

Investigation of Novel Technologies and New Procedures for Environmental Enforcement

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ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

Regulation: *We implement effective regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.*

Knowledge: *We provide high quality, targeted and timely environmental data, information and assessment to inform decision making at all levels.*

Advocacy: *We work with others to advocate for a clean, productive and well protected environment and for sustainable environmental behaviour.*

Our Responsibilities

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We regulate the following activities so that they do not endanger human health or harm the environment:

- waste facilities (*e.g. landfills, incinerators, waste transfer stations*);
- large scale industrial activities (*e.g. pharmaceutical, cement manufacturing, power plants*);
- intensive agriculture (*e.g. pigs, poultry*);
- the contained use and controlled release of Genetically Modified Organisms (*GMOs*);
- sources of ionising radiation (*e.g. x-ray and radiotherapy equipment, industrial sources*);
- large petrol storage facilities;
- waste water discharges;
- dumping at sea activities.

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- Conducting an annual programme of audits and inspections of EPA licensed facilities.
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- Supervising the supply of drinking water by public water suppliers.
- Working with local authorities and other agencies to tackle environmental crime by co-ordinating a national enforcement network, targeting offenders and overseeing remediation.
- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
- Prosecuting those who flout environmental law and damage the environment.

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- Monitoring and reporting on the quality of rivers, lakes, transitional and coastal waters of Ireland and groundwaters; measuring water levels and river flows.
- National coordination and oversight of the Water Framework Directive.
- Monitoring and reporting on Bathing Water Quality.

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- Monitoring air quality and implementing the EU Clean Air for Europe (CAFE) Directive.
- Independent reporting to inform decision making by national and local government (*e.g. periodic reporting on the State of Ireland's Environment and Indicator Reports*).

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- Preparing Ireland's greenhouse gas inventories and projections.
- Implementing the Emissions Trading Directive, for over 100 of the largest producers of carbon dioxide in Ireland.

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- Funding environmental research to identify pressures, inform policy and provide solutions in the areas of climate, water and sustainability.

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- Monitoring radiation levels, assessing exposure of people in Ireland to ionising radiation.
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- Providing, or overseeing the provision of, specialist radiation protection services.

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- Advising Government on matters relating to radiological safety and emergency response.
- Developing a National Hazardous Waste Management Plan to prevent and manage hazardous waste.

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- Generating greater environmental awareness and influencing positive behavioural change by supporting businesses, communities and householders to become more resource efficient.
- Promoting radon testing in homes and workplaces and encouraging remediation where necessary.

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- Office of Climate, Licensing and Resource Use
- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Radiological Protection
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet regularly to discuss issues of concern and provide advice to the Board.

EPA Research Programme 2014–2020

Investigation of novel technologies and new procedures for environmental enforcement

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EPA Research Report

Prepared for the Environmental Protection Agency

by

National University of Ireland Maynooth

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Contents

Executive summary	ix
1 Introduction	1
1.1 Research project objectives	1
1.2 Project team	1
2 Understanding of waste enforcement issues	3
2.1 Background to waste enforcement	3
2.2 National survey on environmental enforcement issues	5
3 Technologies identified and field deployments	14
3.1 Introduction	14
3.2 Technologies identified	14
3.3 Summary log of technology field deployments	28
3.4 Cost–benefit analysis of technologies	28
4 Recycling bring bank analysis	34
4.1 Design and planning of bring bank centres	34
4.2 Technology deployed at bring centres	35
4.3 Human behaviour at bring centres	35
5 Dissemination of research	36
6 Conclusions	37
References	38
Abbreviations	40
Appendix A Environmental Waste Enforcement Research Survey	41

List of figures

Figure 2.1.	Irish local authorities that participated in the survey study	6
Figure 2.2.	Main environmental issues in local authorities in Ireland	6
Figure 2.3.	Waste enforcement technology applications in rural areas	9
Figure 2.4.	Waste enforcement technology applications in urban areas	9
Figure 2.5.	Complaint systems used by local authorities	10
Figure 2.6.	Average numbers of complaints per local authority for 2011	11
Figure 2.7.	Average numbers of warning letters, criminal procedures/sanctions per local authority in 2011	11
Figure 2.8.	Average local authority annual clean-up spend	12
Figure 2.9.	Level of best practice sharing carried out by surveyed local authorities	13
Figure 3.1.	Log of technology field deployments	29

List of tables

Table 2.1.	Ranking of illegal dumping hot spots in urban areas	8
Table 2.2.	Ranking of illegal dumping hot spots in rural areas	8
Table 3.1.	Effectiveness of audio device at bring banks	24
Table 3.2.	Cost–benefit of technologies	30–33

Executive summary

A vigorous approach will be adopted in bringing to justice those who abandon their waste in our countryside and engage in illegal activity.

*Phil Hogan TD, Former Minister for Environment,
Community and Local Government*

Local authorities across Ireland are continually challenged with illegal dumping and fly-tipping of both domestic and commercial waste in their jurisdictions. Areas commonly affected include road margins, forested areas, bogs, mountains, derelict property and recycling bring bank centres. Owing to its random nature, illegal dumping along roadsides in both urban and rural areas is one of the significant challenges facing local authorities.

This project identifies novel technologies and practices for environmental waste enforcement to support local authorities in this area. Researchers from the National University of Ireland Maynooth (NUIM) engaged with the Environmental Protection Agency (EPA) and local authorities in Fingal, Cavan and Westmeath throughout the project. In order to understand the current environmental enforcement issues, all 34 local authorities were invited to participate in a survey that focused on understanding the current issues, the technologies used, the legal processes, associated costs, public awareness and best practices. This information provided a foundation for deciding areas of focus for the research team.

Horizon scanning of existing and emerging technologies for waste enforcement, coupled with requests from the national local authority survey, led to the selection of nine technologies for exploration. One constraint that guided technology selection was the desire for reliable and effective low-cost solutions. A total of 37 technology deployments were carried out in real-life

situations across the three core local authorities and NUIM to understand the strengths and weaknesses of selected technologies. Worst-case scenarios were used when testing the various technologies. For example, in the case of closed-circuit television (CCTV) technologies, local authorities highlighted that they had issues with CCTV at night, in hostile and problematic areas, in remote areas with no mains power and when used covertly. Technologies were identified and tested in each of these scenarios and proved to successfully address all of the issues raised.

In order to support local authorities to select the optimum technology for their application, a cost-benefit analysis of all the technologies was completed. This tool identifies typical applications for each technology in addition to its strengths and weaknesses. Typical costs for the technology and other relevant parameters are also captured.

