better connectivity is required, such as for solar bins. LoRaWAN networks should be pilot tested for their suitability and are not recommended for solar bins.

- Using a sensor system that has self-improving collection predictions will assist in predicting collection frequencies.

  Recommendation – Use a system with integrated collection prediction software to reduce collection time.

- Where bin fullness level information is based on real time data, the level can change over the course of the collection period and confuse operational staff.

  Recommendation – Choose a system that enables collection routes to be calculated once only before collection departure if this is makes things easier for collectors.

- The bin fullness alert level may be set too high limiting the time required for operators to respond.

  Recommendation – Choose a system that allows the bin fullness alert to be adjusted to suit operator response times.

- Sensors that transmit once a day may not be suitable for high traffic areas. The bins may fill again after the sensor has transmitted.

  Recommendation – Use sensors that transmit daily in low traffic areas. Do not use in high-traffic areas.

- Undertaking a trial can be beneficial and allow suitable configurations of bins and services to be devised before purchase.

  Recommendation – Choose a system that can be trialled on a smaller scale and a supplier that will allow it.

- Integrated bins can be designed to improve visual amenity, provide waste collection signage and be equipped with various optional features such as LED backlights, LCD panels, graphic wraps, and Wi-Fi routers.

  Recommendation – Choose bins with these features where these elements are important or can aid council's education and marketing programs

- Onboarding training eases integration of the smart waste management technology into the existing system.

  Recommendation – Choose a supplier that provides comprehensive training and support

- Vibrations sensors allow reporting of bin damage such in the case of vandalism or car collisions.

  Recommendation – Choose a system that has this feature if bins are prone to damage or vandalism.

6.3 General suggestions

The case studies also revealed some more lessons for the installation and use of bin sensors and for public place bins in general:

- Placing bins in pairs, one for general waste and one for recyclables, increases collection of recyclables and reduces contamination
- Emptying bins before they overflow prevents dumped rubbish
- Using bin enclosures that lock prevents overflowing bins and minimise litter and vermin
- Collecting during off-peak periods improves public amenity and traffic safety
- Some companies provide ongoing waste strategy support
- Regular cleaning and servicing of bins and sensors improves transmission quality
- Collaboration with contractors and staff makes implementing bins with sensors easier. They should be engaged early in the testing and acquisition process
- Providing a cigarette disposal tray reduces cigarette waste.

APPENDIX A

Detailed Bin Sensor Information

Integrated Bin Details

Manufacturer	Australian distributor Contact Details	Model Names and Numbers	Councils, organisations or groups using the system	Operation	Details of data transfer	Data	Acquisition	Software	Life Expectancy	Convenience and feedback	Specifications	References
Big Belly Solar	SmartSensor Technologies Silke Stolze, Director of Operations E: silke@smartsensor.com.au m: 0408 060 872 Phone: +1-888-820-0300 / 1300 893 610 Fax: +1-781-444-5651 Email: info@bigbelly.com	Big Belly integrated solar powered bin	Big Belly bins • City of Melbourne • City of Canada Bay • Hume City Council • Waverley Council • Townsville City Council • Mosman Council • Lane Cove Council • Karlskoga, Sweden • City of Greater Bendigo Combination of SmartSensor and Big Belly sourced through SmartSensor Technologies: • Lane Cove • City of Canada Bay • Property NSW in Darling Harbour • Parramatta • Telstra • Wyndham • Waverley Council • Canterbury Bankstown Council • Bondi Beach • Crown Casino Melbourne • Port Stephens Council	A solar powered mechanism in the bin compacts waste up to 600 L capacity. The bins function on cloudy days and in temperatures from -40 to 85°C. Bins retain full function even when submerged under 508 mm of water, and experience only minor technical issues under 915 mm of water. The bins can be customised to service different waste streams, including multi-stream waste, single stream recycling, bottle/can recycling, paper recycling and organics. When the bin is 85% full, it sends a text message and email. When a unit reaches its capacity, sensors in the unit trigger an internal compactor that flattens the contents. Wrapping around the bin includes full colour wrapping, anti-graffiti wrapping, advertisement to earn revenue, interchangeable skins and pressed stainless steel. Some bins now say 'thank you' when you open them. Internal bins have straight sides to avoid waste getting stuck at the bottom. There are at least two barriers between the public and the other side. Big Belly offers additional technologies like public Wi-Fi, such as a Telstra modem. This can become a public space Wi-Fi. Wi-Fi is installed at two nearby bins that allows that area to have public Wi-Fi. Other additional technologies include TellyBelly. Telecommunication boxes can be put out of side and on bins. Helpful for telecommunication works. Solar Bins Australia provide delivery and installation Australia-wide. Solar Bins Australia runs 'how to' workshops for the contractors involved and waste management, operations and environmental teams. Training sessions and workshops show how to use the cloud system CLEAN, where the data is accessed, are provided. Devices used include desktops and smartphones The compactors are recommended for high traffic areas.	Big Belly only works on cellular networks and cannot run on another network. This is because the bins are releasing multiple and different types of information at once. LoRaWAN can only handle small packets of information at a time and cannot handle the information that coming from solar bins. High traceability and reliability of data. Data shows exact place and time particular bins were used. Security System prevents access to the bin stations. If a station is breached, authorities are alerted by a text or an email. Security provided through a physical security plate and the CLEAN Management Console's Security Management Module. The module enables the following functions: • Event Creation – Create and easily add or delete stations from a security event. • Event Scheduling – Stations are automatically placed into and removed from Secure Mode based on the specified event start and end time. • Security Notifications – Security Notifications can be sent to any staff or law enforcement personnel. • Security Dashboard – Easily monitor and manage security events. • Security Plates – Security Plates are installed during special events to prevent access to Big Belly compacting or non-compacting stations. Custom graphics can be added that communicate that the stations are out of service. .	Data is stored and transmitted to the client constantly through interactive status maps showing station location, type, fullness level, operational state, real time status reports of statistics per station over time for tracking performance and efficiency, daily collection activities and analysis and logging of critical station errors, including pen door, low battery, communication errors, alert history, communications, collection history, collection amounts, collection frequency, to the minute collection time and more, heat maps of utilisation and collection trends of each station, online monitoring and maintenance tools, and alert forwarding to the current software by API feed, and message forwarding by email or text. Bin volume and data on when the waste needs to be collected is monitored, reported and communicated to the cloud. Clients can view the real time bin capacity of the bins on the network. No electricity is needed. The bin also can permit access to a Wi-Fi network controlled by the client. From the website, the Wi-Fi enables the following: • Full control over how users access the network • Ability to offer access free, paid or a mixture of both • Ability to fully customise the splash page branding and appearance • Ability to capture user info in exchange for Wi-Fi access through splash page (for example, provide an email or answer a survey in exchange for access) • Ability to track advertising statistics on views and clicks • Access to management portal where you can monitor all devices and access detailed reporting • Support 7 days a week via phone, email and online chat • 24/7 equipment monitoring (we notify you if an access point goes offline)	Units can be purchased under a leasing program. - $6,500 per bin Software and connectivity is: - Annually - $195 per bin - 5 years – approve, $1,000 per bin Maintenance: $40 per month per bin, however, maintenance is rarely required. Most bins can be left for many years unattended. Bin components can be replaced. The whole bin doesn't have to be replaced. Typical acquisition program is a small number of testing followed by large scale acquisition. Bin Reorder rate is approximately 95%.	A cloud-based system. The CLEAN management console. Currently CLEAN API can connect with SeeClickFix, a platform for non-emergency repairs.	Bins runs on power from solar panels on the roof of the bin which are protected by a transparent hard covering. The bin knows when it is required to save battery. It has the function to skype a compaction cycle, so that it saves battery when the battery is low. The bin will then not compact until battery is changed and waste is emptied. Councils often put a 10-year lifetime for their bins on their asset registers, however, many councils still have bins operating after 15 years.	Data from averages taken from rural councils and dense urban councils show that bins reduce the need for street collections by 86%. Litter: For organics, a hopper design is used to deter pest access and prevent litter blown by the wind and overflowing waste. Further, additional features may be added to the bin including ash trays, security shields, side panels, wraps and stickers. The bin eliminates access by birds and vermin with its containment, weekend collections and bin overflows. Bins help reduce the number of collection trips by 80%.	-Galvanised sheet metal steel interior and exterior construction (recycled content). -Heavy duty plastic side panels (recycled content) -Exterior Finish: Polyester TGIC powder-coat finish -Internal Bin. Low-density polyethylene plastic leak proof bin -Lift Arm designed for Australian market -Fixed wheel system -Moulded handle -Made from recycled content -CE approved -RoHS compliant -Compaction Features -Compaction Force: 570 KGS -Cycle Time: 41 seconds -Motor Size: 1/6 HP DC gear motor -System Voltage: 12 Volts DC -Drive System: Gear motor with chain drive -Fully automated, IC processor controlled system -3-color LED status lamps indicate compacted trash level, machine status and error codes -Photovoltaic System Polycrystalline silicon cell module Nominal Output: 30 Watts Shock dampening mount system -PV panel protected by polycarbonate bubble Spill-proof, sealed maintenance-free 12V battery Charge maintained by Pulse Width Modulator	link: https://www.sustainabilitymatters.net.au/content/waste/product/bigbelly-solar-powered-rubbish-compactor-582819000 Phone call with Silke Stolze 15/07/19. See meeting minutes in folder.