Recycling bring bank centres are widespread throughout all local authority areas. Although they are a valued service in the community, many of them have on-going issues with illegal dumping. This ranges from a user leaving a cardboard box on the ground after recycling its contents to incidents in which black refuse bags of household waste are deposited and, in more extreme cases, trailer/truck loads of waste are deposited. The research identifies opportunities for improving these issues through design and planning, integration of appropriate technologies and human behaviour analysis.

Research findings were disseminated throughout the project at both national and international conferences and two papers were accepted for journal publication. Each local authority will have access to the entire project report, which will act as a reference and guide for investing in environmental enforcement technologies.

1 Introduction

1.1 Research project objectives

This project set out to investigate novel technologies and new procedures for environmental enforcement in Ireland. It was commissioned by the Environmental Protection Agency (EPA) and was completed by a research team in the National University of Ireland Maynooth (NUIM) between February 2012 and December 2013.

The main project objectives were:

1. (a) To develop an understanding of the environmental waste enforcement issues facing local authorities across Ireland and Pareto them in order of significance. (b) To identify and report on waste enforcement best practices at both national and international levels.
2. (a) To engage in an in-depth literature review of existing/emerging/novel waste enforcement technologies internationally to identify five technologies to select for field trials. (b) To complete field trials for each of the five technologies across three local authorities. (c) To outline the strengths and weaknesses of each technology deployed.
3. To deliver a Strengths, Weakness, Opportunities and Threats (SWOT)/cost–benefit analysis of each of the five chosen waste enforcement technologies. This will inform waste enforcement agencies on the optimum solution to invest in depending on their requirements and therefore ensure maximum return on investment.
4. (a) To offer significant contributions to research literature in the area of waste enforcement. (b) To publish the findings in peer-reviewed journals and at least one national and one international conference.
5. To inform future strategy, legislation and policy development so that waste enforcement practices are aligned to emerging technologies.
6. To disseminate the experience and knowledge gained in this research into novel technologies for waste enforcement to the EPA, local authorities and other interested parties.

1.2 Project team

The project team consisted of a core team based in NUIM and an extended team in supporting local authorities and the EPA as follows:

NUIM core team

Project sponsor:	Dr Ronan Farrell
Project co-ordinator:	Dr John Dooley
Researchers:	Aidan McDermott (for full project duration) Dr Alvaro Palomo (for the first 12 months)

Extended team

The extended team included the EPA, three local authorities and various external vendors.

EPA: Niamh Connolly (year 1), Dr Shane Colgan (year 2) and Kealan Reynolds (full project duration).

Local authorities: Three local authorities supported the project through participation in the extended project team. They acted as a sounding board for the core team providing insights and direction and also supporting the team during technology field deployments. They were:

- Fingal County Council: Martin Daly, Brendan Fleming, Aine Donlon Kavanagh and Aoife Scally;
- Cavan County Council: Michael Mussi and Conor Craven;
- Westmeath County Council: Anne Bonner and Larry Murphy.

These local authorities were chosen because they represent a mix of urban and rural areas with various environmental enforcement challenges. They were also considered very proactive in environmental enforcement and were within easy reach for the core team in NUIM. It is important to highlight that each of these local authorities was very open to sharing its “problem” areas and, as a consequence, technology was deployed in worst-case situations. The problems highlighted are not unique to the core local authorities, but rather echo with local authorities across Ireland and beyond.

In addition to the extended team mentioned above, all 34 local authorities in Ireland were invited to participate during the data-gathering phase of the project.

Two workshops were convened with the core and extended project teams throughout the project duration. The aim of the first workshop in June 2012 was to align the entire team on the current environmental enforcement issues faced by local authorities across Ireland as gathered through a national survey. The team agreed

on technologies to be investigated and where these technologies would be deployed. The extended team expressed a need for low-cost solutions to meet their needs. The intent of the second workshop in April 2013 was to review progress on deployments completed and the effectiveness of technologies deployed.

2 Understanding of waste enforcement issues

2.1 Background to waste enforcement

The principles of environmental enforcement in Ireland, as set out by the Office of Environmental Enforcement (OEE, 2003), are:

- proportionality in the application of environmental law and in securing compliance;
- consistency of approach;
- transparency about how the OEE operates;
- targeting of enforcement action and implementation of the polluter pays principle.

The polluter pays principle has become widely accepted and is referenced across numerous waste enforcement policy documents from EU directives to local authority by-laws. Now that waste collection services have been privatised across 31 of the 34 local authorities the Organisation for Economic Co-operation and Development (OECD) believes that the financial burden on households may explain an increase in the practices of fly-tipping and backyard burning (OECD, 2008).

According to the EPA, civic amenity centres and bring banks have an important role to play in waste management facilities (McCoole et al., 2013). They accounted for 16% of the overall household waste for 2011. However, this report also found that 30% of households do not use a kerbside waste collection service. This may be because the service is not available or they choose not to use it. The estimate for uncollected household waste in 2011 was 276,665 tonnes (McCoole et al., 2013) and there is no traceability on how this waste was disposed.

However, Ireland has made significant progress since the introduction of the Waste Management Act (1996). The government's new waste management policy, *A Resource Opportunity – Waste Management Policy in Ireland* (Department of the Environment, Community and Local Government, 2012), sets out a roadmap to reduce dependence on landfill and maximise recovery from waste. The minister states a “vigorous approach will be adopted in bringing to justice those who abandon their waste in our countryside and engage in illegal activity”. This will be achieved through the establishment of a team of waste enforcement officers. This

new waste management policy includes the following new proposals for the regulation of household waste collection:

- All householders will be obliged to demonstrate that they are availing themselves of an authorised waste collection service or are otherwise managing their waste in an environmentally acceptable manner. The intent here is to combat illegal fly-tipping, littering and backyard burning of waste.
- Awareness and education measures for households will be strengthened.
- All waste collection service providers will need Customer Charters in place to support customers in difficulty.
- A waiver scheme and other alternative support schemes will be introduced for low-income households.
- The Producer Responsibility Initiative model will be implemented to encourage re-use and recycling of waste.

In addition, under the new policy, all local authorities will be expected to participate in the Local Authority Waste Prevention Demonstration Programme. This is aimed at providing the skills to develop waste prevention within local communities. Effective implementation of the new waste management policy will support the four challenges for the environment as set out in the fifth state of the environment report, *Ireland's Environment 2012* (Lehane and O'Leary, 2012):

1. valuing and protecting our natural environment;
2. building a resource-efficient low-carbon economy;
3. putting the environment at the centre of our decision making;
4. implementing environmental legislation.

During the current economic climate, when budgets are constrained, local authorities need robust cost-effective solutions to enable them to deliver on these four challenges. In particular the overhead associated with waste enforcement is a significant drain on resources, with 50% of environmental enforcement staff involved

in waste enforcement (EPA, 2009). Therefore, it is important to identify opportunities for new technologies or practices to support local authorities in meeting their challenges.