Manufacturer	Australian distributor Contact Details	Model Names and Numbers	Councils, organisations or groups using the system	Operation	Details of data transfer	Data	Acquisition	Software	Life Expectancy	Convenience and feedback	Specifications	References
Escola ebin	Street Furniture Australia Contact: - Kieran Bennett, Sales Consultant E: kbennett@streetfurniture.com T: 02 8774 8828 M: 0403 911 820 T: 02 8774 8888 T: 1300 027 799 M: 0488 404 065 Email: nsw@streetfurniture.com	Escola ebin models 120 L and 240 L		Escola ebin is a sturdy, wear-resistant bin fitted with a Smartsensor. Like Big Belly, the bins are customizable in the colour, advertisement and bin decoration, waste deposit opening size, roof angle, if it is mounted or free standing and if there is an ashtray and/or dog bag dispenser present. Smartsensor detect fires, geolocation and fill level. The bin network and positioning relative to other bins and analytics (map, fill levels, route planning to only full bins) are tracked in the Smartsensor waste dashboard on a phone or laptop. Information can be used for monitoring and management, such as moving bins which are rarely full to high traffic areas. Street Furniture Australia offers the sale of replacement parts. Street Furniture Australia coats bins with a Teflon paint that is largely graffiti-proof. Desktop and smartphone devises can be used. As there is no compactor, high traffic places are not recommended.	Receives data on collection routes to follow. Not recommended in built up areas.	Data includes bin capacity, temperature/fire sensor, GPS location	12-month trial with access to the asset management app. Can then stay on the system with plan extension. Cost between $2,300-$4,000 per unit Contract is ongoing and arranged with Smartsensor. When the plan expires access to the dashboard of bin analytics ends.	Smartsensor's technology, textura for the bin's exterior.	Uses smart sensor to measure capacity but the bin is/can be solar powered	Maintenance level rated easy-medium	'MCODE EBIN-E120 DIMENSIONS (mm) 570W x 590D x 1180H CAPACITY Fits 120L wheeled bin ROOF Angled, Flat, Flat with tray return, Tailored BODY Stainless 304, Stainless 316, Tailored FINISH (ROOF, TRAY & SIDES) Powder Coated Panels (see colour chart), No.4 Finish (brushed), Tailored FINISH (FRONT & BACK) No.4 Finish (brushed) standard, Powder Coated Panels (see colour chart), Tailored OPENING INSERT Rectangle, Circle, Slot, Tailored SIGNAGE Sublimated metal plate None, Garbage (Lobster Red), Recycle (Brilliant Yellow), Tailored MOUNTING Surface Fixed, Freestanding, Tailored ASH BOX Stainless steel No.4 finish (brushed) No, Yes, Tailored DOG BAG DISPENSER No, Yes, Tailored Some options incur additional fees and lead time. For a tailored solution please contact a sales representative. '	http://wastemanagementreview.com.au/smart-bins/
SPARK	SPARK furniture Phone: 1800 688 367 Email: design@sparkfurniture.com.au Website: https://www.sparkfurniture.com.au/products/ilevel-bin/ilevel-bin/	iLEVEL Bin enclosure equipped with sensor		iLEVEL developed in partnership with Smartsensor. The iLevel bin is fitter with a Smartsensor. The iLEVEL itself is an enclosure to be retrofitted around older bins. This protects bin litter from spilling out and overflowing and prevents access to the litter from bird and other vermin. It can be custom designed to the customer's specifications or it can be retrofitted in a standard design. The waste management technology sensor technology is run by Smartsensor. Concealed sensor reads bin fullness levels and reports to customers' dashboard.	Maps the most economical route to empty bins that need attention Reports data to customers' dashboard	Bin volume Temperature Network maintenance requirements Categorises bins by regularity of use and reduces emptying costs. Determines hotspots for future infrastructure development requirements.		Smartsensor's technology			Cowl design reduces vermin and weather ingress	
Yindi Smart Bin	Yindi Phone: 1300656756 Email: info@yindibins.com Website: http://yindibins.com/	Integrated bin Yindi 120, Yindi 120 Twin, 120 L Smart Module, Yindi 240, 240 L Smart Module	Northern Beaches Council City of Yarra Council Fairfield City Council Shelley Beach	Bins can be upgraded to compaction system using the smart module. Can increase capacity up to six times. Designed to house standard 120/140/240 L bins. Ultrasonic sensors measure bin fullness. LED light indicates fullness of bin or app highlights all bins that are over 80% full. Can be used on a phone with an app or anything with a web browser Can be used anywhere, can be designed for high or low traffic Operator can visit bins on route and observe the LEDs on the bins which indicate how full and decide if bin needs emptying. Operator can also download the app to see data on bins.	Ultrasonic sensors relay information about bin capacity once per hour to the vStream cloud service. The bin will continue to communicate with the vStream cloud management software to log when it is ready for pick up and to log service conditions. Also features error detection, photoelectric sensors and safety shield to ensure safety of cleaning staff and public. Uses Wi-Fi, 3G and 4G through sim card installed. Camera takes photos and transmits information to show contamination. For best longevity can use LoRaWAN, to preserve battery. Focus is on security. Complies with ICT Standard Protocols by using HTTPS.	LED light indicates fullness of bin or app highlights all bins that are over 80% full. Parameters can be altered so operators can see bins with a different level of fullness, or only see bins within a certain distance.	Can be bought outright with or without the compactor and can also be leased daily, monthly or yearly. A six-month free trial is also optional. No training provided Each bin between $3000-$4000 for a base product. One council paid up to $8000 for special design. 24-month warranty. Broken compactors can be returned for $500 and will be replaced. For repairs, the smart module (compactor) can be unplugged and returned to Yindi for a service. During this time, the bin will function as a conventional bin. When the compactor returns, it comes with a new warranty.	vStream cloud service and management software. API software merges with third party groups.	Up to 20 years. The bins are also solar powered, so no infrastructure is needed to operate them. The compactor will need to be replaced after 5 years, and this is a completely detachable technology.	Public feedback is very positive. Some bins are transparent and often the pedestrians will stop to watch. Older model had same compaction system as competitor. Issues with compaction system breaking due to flawed design. Contacting City of Melbourne revealed they also experienced a lot of breaking. Now have new design which does not break, relies on a scissor compactor system. Sensor system was unreliable with one sensor. System now has an ultrasonic sensor and an infrared sensor so when both receive input, Client is certain the bin is full, in case the topography of the bin inside is misleading.		