Reactive rather than preventative measures are often used to address illegal dumping. For example, in recent times many local authorities have been attracted to service providers operating on a “no foul no fee” basis whereby they are paid for only the illegal dumping incidents they capture that are “prosecutable”. However, this business model is reactive and fundamentally flawed: the more dumping that occurs, the better it is for the service provider and therefore it is not in their interest to reduce illegal dumping. The model also has a significant risk of entrapment associated with it whereby an area may be left untidy in order to attract further illegal dumping, which is captured using covert closed-circuit television (CCTV). Research has shown that rubbish attracts more rubbish (McDermott et al., 2013). Furthermore, some service providers are interested in only targeting “easy” catches in areas such as bring banks, but cannot afford to monitor remote areas where significant dumping, burning, destruction of habitats and pollution of water systems occur. The balance of focus needs to be shifted to preventative measures to reduce dumping and stop it occurring in the first place.

The European Commission is taking a series of steps to strengthen the implementation of EU waste legislation. As part of these efforts, the Commission requested a feasibility study to outline the benefits and costs of creating a dedicated agency to support the implementation and enforcement of EU waste legislation across all member states (Zamparutti et al., 2009). The final report of this study advises that there exists an urgent need for such an agency to co-ordinate a number of waste management activities across Member States. The activities of this proposed agency are targeted to address the current shortfalls in establishing a European waste management initiative.

Reviewing recent reports prepared for the EU Network for the Implementation and Enforcement of Environmental Law (IMPEL) and the European Commission, a clear picture can be drawn of the obstacles to waste enforcement across Member States (Faure and Heine, 2000; Fischer et al., 2008; EC, 2009; EEA, 2009). Highlighted in these reports are the following:

- A large number of authorities are involved: national enforcement of waste legislation can depend on a large number of government bodies, including environmental officials, police, customs and the judiciary, as well as several levels of government. In most Member States these authorities have divided competencies and suffer from poor coordination and communication.
- Waste enforcement is given a low priority in many Member States.
- There is a lack of administrative and enforcement capacity, including a lack of knowledge of inspection methods.
- There is poor understanding of EU legislation and documents.
- There is a lack of guidance, harmonisation and standards.
- There is a lack of prosecution of crimes, often compounded by small fines and short sentences.
- Better communication on waste enforcement issues across Member States is required, especially in the case of illegal waste shipments.

There is opportunity for countries such as Ireland to learn from the Scandinavian countries in terms of best practices for waste enforcement. Scandinavian countries, including Norway, Sweden, Finland and Denmark, along with the Netherlands, Germany, Austria and Switzerland, have a strong commitment to pro-environmental attitudes and behaviours (Kelly et al., 2007). On the other hand, Bulgaria and Latvia were the least committed; Ireland, the UK, Spain and Portugal were in the middle. Similar trends were also found when investigating each country's willingness to pay increased costs to protect the environment.

Regardless of the difficulties faced by the various authorities in enforcing EU Directives, failure to comply with the instructions set out in Directives can incur large fines on the Member State found to be in breach. It is therefore the obligation of each Member State to address its own difficulties in providing adequate and effective environmental enforcement. For example, in Ireland the number of “live” environmental infringement cases under EU and international law against Ireland dropped from 15 to 12 during 2012 (Department of the Environment, Community and Local Government, 2013). Investment in prevention of issues is critical in order to meet future EU environmental targets.

The EPA and local authorities in Ireland have had an active attitude towards gathering solid information on environmental trends and both regulating and policing activities that might otherwise cause pollution. Reports (Coakley et al., 2007) show the amount of ground Ireland needs to cover in order to meet its obligations under EU Directives and the Kyoto Protocol. In addition, publications from the OEE and the Network for Ireland's Environmental and Compliance Enforcement (NIECE) have highlighted the successes of enforcing EU Directives and Irish waste legislation in Ireland. These reports highlight a common understanding across stakeholders in NIECE about the problems faced, the merits of using currently available technology and the willingness of members of the public, through local and national hotlines, to report illegal dumping activity.

Building on these positives, it is now important to extend the expertise and effectiveness of national agencies using new and emerging technologies to address key areas set by the OEE (2009):

- illegal disposal of waste;
- illegal movement of waste to Northern Ireland;
- illegal movement of waste to Europe and beyond;
- unauthorised collection and fly-tipping of waste;
- backyard burning of household waste;
- operation of unauthorised transfer stations and waste-processing facilities.

Technology solutions and best practices applicable to one local authority will also be applicable across others. CCTV is the most commonly used technology for waste enforcement across local authorities despite it having some application drawbacks, such as night-time monitoring, monitoring of high-risk or hostile areas and battery-powered CCTV systems for short-term or remote deployments (Palomo Navarro et al., 2013). If a technology can be proven to be effective in one local authority, then it is likely to be effective in others. There is an opportunity to align local authorities on optimum waste enforcement technologies and, in doing so, further fulfil obligations under the Public Participation Directive (2003/35/EC). A number of these technologies will be analysed later in this report.

2.2 National survey on environmental enforcement issues

2.2.1 Introduction

The original project proposal identified five technologies for the research team to investigate throughout the project. These five technologies were selected based on the researchers' experience rather than direct feedback from local authorities. Therefore, it was decided to conduct a survey across all local authorities in order to gather accurate data so that the research would focus on addressing real needs and ultimately provide solutions that are beneficial to the EPA and local authorities.

The survey focused on the following five areas:

- understanding the current waste enforcement situation across local authorities;
- technology used for waste enforcement;
- prosecutions of offenders;
- financial resources;
- networking, information sharing and ideas for improvement.

"An investigation into environmental waste enforcement in Ireland" by Palomo-Navarro et al. (2013) publicises the findings of the survey, as detailed below.

All 34 local authorities in Ireland were invited to participate in an online survey in May 2012. A total of 17 local authorities completed the survey; a 50% participation rate. The participating local authorities covered geographical areas that included urban, rural, coastal, mountain and midlands, as shown in Figure 2.1.

The following sections detail the findings from the survey.

2.2.2 Current situation regarding waste enforcement in local authorities

The first section of the survey was aimed at gathering information regarding current environmental enforcement issues in each local authority. To fulfil this mission, each local authority was asked to share its top waste enforcement issues.

The results collected from the participating local authorities are shown in Figure 2.2.

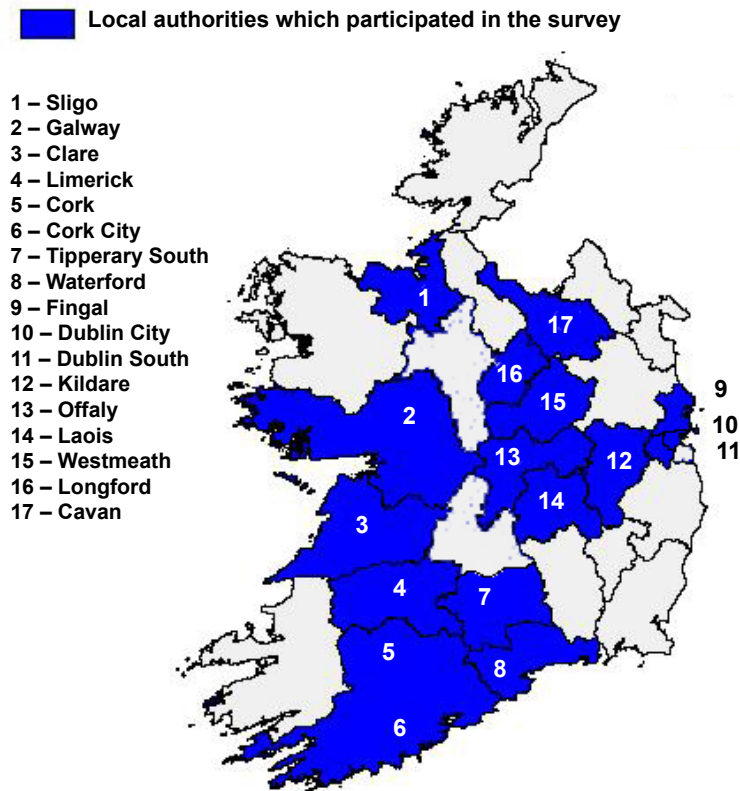


Figure 2.1. Irish local authorities that participated in the survey study.

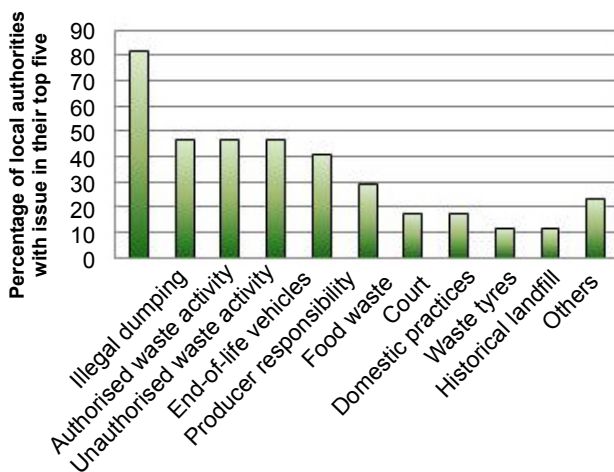


Figure 2.2. Main environmental issues in local authorities in Ireland.

More than 80% of the local authorities stated that illegal dumping of waste, also known as “fly-tipping”, was their main issue. According to *The Nature and Extent of Unauthorised Waste Activity in Ireland* (EPA, 2005), fly-tipping can be described as the indiscriminate dumping of bags containing household waste, electronic waste and electrical equipment, end-of-life vehicles (ELVs), pallets and construction and demolition and other waste streams. Fly-tipping is not a new problem to

the Irish local authorities and the EPA. The magnitude of this illegal practice in Ireland has been documented in previous studies, where it was highlighted as one of the main waste enforcement issues in the country (Davies et al., 2006; EPA, 2009).

The second biggest issue was the monitoring of facilities operating with a Waste Permit. Ireland, like all other EU countries, is obliged to carry out intensive actions in terms of recovery and recycling of waste without endangering human health, and to establish an integrated and adequate network of disposal installations (EC, 2006). While the EPA is directly responsible for reinforcing these directives through inspections of large waste management facilities such as landfills or waste transfer stations, the local authorities are responsible for carrying out inspections in their jurisdictions for smaller scale licensed waste activities (EPA, 2009). These include inspections to the facilities of licensed waste collectors, tyre outlets or vehicle checkpoints. All these inspections are planned and logged in Recommendations for Minimum Criteria Environmental Inspections (RMCEI) reports (EC, 2001). The promotion of producer responsibility for the management of their products when they become waste (EC, 2008), the separation of organic waste, the management of historical landfills and the

control of waste tyres are other points that fall into this category, which were expressed separately in Figure 2.2 because of the number of times they were mentioned in the survey responses.

The issue ranked third was unauthorised waste activities, which includes unauthorised waste collection, unpermitted waste disposal and waste movement across borders. Unauthorised waste collection has gained more importance in recent years because of the implementation of “pay-as-you-throw” waste collection schemes (Dunne et al., 2008) and the progressive privatisation of the waste collection activities by most local authorities (Cradden, 2008). This privatisation has entailed the termination of waiver schemes in some local authorities such as Fingal County Council (Cotter, 2011). Currently, private waste collection dominates the sector, with only Galway City Council, Waterford County Council and Kilkenny Borough Council remaining as public waste collectors (McCoole et al., 2013).

Finally, ELVs were mentioned by many local authorities, mostly because of the strong regulations from the EU about their dismantling and recycling (EC, 2000). Problems associated with ELVs fall into two categories: some are illegally abandoned (and sometimes burned) in remote areas, which would fall within illegal dumping, and others are processed by unauthorised car dismantlers that do not follow the correct dismantling and recycling procedures, which would fall into the unauthorised waste activities section. Other minor issues related to the application of environmental law in court and the promotion of environmentally friendly domestic practices.

When facing these environmental issues, the surveyed local authorities were requested to share the “preventative” and “reactive” practices used in their jurisdictions to address illegal dumping activities and to assess their level of satisfaction in terms of effectiveness. Preventative solutions are methods that seek the avoidance of the illegal activity by deterring the offenders from committing them. On the other hand, reactive solutions seek the identification and prosecution of the offenders after an illegal action is detected.

In general, the local authorities employ preventative practices based on inspections of authorised waste facilities and monitoring of “hot spots” by environmental officers and by CCTV systems. Hot spots can be defined as locations where the cases of illegal dumping

take place on a regular basis. In a preventative way, the environmental officers patrol certain areas, carry out non-routine inspections and set up vehicle check-points. A small number of them mentioned preventative measures related to environmental education provided in schools and community centres and through the local authority website. The survey used a five-level Likert scale to determine the current level of satisfaction with preventative solutions (Likert, 1932). The satisfaction scale ranged from “1 – Not Satisfied” to “5 – Totally Satisfied”. The average satisfaction level on the Likert scale was 2.43, which indicates dissatisfaction with the preventative solutions employed.