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Guardforce	Guardforce Contact: Sean McCarthy at: M: 0402 120 082 from SecureCorp Phone: 613 8527 8888 Email: INFO@SECURECORP.COM.AU	Guardforce's Smart Waste Bin		Hybrid solar powered bin with regular bin inside. Ultrasonic fill level sensor indicates level. Metal casing to prevent access, damage and movement of the bin. Lightboxes on side of the bin may also be used for advertising. Bins are fitted with compactor which compresses the waste when full to roughly 1/8 of its original volume Works best in high traffic areas as the compaction enables large capcity	Fleet Management Platform used to manage collection route and schedules based on the real time data in cloud. Desktop and smartphone devices can be used	Fullness, also detects presence of a human hand, which will halt the crushing process for safety, fire alerts to customer devices.		Fleet management platform		Bins hold up to 8 times more waste and reduce collection frequency by up to 80%.		
Ecube Labs	Smart City Solutions Contacts: - Kyle Choi, Global Business Development Team Manager E: kyle@ecubelabs.com T: +82.70.7725.5358 M: +82.10.3100.1746 - Samira Hughes, Chief Operating Officer E: samira@smartcitysolutions.com.au M: 0417 546 977 - Raymond Hughes, Director of Sales E: raymond@smartcitysolutions.com.au T: +1-213-282-7850 E: marketus@ecubelabs.com; market@ecubelabs.com; Website: https://www.ecubelabs.com/contact/ Ecube Labs is a group based in Los Angeles and Seoul which provides both a stand-alone sensor and an integrated bin, a cloud service to manage their data and a waste collection management platform.	CleanCUBE and CleanFLEX Integrated bin and stand-alone sensor	City of Gold Coast, City of Moonee Valley, The Hills Shire Council, Monash University, City of Playford, Town of Walkerville, Campbelltown City Council	The integrated bin is a hybrid, solar or AC powered compactor which is compatible with 120 and 240 L bins. Bin can compact up to eight times more waste than non-compacting bins and can be equipped with additional services such as LED back lights, LCD panels, graphic wraps, ash trays, mounting brackets, audio speakers and a Wi-Fi router. Can take general waste and recycling and has a foot pedal. By looking at collection performance and efficiency, overflow frequency, waste generation, sub-optimal collections, and more comprehensive reports, users can identify areas for improvement. The machine algorithm eventually learns the waste generation habits of the bins and can offer predictive models to use to arrange collections before they are needed. Best used in high traffic areas. Extensive training offered for installation and operation.	CleanFLEX monitor system uses wireless ultrasonic connection to monitor a container's fill level, regardless of solid or liquid waste type. The information from both of these devices is sent to the CleanCityNetworks (CCN). Can use tablet, smart phones and any device with an Internet connection. Uses 3G/2G, LoRaWAN, NB-IoT Has an external antenna for situations with weak cellular strength.	Monitors fill levels, has safety sensors in case of fire, tracks GPS locations, check battery levels, geographical locations, collection history, overflow status, response times, fire events. History of bin capacity and collection paths. Can be used to manage waste management routes. These can be optimized using machine learning algorithms so they will continue to get better over time. This also allows users to have real time monitoring of routes, analysis and asset management, including vehicle status, driver behaviour and fuel consumption. It also allows drivers access to reporting tools.	Leasing requires a minimum order or, if bought outright, comes with a monthly service fee. Either is possible. $449 each During the warranty, free technical support is offered and the same should be offered after warranty. Ecube engineers offer troubleshooting. Otherwise it is monitored by users	Uses Amazon Web Services (AWS). Fully AWS (Web server + Database + Data Storage). AWS maintained effective controls over the Security and availability of Amazon Web Services System to provide reasonable assurance that: • the Amazon Web Services System was protected against unauthorized access, use, or modification to meet AWS' commitments and system requirements • the Amazon Web Services System was available for operation and use to meet AWS' commitments and system requirements ISO 27001 compliant under AWS compliance (https://aws.amazon.com/compliance/)No software is needed, can log in online. API software compatible with third party groups.	Battery lasts 3-4 years and its solar panel should be replaced every 15 years. CleanTILT contains replaceable lithium battery which needs to be replaced every 5 years. Each flex has a life span of 3000 reporting cycles. Depending on how frequently you use those cycles the battery can last from 1 Year to 8 years. All our flex's have interchangeable batteries. CleanCUBE lasts for 7-8 years. Email reports 10 years.	Used to be a 20-25cm blind spot and that the sensor couldn't be placed on the side of bins at an angle and get an accurate reading. This has been changed to solve the problem. Now have two sensors monitoring instead of one and we have made the sensor with some rotation and flex so it can be placed on the side of any bin, angle the sensor to suit and still be robust and give accurate readings and we have eradicated blind spot issue. Bin will hold up to 8 times more waste and reduce collection frequency by up to 80%. Claims bin enables cities and waste management companies to increase their operational waste collection efficiency by up to 50%.	.	
Victor Stanley Inc	VICTOR STANLEY P.O. Drawer 330, Dunkirk, MD 20754 USA TEL - 301.855.8300 sales@victorstanley.com	Victor Stanley Relay Victor Stanley Relay Sensor The integrated bins come in packages named CCS-200SCL, CCS-210SCLW, CCS-220DCL, CCS-230DCLW, CCS-300SCW, CCS-310DCW or others. See Supplier Data for more details. Integrated bin and stand-alone sensor	Pittsburgh, Washington DC	An all-in-one solution, Victor Stanley Relay features fully integrated sensors in new and existing Victor Stanley litter receptacles and recycling stations, wireless communications, and dedicated web portal for access to container conditions. Best in high-use, commercial and urban environments at street level. Sensors can be hidden in most litter bins, recycling stations and lids. Work with any type of waste (garbage, mixed recyclables, paper, glass, metals, etc.) Customizable alert triggers and push notifications can be set to receive information regarding fill level spikes, container location, collection status and dispatch reporting	Data automatically transmitted to Victor Stanley Relay Service using standard cellular networks. Access from anywhere through any device (via web portal) including web browser, smartphone, tablet, etc. WCDMA (UMTS) and GPRS/EDGE and standard Cellular networks	Fill level, weight, system temperature, container location, and collection status are continuously monitored — and real-time container conditions. On-board GPS module provides longitude and latitude coordinates of each container Users can check real-time status of containers Real-time and historical information to maximize collection planning, scheduling, routing and resource utilization	Customers pay a monthly/yealry/multi-yearly subscription fee.	Log in with a web browser. API software compatible with third party groups.		Eliminate inefficient fixed collection routing Reduced fuel costs, resource costs, and CO2 emissions Efficient resource allocation saves an estimated 40-60% in collection expenses.		https://www.victorstanley.com/product/relay/ https://www.habitat-systems.com/victor-stanley-announces-relay/

Sensor Details

Manufacturer	Distributor Contact Details	Model Names and Numbers	Councils, organisations or groups using the system	Operation	Data Transfer Details	Data Collected	Acquisition Options and Costs	Software	Battery and Unit Life Expectancy	Convenience and feedback	Specifications	References
Smartsensor Australia	Smartsensor Technologies Contact at Smartsensor Technologies Silke Stolze, Director of Operations E: silke@smartsensor.com.au m: 0408 060 872 Web: https://www.smartsensor.com.au/contact Email: support@smartsensor.com.au Phone:1300 893 610.	Smartsensor Ultrasonic Waste Sensor 2.0 Stand-alone sensor	Glasgow City Council? • Street Furniture Australia. The Escola eBin uses the Smartsensor. • SPARK Furniture. The iLEVEL bin uses the Smartsensor. • Gossi Park Furniture. • 'Street and Garden'	Smartsensor is an ultrasonic sensing unit attached to bins which requires no additional software. It is a cloud-hosted service is designed to provide clients with fullness levels of rubbish bins, collection efficiency, critical zones, alerts and savings 24/7. For onboarding, Smartsensor provides one hour of online training for each new customer for training and an overview of the Smartsensor platform. This includes zones, assets, inventory, reports, locations and custom settings. Devices that can be used include tablets, smartphones, anything with a web-enabled browser Can be used for high or low use bins. Some councils have installed them on outskirts of areas with low use, some roll them out in all public space bins. Sends up-to-the-minute reports and directions to drivers. Contractors get their own login details. Lots of contractors that are engaged by councils use this technology, including Cleanaway and Citywide. Some contractors use it in their tender submissions to use it as an innovative product to councils.	- Uses 3G/4G via Vodafone Network - Uses LoRaWAN - Uses NB-IoT (this is an industrial grade LPWAN (low power wide area network) which allows long range communication for low bit rate devices such as sensors) -CAT-M1 -SigFox First preference for use is cellular networks. This is because there is always connectivity. With LoRaWAN, the risk that If the network is down, the sensor can't connect to anything and hence can't pass the data on to the customer. This doesn't happen with cellular which is a continuous network. Customers buy networks as gateways between the sensor and their platform. Customers sometimes think its cheaper to use LoRaWAN, but from the perspective of Smartsensor Technologies, there is no price difference.	Data is sent to devices that connect to the Internet, and presented on platforms such as Smartsensor Dashboard, Smartsensor App and Smartsensor Voyager. It monitors the data, reports it and predicts when the bin will be full, enabling control of the collection frequency of a bin. This data is then used to determine the most efficient route to collect bins. Routes and collection schedules are based on live collection levels, critical time requirements or defined schedule collections. The GPS enabled system connects the full containers from collection point, the collection vehicle, the waste depot and refuse station all on a single map. Smartsensor Dashboard can: • Identify potential issues before they exist • Observe all elements of waste network in a real time map • Zoom in on each bin, truck, or depot and receive up to the minute information • View fullness and temperature levels of each bin, and receive maintenance alerts • View reports and predictions Smartsensor® Dynamic Routing enables customers to: • Gain a city-wide view of entire waste management operation • Pull instant routing reports on the most efficient routes possible • Daily plan and print routes ahead of schedule • Connect to multiple Smart City Platforms • Engage directly with fleet and drivers • Track fleet dynamically and safely • Manage customer service and KPIs efficiently, Users can specify at which fill levels the alert will trigger and can arrange a temperature alert. Onsite support is provided in metro areas for installation of the sensors, bin placement, set up and training. Other devices can be imported into Smartsensor platforms. The Smartsensor has a complete REST API library so it may connect to data on any other platform. Api data can be pushed out onto other customer platforms. Customer owns all the data. There is no issue with hacking.	Cost per 100 units differs based on connectivity types and inclusions. Customers buy sensors and then have a monthly subscription that includes connectivity, software, etc. Cost is quantity based and varies with each situation and requested inclusions, but on average, costs are: • $269 for sensors • $10 per sensor per month for connectivity, software, etc. Smartsensor provides phone and email support between 9am-5pm Monday-Friday GMT. Onsite support will also be provided for the placement of bins. Smartsensor's, set up and training in metro areas only. Devices 'dead on arrival' will be replaced, as will batteries once depleted. Smartsensor is Australia based and work very closely with their customers. Convenient for maintenance. A 12 month warranty is provided and 4 year warranty, with extensions offered for sale.	-Smartsensor Dashboard -Smartsensor App -Smartsensor Dynamic Routing -Smartsensor Voyager. Unlimited users per device / software.	The battery is 1 - 2 C Cell from SAFT. Battery life depends on the connection method the Smartsensor is using. On 3G/4G, it lasts 12 months based on one hour heartbeats. On LoRaWAN battery life is between 24-36 months based on one hour heartbeats. On NB-IoT, the battery life is 24-48 months, based on one hour call ins. System uses 2 batteries to double the lifetime of the product. The Smartsensor will notify the customer when the batter is about to die. Easily open device and change battery when its required.	Claims save up to 50% on collection costs and wasted collection trips. With the benefit of two-years of data customer will know exactly what it wants the contractor to do. Councils will know if bins are being picked up and the exact number of times. They will also have data power to negotiate contracts. Other use Smartsensors in their technologies, including: A lot of companies create normal bins that fit smart sensors, if clients want them for the future. They then buy Smartsensors to attach to their bins when clients want a smart bin.		Phone call with Silke Stolze 15/07/19. See meeting minutes in folder.
SmartBin	Smart Bins Tel: +61 407562464 Email: sales@smartbin.com Website: https://www.smartbin.com/	IoT Fill-level Sensors Stand-alone sensor	-Cascais Ambiente -Portugal (Recyclables) -aaronoil company inc (waste oil) -Goodwill (clothing collection)	Smart Bin's IoT ultrasonic sensors have non-corrosive shell requiring no maintenance, senses up to 3 metres in depth to waste surface and can be used for any waste product. The operator uses a tablet or smartphone Any device with a web enabled browser to receive and monitor the collection route they are to take.	Uses cellular networks (3G/4G?)	Measures and records bin fill levels, temperature and geo locations. Clients log into their accounts and, based on this information, plan collection routes which are optimized for time efficiency in SmartBin Live. SmartBin Live enables the following features: • Enjoy a war room view of operations • Generate efficient waste collection routes for only the containers requiring servicing • Send routes directly to drivers tablets or smartphones • Track drivers as they service their smart routes • Analyse and benchmark the performance of your operation • Know the volume and value of collection routes before you go • Inform strategy with detailed KPI reports Drivers are sent routes directly at smartphone or tablet. Routes are received in app and followed to collect at the optimum time.	SmartBin provide 24/7 support for all clients. SmartBin clients can contact their designated Account Manager for support on sensor installations or SmartBin Live account configurations Support documentation and videos are also available on the clients' SmartBin Live account. No training provided	SmartBin Liv	Over 3 years of battery life	Claims to cut service costs up to 50%. Case studies are discussed here https://www.smartbin.com/clients/		