As regards reactive solutions, the answers gathered from the surveyed local authorities indicate that the prosecution of offenders is the main technique. Prosecution escalates from on-the-spot fines to court appearances and the confiscation of vehicles involved in illegal dumping activities. In all these cases, the Irish environmental law, mainly represented by the Waste Management Act (1996) and the Litter Pollution Act (1997), is applied together with the local authority’s own by-laws. In addition, CCTV and aerial photography are also used to detect illegal activities, such as abandoned ELVs, and offenders. Using the same satisfaction five-level Likert scale that was used for the preventative solutions (“1 – Not Satisfied” to “5 – Totally Satisfied”) the average satisfaction level was 2.83. Although this is an improvement on the result for preventative solutions, it still represents opportunities for improvement of reactive solutions.

The survey found that CCTV and enforcement officers were the most commonly used resources for both preventative and reactive enforcement actions. A lack of purely preventative measures, such as environmental education and awareness, was also observed. Previous studies have demonstrated that environmental education is a crucial part in positive waste management, since it creates communication links between the end-users and local authorities (Davies et al., 2006). In addition, when the users are made aware of the real environmental situation of their community and the improvement that positive waste actions can make, they show a greater willingness to adopt positive actions themselves (Barr, 2002). However, both studies remark the importance of providing this information appropriately adapted for the target audience and by trusted sources.

From the preventative and reactive solutions, the local authorities were requested to stipulate which of these are considered best practices. Best practices are methods or techniques that have consistently shown results superior to those achieved with other means. In addition, they were also asked to provide details about other national or international best practices in the area that they were aware of. The analysis and comparison of the answers gathered from the local authorities show that, for all of them, best practices are synonymous with two waste enforcement areas: CCTV or aerial monitoring, and prosecutions. In their answers, none of the local authorities identified environmental education and awareness actions implemented by them as best practice. This shows a tendency of the local authorities towards reactive measures for environmental enforcement instead of preventative solutions. This tendency can be also seen in the answers obtained about international best practices they were aware of, where most of the answers focused on inspections, CCTV and the creation of a specific and dedicated environmental court for waste enforcement.

Illegal dumping, the main environmental enforcement issue as seen in Figure 2.2, tends to be carried out in random areas, usually away from public view. Previous studies showed that, in rural areas, illegal dumping tends to occur in remote areas that are difficult to access, such as bogs, forestry areas and commonage land. In urban areas, illegal dumping mainly takes place in recycling centres, normally designated for bottles and clothes collection, and civic amenities (EPA, 2005). In order to finalise the overview on current waste enforcement, the local authorities were asked to rank the main areas where illegal dumping takes place in their jurisdiction. To do so, they were provided a list of possible

locations for urban and rural environments, and these had to be ranked in ascending order with 1 representing the most severe hot spot and 9 the least severe one.

The illegal dumping hot spot rankings obtained from the surveys are shown in Tables 2.1 and 2.2. For urban areas, derelict buildings topped the ranking of illegal hot spots. These are normally areas where the front and backyards (and, on some occasions, the inside) are used for illegal dumping by the offenders. Following in the ranking, roadside areas and bring banks (or recycling areas) were highlighted. For the rural areas, roadsides remained the highest ranked type of hot spot, followed by bogs and forest areas.

The presence of roadside areas towards the top of both charts highlights their current importance. Out of all the types of areas, this one could be considered the one with the most random nature and where, as a consequence, it is most difficult to apply technology for the identification and prosecution of offenders. As was pointed out by some of the surveyed local authorities, some of them carry out random vehicle inspections to attempt to tackle this practice. However, this is a resource demanding practice that requires the coordination of the local authority workers with other public bodies such as An Garda Síochána.

2.2.3 Waste enforcement technology

Both preventative and reactive solutions for waste enforcement usually imply the application of technology. In the first case, technology is used with informative, educational or deterring purposes in order to avoid the illegal activity being performed by potential offenders. In the second case, technology is used for the identification

Table 2.1. Ranking of illegal dumping hot spots in urban areas

Rank	Urban area hot spot
1	Derelict areas
2	Roadside
3	Recycling centres
4	Residential
5	Industrial areas
6	Retail areas
7	Parks
8	Beach/coastline/rivers
9	Others (e.g. bus stops)

Table 2.2. Ranking of illegal dumping hot spots in rural areas

Rank	Rural area hot spot
1	Roadside
2	Bogs
3	Forest areas
4	Field gateways
5	Picnic areas/lay-by
6	Quarries
7	Rivers/lakes
8	Beach/coastline
9	Others (e.g. farms)

of illegal actions and offenders in order to carry out a legal prosecution. The Irish legislation on environmental enforcement, with the Waste Management Act (1996) and the Litter Pollution Act (1997) as main references, aligns with the European environmental law in terms of the “polluter pays” principle (EC, 2004).

In order to establish the current level of use of technology for waste enforcement, local authorities were asked what technology they use and the level of satisfaction with the results. Owing to the relevance that environmental officers have within waste enforcement actions, they were added and compared together with the rest of technologies. Figures 2.3 and 2.4 outline technologies employed by local authorities for waste enforcement in both rural and urban areas, respectively. As is evident from the results, CCTV and enforcement officers are the main two technologies employed in both environments. This was expected, since both of them are the main reactive and preventative measures used by the local authorities, according to the results in the previous section.

Aerial photography, also mentioned as a preventative and reactive solution, appears as the third most employed option. The aerial images are normally taken from a helicopter or from unmanned aerial vehicles (UAVs) such as quadcopters. Application of the latter in environmental enforcement is increasing because of its varying capabilities and low cost compared with other options such as satellite imaging (Lega et al., 2012).

Satellite images are rarely used by the local authorities, as seen in Figures 2.3 and 2.4. When they are employed, the images are obtained from low-resolution free-source systems, such as Google Maps (Google). High-resolution satellite images are an expensive resource for local authorities and they do not ensure a high chance of success in identifying offences and offenders.

Finally, sensors see the lowest usage as a technology for environmental enforcement. Only one local authority claimed to use them in rural areas, more specifically in forests and bogs. Sensors are generally employed for “sensing” different environment parameters such as air or water quality and noise levels on a constant basis. In addition, they are employed for inspections of premises where emissions to the air or discharges to water are carried out.

The effectiveness of the technologies applied to environmental enforcement can be analysed in terms of the possibility of identifying illegal actions and the offenders, as well as using their outputs to carry out legal prosecution actions against the offenders. The local authorities’ replies showed a high level of satisfaction with the use of CCTV, environmental officers and aerial imaging, whereas the level of satisfaction with other technologies, such as low-resolution satellite imaging, was low.

Overall, CCTV was considered the most successful technology for environmental enforcement. CCTV

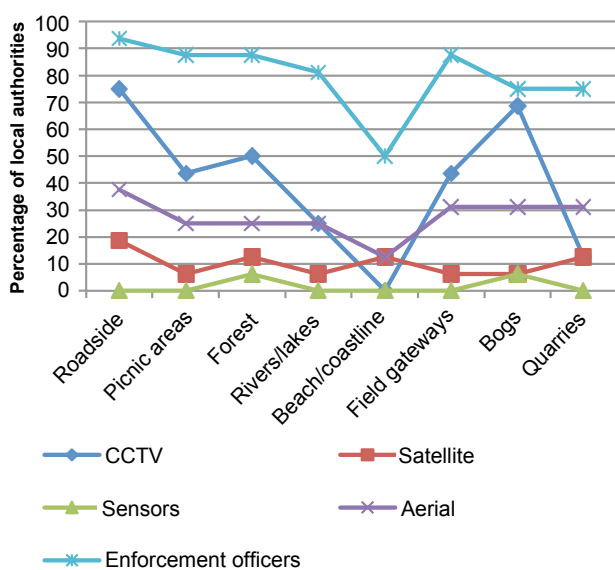


Figure 2.3. Waste enforcement technology applications in rural areas.

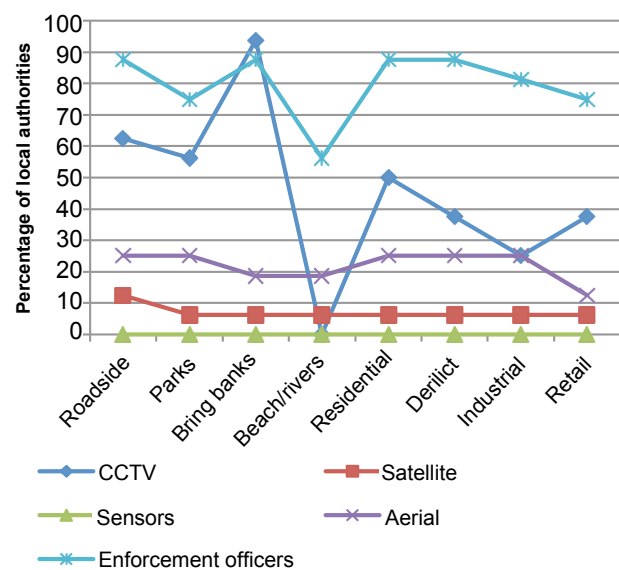


Figure 2.4. Waste enforcement technology applications in urban areas.

costs less than sensors or aerial photography taken from helicopters, images are available immediately, compared with outdated image systems such as historical satellite images, and it can be remotely controlled by environmental officers. More important, CCTV systems are the only technology solutions that allow the illegal action to be recorded while it takes place, and not just the consequences of such an action, a point that is crucial in the prosecution process. For example, under the Litter Pollution Act (1997), if the licence plate of a vehicle used for an illegal environmental activity is recorded, the owner of the vehicle can be prosecuted as a responsible person.

However, challenging circumstances for the application of CCTV were also expressed, such as night-time monitoring, battery-powered CCTV systems for temporal deployment or monitoring remote areas and CCTV monitoring of high-risk or hostile areas. For these three scenarios, possible solutions based on off-the-shelf commercial CCTV devices have been proposed (Palomo-Navarro et al., 2013).

When the local authorities were asked in what area in technology for environmental enforcement they would like to see advances, apart from the CCTV improvements described before, most referred to the application of internet technologies to enforcement tasks. Some of the ideas proposed were sharing of databases between agencies, internet technology tools to assist in inspections, real-time information from waste collectors, waste traceability, database of best practice information and integrated internet technology applications for environmental officers.

The local authorities were surveyed on the utilisation of external contractors for managing the technology deployments and their opinion about new technologies applied to environmental enforcement. Out of the 17 local authorities that completed the survey, 76% of them employ external contractors for managing some technology, whereas 24% of them do not use contractors.

2.2.4 Prosecution of offenders

In Ireland, the environmental departments of the local authorities are the first point of contact for environmental complaints. In 2006 and 2007, the local authorities received about 70,000 environmental complaints about a wide range of environmental issues (EPA, 2009). Traditionally, the main environmental complaint channel

has been dedicated phone lines provided by the local authorities at a regional level, or by the EPA at a national level with a National Environmental Complaints Line (NECL), initially named “Dump the Dumpers”. However, with the development of internet technologies, new complaint channels, such as online forms and smartphone applications, have been made available. Seventy-five per cent of the complaints received through the NECL in 2006 and 2007 were in relation to illegal dumping and burning of waste (EPA, 2009).

The information gathered from the surveyed local authorities showed that the average number of environmental complaints received by local authorities in 2011 was 2082, which is an increase of 13.9% from 1828 in 2010. These are received predominantly through phone calls or web-based forms. Ninety-four per cent of local authorities highlighted phone calls directly to the environmental department as the main conduit for complaints, while 88% of local authorities also received complaints through the EPA national complaints line, as shown in Figure 2.5.

The Pareto chart of complaints received is shown in Figure 2.6. The majority of complaints received related to waste, in particular litter, averaging at 1520 complaints for each local authority in 2011. The number of waste litter-related complaints was as many as 5142 for the most-reported local authority and as few as six for the least-reported local authority.

The type of sanctions carried out to solve an environmental issue can be classified as administrative sanctions or criminal sanctions. Unlike criminal sanctions, administrative sanctions can be imposed directly

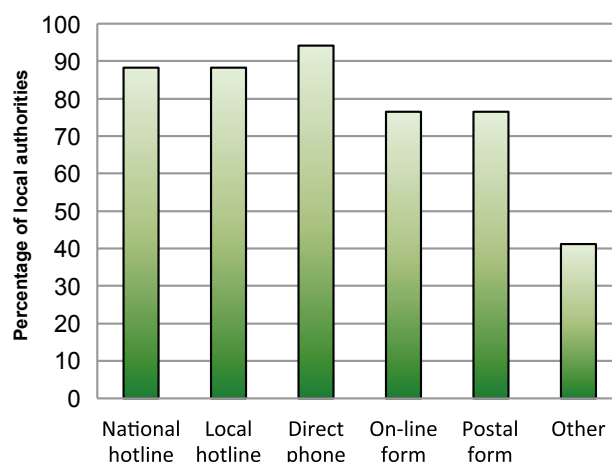


Figure 2.5. Complaint systems used by local authorities.