Manufacturer	Distributor Contact Details	Model Names and Numbers	Councils, organisations or groups using the system	Operation	Data Transfer Details	Data Collected	Acquisition Options and Costs	Software	Battery and Unit Life Expectancy	Convenience and feedback	Specifications	References
netBin	Draffin Street Furniture. Contacts: - Lloyd Scott - Project Deployment manager E: lloyd.scott@farsite.com M: +44 (0) 78813 44467 Skype: farsite.lloyd - Dan Stebbing - Draffin Street Furniture E: Dan@draffin.com.au M: 0421 805 444 T: (03) 9720 1033 T: +44 (0)1256 330461 E: iot@farsite.com Web: www.iot.farsite.com T: 1300 DRAFFIN E: sales@draffin.com.au Web: www.draffin.com.au UK based FarSite Communications owns NetBin which distributes three products and accompanying software. nPod is one of those products.	nPod fill level sensor Stand-alone sensor	Derby City Council. BIU Group, UK New Delhi Government Suburb of Toronto, Canada Cornerstone Recovery, Toronto Nathans Waste Savers, Northern England Northern England Council Macao Government, Macao	nPod is a bin sensor device which uses dual ultrasonic sensing. The dual sensors have a depth range between 3 cm – 4 m, which can be boosted to 6 m with a long-range sensor. Once the nPod is screwed to the side of the bin, the ultrasonic sensor rotates anywhere within 135-degree range to position itself, so it has the most accurate reading of the bin's capacity. NetBin has two other products: nTag and nLok. NTag is a separate collection notification tag which reports in real time when the cleaner empties the bins. nLok is a physical security lock system which adds onto the nPod. The nLok system detects via Bluetooth connection if the smartphone on the person approaching the bin contains the netBin nLok app. Upon detecting this app, the bin's open command will be verified and the locking mechanism on the bin will release. The discrete Bluetooth nTag fixes inside the bin and pairs with our INSPECTOR app reporting; distance from bin to cleaner, location and duration cleaner is at the bin for. nTag automatically connects with the cleaner's smart phone when they arrive at a bin Commissioning via SETUP app. Each nPod's QR code is scanned before install updating the HUB with the new location and bin details. Operates on desktops and smartphones Best location are places that are expensive to collect for example low traffic bins in parks or outer urban areas or where access is awkward. Bins that are prone to overflowing such as city centre or tourist areas. Bins that have sporadic filling patterns and would benefit from an automated collection request. Operator must download netBin COLLECT smartphone app to receive jobs assigned by the netBin HUB.	Data is logged to a cloud-based server. GPRS, 3G, NB-IoT, LTE, CAT-M1. Bluetooth local connectivity, Large antenna inside the nPod which helps transmission in lower signal areas. NB-IoT is very effective method for built up areas as it has excellent building penetration. nPods are installed in underground bins on many systems and they have not needed an external antenna. SSL access to the user interface and all communications between the nPod and the cloud encrypted. nLok brings access control systems to netBin allowing complete control and traceability of access to container areas fitted with nLok.	Fill Level, Location (with GPS option), Collection events, Temperature (in case of fires), Battery Level, Signal Level Duration of collector visits (if collector has a netBin app and is connecting to the nPod via Bluetooth) GPS position provides information on whether bin has been stolen or moved, temperature sensing to detect fires, tilt sensing to record when the bin has been emptied. Has battery conservation function. The netBin HUB displays information and allows access from an account manager and sub users. Analytics are provided per bin. HUB enables selection of correct bins, automatically optimise the order and estimate trip duration, costs and distance. Routes can then be scheduled and assigned to drivers. Unexpected behaviour in the network is logged in alerts which are transmitted as an email, HUB notification and, optionally, a text message. Changes in bin levels over time are recorded. Raw data may be accessed and examined in Excel through the netBin ANALYSER app. The netBin COLLECT app must be on driver smartphones. Route received on phone. Driver can report information to headquarters. If for any reason a bin cannot be serviced netBin Collect will notify netBin Hub that a bin has been missed off the collection route so that a solution can be worked out by the network manager. Allows • Analyse existing collection routes against actual fill levels • Monitor staff and bin performance • Gather evidence for new collection improvement schemes The HUB maintains comprehensive information on all containers being managed: their type, function, capacity, status, location and a history of events. This information is stored in a database which is automatically updated as netBin sensors report changes to their status. Can generate alerts for fire If for any reason a bin has a problem netBin COLLECT can notify netBin HUB supplying photographs and notes allowing the network manager to determine what action to take. Timely warnings when bins are full.	No training provided. Two resellers in Australia Two different ways to purchase. Options include a service contract for 24, 36 and 60 months after which a lower monthly service subscription will be offered. Pricing includes the netBin application running in a cloud environment, nPod bin sensor with wireless operation over a mobile phone network (GPRS or 3G), associated Smartphone apps for use by the collection operatives, warranty and free upgrades to the netBin software for the duration of the contract. Installation and shipping of units is not included, if required this will be a separately quoted item. Split Purchase Model: Use of netBin for 24, 36 and 60 months. Once off initial payment with small monthly payments for the duration of the contract length. Up to 100 units $10.03 each for 24 and 36 months, $9.13 each for 60 months 500 units $7.29 for 24 and 36 months, $6.63 for 60 months Full Purchase Model: Use of netBin for 24 and 36 months in one payment. After contract ends there will be a monthly charge per sensor installed, in line with a monthly ongoing rate used in split purchase arrangements. 100 units $543.34 for 24 months and $599.04 for 36 months The optional GPS module allows automated location of the nPod to the HUB: $39.60 for the GPS. Small Systems Charge: Where netBin systems have less than 100 nPods you will be subject to a small system charge for setup and monthly use. This contributes to fixed costs associated with creating and maintaining customer instances. If the total number of nPods increase to 100 or more, then the ongoing maintenance fee will be removed. Upfront setup cost: $660. Monthly maintenance fee: $110. Up to 10yr warranty and netBin suite if paid for monthly. Maintenance and support service is provided as part of netBin system. Includes updates to the netBin Suite, replacement of faulty hardware and technical support for the duration of the contract.	netBin COLLECT netBin HUB Flexible open API for easy integration with 3rd party programs. Integrates valuable netBin data into existing third-party collection and bin management systems. Scheduling software doesn't need to be replaced, netBin API allows powerful bin data to be sent between software packages Trends in bin behaviour can be analysed in Excel tool ANALYSER, API Interface to big data API software complies with third party groups. Ability to connect via Bluetooth with nearby netBin apps and allows the future opportunity to work with 3rd party Bluetooth sensors.	nPod has a lithium Thionyl Chloride battery that updates twice a day on average and lasts 10 years. The nPod has been designed to accommodate various capacity batteries to suite a wide range of netBin applications, this helps balance cost and battery life without sacrificing performance. 10yr minimum life expectancy.	Majority of problems have been due to poor installation by the customer, which leads to poor fill level data. UK council: Using netBin we reduced our collections by 80%. Using netBin Analyser, we can see that bins are over collected by 30%. Derby City Council: After installing netBin sensors we reduced our complaints by 100%		See reference pdf titled 'netBin References Site List 28-05-19', which discuss a handful of projects. Pdf saved in client data and/or supplier data folder. Case studies discussed.