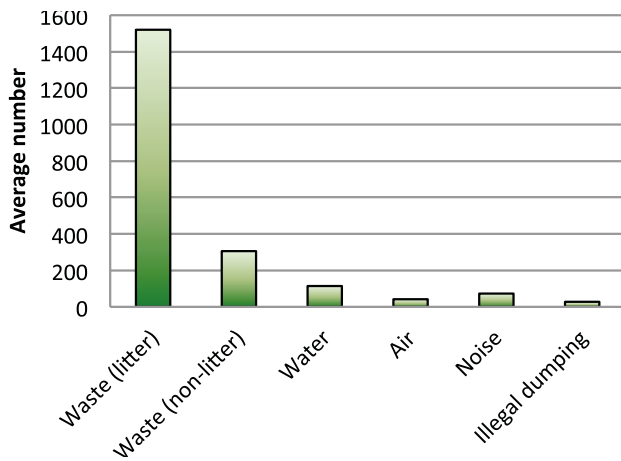


Figure 2.6. Average numbers of complaints per local authority for 2011.

by the regulator, i.e. local authority, without intervention by a court or tribunal. Some of the administrative sanctions that can be issued by the local authorities are information notices, mandatory environmental audits, warning letters, clean-up orders, licence amendments and entry powers (A&L Goodbody, 2009). The administrative sanctions are limited in terms of fines for the local authorities, with a maximum €150 penalty being the only option for on-the-spot littering (Protection of the Environment Act, 2003). Higher penalties can be applied under the Litter Pollution Act (1997) and Waste Management Act (1996) following criminal prosecutions.

The importance of the use of warning letters as an administrative sanction has been demonstrated by some European countries in terms of environmental enforcement (Kok, 2005). They are considered efficient in cases involving a first offence relating to activities not covered by the key regulations. In Ireland warning letters are widely used by the regulators, such as local authorities, although they do not have any formal statutory basis. In 2007 the Irish local authorities issued 2640 warning letters, whereas 3768 were issued in 2008. If the offence addressed by the warning letter is repeated or persistent, other administrative or criminal sanctions are applied.

The average numbers of warning letters issued and criminal sanctions followed by the surveyed local authorities are shown in Figure 2.7. The average number of warning letters increased from 119 in 2009 to 162 in 2010 and 155 in 2011. The average number of criminal prosecutions for 2009, 2010 and 2011 was 59, 62 and 15, respectively. The drop in the average

number of criminal prosecutions in 2011 is very dramatic. The average number of criminal sanctions also dropped from 16 in 2009 to 5 in 2010 and 7 in 2011. Although the number of criminal prosecutions dropped dramatically in 2011, the success rate increased markedly from 7.7% in 2010 to 45.3% in 2011.

As is evident from the individual survey results, some local authorities have 100% success rates in cases they bring to court while others have 0% success rates. In order to successfully prosecute an offender, the local authority must have very clear evidence collected and presented in a manner that is acceptable to the judge. Local authorities cited the main reason for prosecutions being unsuccessful as judges interpreting and implementing the Litter Pollution Act (1997) and Waste Management Act (1996) differently.

In 2011, according to the surveyed local authorities, the average cost of bringing a case to court was €2300. The Irish environmental legislation, in particular the Litter Pollution Act (1997), establishes that “when a person is convicted of an offence in proceedings brought by a Local Authority, the court shall order the person to pay to the Local Authority the costs and expenses measured by the court, incurred by the Local Authority in relation to the investigation, detection and prosecution of the offence, and the costs and expenses incurred by the Local Authority in the collection and disposal of any litter to which the prosecution relates”. Therefore, it is crucial for local authorities to have a high success rate with criminal prosecutions.

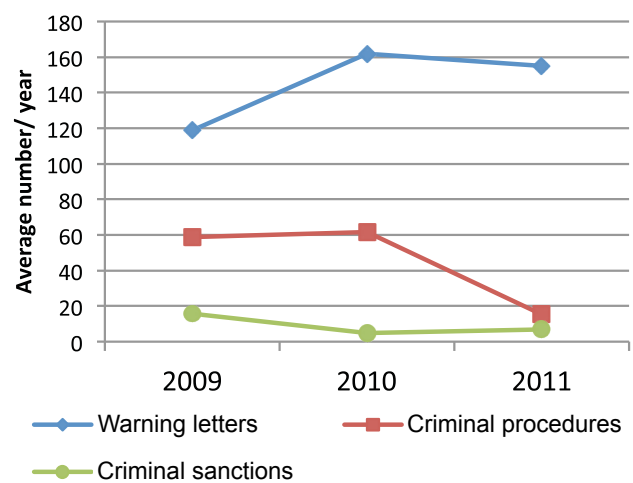


Figure 2.7. Average numbers of warning letters, criminal procedures and sanctions per local authority in 2011.

When asked about how to improve the prosecution process of environmental offences, all local authorities agreed in the necessity of a more homogeneous criterion for the application of environmental law; for example, the creation of an environmental court with specialised judges who could travel to various regions when environmental cases are being held.

2.2.5 Environmental enforcement cost

As a consequence of the current economic recession in Ireland, Irish local authorities' budgets have suffered cuts, which affect both the number of staff and the services available. For 2011, the average number of full-time staff per local authority dedicated to environmental enforcement was 5.1 employees. As seen previously, environmental officers and CCTV are the two main resources employed for environmental enforcement. In general, the satisfaction with their enforcement actions is high, with 71% of local authorities believing they achieved value for enforcement solutions whereas 29% believed they did not. Therefore, a reduction in staff numbers could have a significant impact on the effectiveness of environmental enforcement.

Illegal dumping represents the biggest environmental enforcement issue for all Irish local authorities. The cost of cleaning up the scenarios where illegal dumping takes place represents another significant factor in the cost of environmental enforcement for the local authorities. From the survey, it was found that the average cost incurred for cleaning up after illegal dumping, in 2011, was in excess of €118,000 for each local authority, as shown in Figure 2.8. This is an 11% increase on the costs stated for 2009 and 2010.

Ireland does not have administrative sanctions that can be issued to an offender to recover the cost of clean-up for illegal dumping cases, unlike other countries such as the UK or Germany (A&L Goodbody, 2009). Instead, local authorities can recover the cost of clean-up only if the offender is successfully charged with the criminal offence. Considering the small number of successful criminal offences shown in Figure 2.7, the local authorities do not have any option other than to include the cost of cleaning the illegal dumping scenarios with their own budget, which affects the resources available for other reactive and preventative environmental enforcement actions.

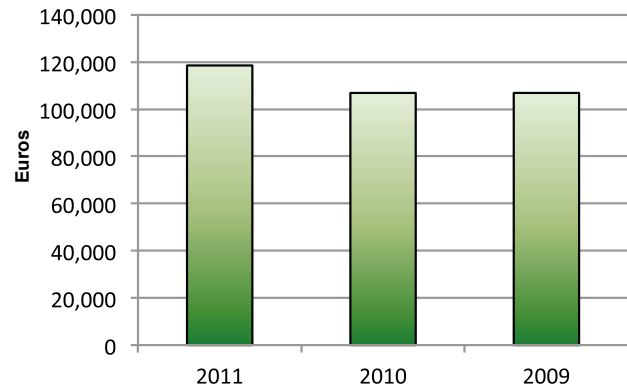


Figure 2.8. Average local authority annual clean-up spend.