Manufacturer	Distributor Contact Details	Model Names and Numbers	Councils, organisations or groups using the system	Operation	Data Transfer Details	Data Collected	Acquisition Options and Costs	Software	Battery and Unit Life Expectancy	Convenience and feedback	Specifications	References
Nordsense	Contact: Ann (Annmette) Haugaard E: annmette@nordsense.com T: +45 3172 2703 Website: https://nordsense.com/contact/ Email: contact@nordsense.com Phone: +1 (650) 433 9953 /+45 31540137. Based in USA and Denmark.	NS Pod Tall and NS Pod Flat Stand-alone sensor	Copenhagen San Francisco Ramla and Netanya in Israel, Vestforbrænding (waste management company) No Australian customers, no Australian reference. Process is the same regardless of country.	NS Pod comes in a tall and flat form. The sensor can detect waste lined in a plastic bag and can detect waste within the first 30 cm of the sensor. Can be placed in any container regardless of shape, size (especially small containers) or their contents. It's an optical sensor, which detects a 256-pixel resolution that enables it to produce 3D depth maps of a bin's content. Increases accuracy by providing multiple reference points. The sensor also detects movement and orientation. Has a range of 5 metres. The size of the sensor is customizable and can be made to fit even the smallest of containers. Sensor is volumetric sensor with high accurate multipoint measurements with a range from 0-5 meters (1cm resolution). Works in most bins and containers. Sensor measures 16 points as waste. Report will show over or under servicing and show how efficient waste management handling is. Tablets, smartphones, any device with a web enabled browser can be used. Desktop recommended for the best experience, and the installation and navigation apps are available on iOS and Android devices. Recommended bin locations are provided with use of the sensors after a few weeks of traffic monitoring. Works in all areas but outdoor locations are optimal. This includes public street bins, dumpsters, public parks and beaches. The app indicates when a bin is ready to be collected and sends the notification to the nearest driver. Rerouting occurs automatically should the route change. This route verbally directs them to the specific containers and provides a picture of what the container they will service will look like.	Uses Global 2G/3G/CAT-M1/NB-IoT. Cellular works the best so far. Cellular can handle large scale deployment. 3G is preferred for installation outside of the USA, and coverage tends to be better in urban areas, but it depends on the provider being used for roaming. High quality of customer data protection and not easily hacked. All platforms are housed within AWS.	3D depth maps of a bin's content and fullness Movement and orientation Samples every 15 minutes and reports once a day. Which containers are most or least active, and how quickly they fill. History of capacity Emptying events Routes of the drivers The only data stored are the measurements taken by the sensors. Can be used to determine trends and provide suggestions for optimal container placement to prevent overflowing bins, gaining operational efficiency and minimising complaints. The platform also allows route planning. Can track routes travelled in real time and compare them to optimal route and the trip duration. You can also identify zones of interest to focus attention on a district or customer site. Can also create zones to granularly organize operations, either per zone, or by creating more route plans with multiple zones. The operators use the NS Navigator to perform their daily route more efficiently. The app indicates when a job is ready to be performed and sends the notification to the nearest driver, for efficiency. Customers will receive important analytics such as trip duration and cost estimation. Bin collection routes to the drivers • Reports once a day to the client which display actionable tasks, unless there's something urgent to say. • Topographic view of height and platform inside the bin. Can see how it changes over time. Can change the recommended fill level per bin (generally smaller bins reach a lower fill capacity before a bin is sent) • Uses algorithms and predictions to predict time to full. • Can pre-emptively order an early emptying, and arrange for a notification for when the bin is emptied. • Create zones, specific route plans, restrictions (such as a marathon or street parade or restrictions for when your vehicle cannot be in an area on a certain day). • Specify notifications, register certain vehicles with the cloud management system. • Contractors can upload photos on pick up. This can show council/clients what the bins look up on pick up and confirm that the bins have been picked up. • Can order an 'empty now' option. For examples, if residents are complaining. This automatically adds it to a contractor's pick-up route. Client will be notified once bin is emptied.	Mostly the sensors are offered as a SaaS model with a flat monthly subscription fee to cover device related costs and software platform/apps. However, outright purchasing is optional which comes with a smaller monthly maintenance fee. Normally minimum 100 sensors required, depending on the specific case. Subscription based model – monthly payment per sensor. Includes sensor, software, data usage. Does not include installation, input duties and shipment. Subscription is 12 euros/14 USD per month. Can help install, and send out technicians, or do an onboarding introduction to train the customers personnel to teach them how to install Price can be decreased for large scale implementation If leased, the cost covers maintenance. If bought outright, a maintenance cost is paid. Replacement will be sent when sensors are offline. Customers are alerted when there's unusual activity with their sensor.	NS Platform is the hub from which services are monitored and data is logged Accessible from any device, it enables organising fleet into zones, and suggests when to empty bins when they are full. For large locations, can create zones to organize operations either per-zone or by creating multiple zones. NS Navigator for the waste collector. API software complies with third party groups. Operates on all platforms. App and spoken directions support different languages. Currently English, Portuguese, Danish, German and Hebrew, with more coming soon.	Unit should outlive the battery.	Sensor is not visible but results from case studies show overwhelmingly positive response. Very rarely any problems except if sensor is hit by opaque liquids or a material which sticks and obstructs its vision. This would be detected, and a message sent to the system. Overall costs for waste operations drop 50% and in some municipal cases there has been 90% reduction in daily waste collection. San Francisco drop in public complaints by 95%. Reduce capital expenditure and carbon footprint while improving workflows.		https://nordsense.com/cases/san-francisco/?utm_source=Request+case+stories+from+website&utm_campaign=333472a82c-AUTOMATION__1&utm_medium=email&utm_term=0_21eff9f326-333472a82c-237968885
BioEnable	Phone: +91 9966794823 +91 8600010820 Email: support@bioenabletech.com Email: Sales@bioenabletech.com A live chat is also available. Based in India.	Smartbin Sensors Stand-alone sensor		BioEnable uses an ultrasonic fill sensor to monitor most types of containers and any type of substance in real time. The sensor comes in two models: compact black and longer battery life. Client monitoring can take place through mobile or any Internet accessing device.	Uses 2G and 3G through WCDMA and GSM networks	Bin fill levels and geo locations. Enables users to arrange the bins for collection only when they are full. Routes are optimized to include only the full bins. Route optimization and predictive analytics provide insightful historical data to generate the best routes and estimate the time of containers becoming full. Information collected is sent to the smart waste collection optimization platform known as ECUBE Labs. This is a separate product to the sensor run by a different company. With the smart suite, bin capacity can be tracked as a percentage for each bin. A map to track the placement of the bins is also accessible.	No training provided	The ECUBELabs waste analytics platform	Model 1: 2-5 years Model 2: 5-10 years			
Brighter Bins	Contacts: - Imdad Laskar at E: imdad@smartends.com - Noman Ahmed at E: noman@smartends.com - Ahmed Usman at E: ahmed@smartends.com E: info@brighterbins.com T: +32 487 59 51 22 +971 56 808 8076 Web: https://www.brighterbins.com/ Based in Pakistan and Belgium.	BrighterBins Stand-alone sensor	Belgium Greece Estonia India Australia Sweden Oman UK Ireland and Switzerland Senra, a large LPWAN operator in India, recently committed to deploying BrighterBins in smart cities throughout the country.	Sensor developed by the Belgian company SmartEnds. The sensor functions as a 'stick and go' device, where it is stuck to the bin, either on the internal wall or roof, turned on and begins to be operational. The system has low battery usage and a long range. Desktops and smartphones required. Can be sued anywhere for public bins, underground containers, industrial containers.	Supports LoRaWAN, SigFox, NB-IoT. Cloud platform, or client platform accessed through computer devices Depends on IoT network coverage Effective wireless communication, even in closed metal bins Optional external antenna Wireless technologies support a range between 1,5 to 5 km radius, depending on the urban density.	Bin capacity, Fill levels Fill level detection in 90% of bins View planned, missed and unscheduled collections Track average fill-levels and estimate how fast they are filling up Fire detection alert Battery level read Location Recommended pick-up date Adaptive route learning models are used to create a routing system that meets the needs of local municipal drivers, optimized to their garbage collection routes. Not clear how clients access information or how they are involved in arranging drivers and the collection process. Only technology mentioned is the Truck Driver App which informs the operators how to find each bin through a route transmitted to their smartphone based on GPS location.	Can obtain device only or device + platform. Unclear if leasing or outright purchasing Product warranty is one year	Driver app calculates a map to be followed to collect bins in most efficient way. App shows where to go based on GPS location. Driver can give feedback on things such as reason to deviate from proposed route and any litter and damage status. Two versions of route planning: - Dynamic Route Planning: the best pick-up routes, optimized in real time. - Skip Planning: drivers use current routes, but bins that do not need to be picked up are skipped. Ready for Integration in existing processes and platforms	Non-rechargeable lithium battery. Replaceable. Up to 8 years of battery life Units 5-10 years	Generally positive although sometimes false echoes if the structure of the bin is complex. Bin types taken into account for optimal placement of sensor.	Estimated saving per bin is around €350.	https://partners.sigfox.com/products/brighterbins-stick-and-go https://partners.sigfox.com/products/brighterbins https://partners.sigfox.com/companies/brighterbins-by-smartends https://www.brighterbins.com

Manufacturer	Distributor Contact Details	Model Names and Numbers	Councils, organisations or groups using the system	Operation	Data Transfer Details	Data Collected	Acquisition Options and Costs	Software	Battery and Unit Life Expectancy	Convenience and feedback	Specifications	References
EYEfi Smart Sensors	EYEfi smartsensor@eyefi.com.au Phone: +613 94175777 www.eyefi.com.au/contact Australian company based in Melbourne.	EYEfi Sensor II Stand-alone sensor	City of Melbourne	Ultrasonic camera sensor, although the camera won't be integrated until Q4 of 2019. The sensor detects distance and level, ambient temperature and battery temperature. Designed to have may applications one of which is the analysis of fill levels and the visual appearance (via the camera) of the waste levels in bins. Desktops and smartphones used	Currently 3G/LTE but NB-IoT, LoRaWAN, SigFox, BLE and other mesh networking technologies will be available in future.	Bin capacity by a distance/level sensor Temperature of both the battery and the ambient temperature A camera from Q4 2019 and various sensor and I/O options Data is transmitted to EYEfi Cloud. Smart Waste plugin provides a fill level analysis of bins to alert operators for collection scheduling and routing. Fill level trigger is customizable. EYEfi Spatial Video support will be added to EYEfi Cloud as a plugin and available from Q4 2019		EYEfi® Cloud. EYEfi Cloud is EYEfi's next generation of smart sensors and devices; combining all of our customers remote monitoring needs in one place, through the use of EYEfi Cloud's capability plugins, such as: Smart Waste - fill level analysis of waste levels in public space, bulk or skip bins to provide alerts to waste services providers, with automated collection scheduling and routing for drivers EYEfi's API and suite of smart plug-in capabilities provide support for a wide variety of applications				
Enevo	Smarter Technology Solutions Contact: Danielle Storey - Chief Innovation Office E:danielle.storey@smartertechnologysolutions.com M: +61411349831 Email: info@smartertechnologysolutions.com.au Phone: +617 3368 9083 Website: https://www.smartertechnologysolutions.com.au/contact-us/ US based but distributed in Australia through Smarter Technology Solutions.	Enevo smart sensor Stand-alone sensor	McDonalds	Ultrasonic sensor that detects fill levels and collections. Minimal maintenance is required. Sensor checks when collections are taking place and alerts the system when missed. Can be sued on any device with an Internet connection.		Bin capacity and collections Data is used to track seasonal variations, and obtain a waste collection schedule to adjust to seasonal changes. The most cost-effective route is refined over time by collecting data on when the bins actually need collection, so the waste services offered will eventually fit the waste generation levels.		Information is sent to the customer portal platform. Provides general waste overview, the sites and containers, fill levels, past collections and scheduled pick up times and a live map of the collection fleet and their pickups..		McDonalds saved 12% in collection costs A large donut franchise has saved 28% in collection costs		
Sensoneo	Contact: Dominika Menyhartova - Sales support E: dominika.menyhartova@sensoneo.com T: +42 191 746 2087 A: Science Park, Ilkovicova 8, Bratislava, Slovakia Phone: +44 203 858 0516 Email: info@sensoneo.com Website has live chat function: https://sensoneo.com/ A UK/EU based company.	Sensoneo Smart Sensors Stand-alone sensor	- City of Sofia, Bulgaria - Granvia Operations, Slovakia - Hospital, Central Europe - City of Nitra, Slovakia - Waste management, Central Europe - Tesco retail, Central Europe - Natur-Pack, Central Europe - Waste management, United Arab Emirates - Utility company, Italy - City of Prague - Overflow Warning System, Slovakia	Single sensor uses one ultrasonic beam while quatro uses four ultrasonic beams. Bins may be redistributed or collected less based on the data found. Used with desktop and smartphone. Best locations for sensors are for semi-underground and underground containers. Areas where containers are filled irregularly. Areas too far away from depo. Not so good for small street containers. Built in fire alarm	Uses 4G/LTE, NB-IoT, LoRaWAN, GSM, SigFox, Cat-M Payload and network communication is encrypted on two levels. Sensors use mesh topology which saves costs on the data transmission. In this system, the sensors designated as 'slaves' all send their information to the 'master sensor', and the master sensor is the only sensor that reports to the analytics and storage software. Only quatro sensors can be masters, but any sensor can be a slave..	Bin capacity Temperature and overturn/pick recognition GPS location Battery status Waste type Last measurement Collection schedule Report multiple times through the day on bin capacity, temperature and overturn	Regular weekly conference to demonstration and explanation of sensor product and system. Can purchase samples for a small-scale system before committing to the product. Can purchase only HW - sensors or HW + SW In this case you pay one-time price for HW and then monthly subscription fee for SW. Also offer SWAAS - Smart waste as a service - pay monthly for HW and SW, not one-time price at the beginning. No maintenance provided. Sensor warranty: 2 years.	Citizen App Sensoneo Analytics Route Planning page and personalized depending on the waste type being collected and the facility it is being discharged to. Comparisons can be done of the planned route vs the actual route taken. Costs can also be calculated, based on numerous variables including Costs/m3, Cost/kg, Duration, Length km, Volume m3 and Weight kg and reports are made automatically. Efficiency of collection is presented in graphs (average fill per pick up). A 'citizen app' is also available for regular civilians to check the waste level of nearby bins to find bins with capacity for them to deposit rubbish. The bins can be discovered by waste type and directions can be provided to the bin themselves. Citizens can also send a report on the app if the bin is non-functional. Information is sent to the cloud based platform where the information can be accessed by customers to monitor, control and plan the waste management activities. The information is shown on a digital map which displays capacity, waste type, last measurement, GPS location and collection schedule or pick recognition, as well as a prediction when the bin will become full. Filling cycles for an individual bin are displayed, as well as any missed collections.	Both sensors batteries last several years and can be replaced. Battery life is up to 7 years, depends on the measurement times per day and outside temperature. Sensors life is 10-15 years.	Data transmission depends mainly on signal strength		See: https://sensoneo.com/references/

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