2.2.6 Public awareness and best practice sharing

Irish home owners considered illegal dumping and the lack of available landfill their most significant waste management issues. However, they felt that there is weak enforcement of waste management policies against illegal dumping (Davies et al., 2006). Enhanced transparency, communication and dialogue with the public are decisive ways of avoiding illegal waste practices. For example, local waste knowledge has been proven to have a large influence on willingness to recycle (Barr, 2002). In addition, people are more likely to support government policies for environmental protection if they believe the conditions are harmful for other people (Stern et al., 1985). This could be applied to the illegal dumping cases in derelict areas, which normally attract pests (e.g. rodents) and become a public health risk.

All the surveyed local authorities, except for one, indicated that they have a waste enforcement policy document. However, fewer than half of them confirmed that the document is available on their website. Although others confirmed availability upon request, this poor accessibility can contribute to the lack of public knowledge regarding environmental law and prosecutable actions.

In a section dedicated to networking and improvement ideas, the surveyed local authorities were asked about what type of public training or awareness programmes on waste enforcement are run in their jurisdiction. Such training programmes were not offered by 76.5% of the local authorities, whereas 23.5% replied positively and provided details about the programmes, which mainly focused on household waste management and food waste management for restaurants. Despite the fact that most local authorities do not carry out any awareness

programmes, they are aware of their importance and benefits. For example, one of them expressed it as the main point to improve in the area of environmental enforcement: “In recent years, it seems that enforcement and awareness have become de-coupled, with not enough focus on proper design of regulations and advice/guidance to the public, communities and businesses who have to comply with the law”.

Two additional points for improvement expressed by local authorities were related to the legal side of environmental enforcement, mainly on-the-spot fines and an environmental court, and the necessity of creating more information-sharing platforms among local authorities. This last point aligns with the suggestions made by the OECD in a review in 2008 where it encouraged the Irish public sector to exploit agility, informality and openness, and reduce duplication of coordination efforts (OECD, 2008).

The exchange of environmental enforcement best practice information has been highlighted in the past as a key factor for all the members of the EU. Consequently, in 1992, IMPEL was created in order to develop common views on the coherence and practicality of legislation, commenting on issues of practicality and enforceability, and the development of tools and guidance for use by environmental authorities (Nicholson, 2011). Following the success of IMPEL, similar initiatives have been carried out in the EU Member States at a national level. In Ireland, the NIECE was created in 2005 with the core objective of “bringing improved co-operation and coordination between the various agencies involved in enforcement of environmental legislation so that a higher and more consistent standard of environmental protection is achieved in Ireland” (O’Leary and Lynott, 2011).

The level of environmental enforcement best practice sharing carried out by the surveyed local authorities was analysed. According to Figure 2.9, 25% of the local authorities share their best practices with adjacent local authorities and through the Environmental Enforcement Network (EEN), whereas another 25% share it through only the EEN and 44% share it with only adjacent local authorities. Finally, 6% of them claimed that they do not share any of this information at all. In conclusion, half of the local authorities use the EEN for sharing environmental best practices.

Finally, the effectiveness of the EEN according to the local authorities was ranked in the completed surveys

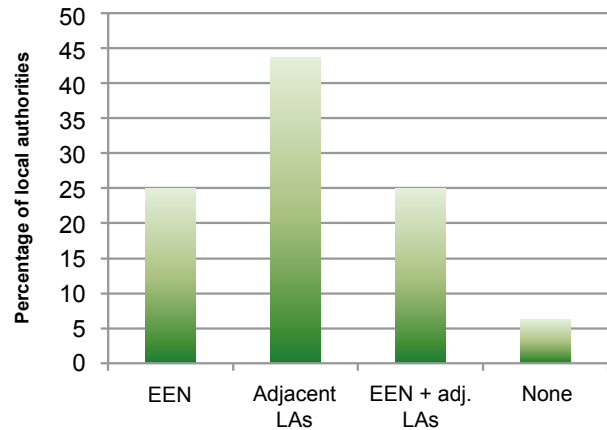


Figure 2.9. Level of best practice sharing carried out by surveyed local authorities.

between 1 and 10, representing “not effective at all” and “extremely effective”, respectively. On average, a mark of 5.5 was given to the EEN. This result suggests that, even though there is a certain level of satisfaction from the local authorities, there is still room for improvement. Under-resourced management and the lack of updated information were the two main areas where the EEN could improve, as pointed out by the surveyed professionals, in order to achieve better results.

This national research survey across all local authorities established a baseline on the current environmental enforcement landscape in Ireland in 2012. As in many other countries, waste-related issues, in particular illegal dumping, top the rank of environmental enforcement actions. Irish local authorities base their enforcement actions on the identification and prosecution of the offenders through warning letters and criminal sanctions. It was demonstrated how this prosecution process could be further improved by introducing more types of administrative sanctions that could be applied directly by local authorities.

The investigation also showed the low investment of local authorities in preventative solutions to illegal waste activities, such as public awareness and education programmes. As in other environmental areas, such as recycling, the introduction of this type of programme would deliver long-term and constructive solutions at the same time as reducing the cost of prosecutions. In this respect, some of the preventative best practices used by other countries could be adopted and the experiences shared across local authorities using the existing national EEN.

3 Technologies identified and field deployments

3.1 Introduction

The purpose of this chapter is to identify novel and emerging technologies for environmental enforcement. The initial project proposal highlighted five technologies worthy of research. However, based on feedback from local authorities and key stakeholders, a total of nine technologies were examined. These technologies were:

- **Satellite imaging:** We explored the feasibility of using satellite images available through sources such as the European Space Agency (ESA) to support the EPA and local authorities in addressing environmental enforcement challenges.
- **CCTV monitoring:** All local authorities are using some level of CCTV, so this was considered a baseline technology that all have some familiarity with. The project identifies cost-effective solutions for issues experienced with current systems.
- **Wireless Remote Environmental Monitoring Sensor (WREMS):** Environmental monitoring is often required in areas with no mains power or internet connectivity. This technology examines monitoring technologies for such locations.
- **Active infrared beams:** This technology is robust and cost-effective for monitoring large areas. It is not a complete solution, but complements other solutions such as CCTV or the programmable audio device.
- **Sensor technology:** Sensors are used in the field to measure water/air quality, noise and waste attributes. Opportunities to improve existing technologies are examined.
- **Enforcement Officer Application (App):** This application was proposed based on feedback from local authorities for a technology to streamline the daily workload of the enforcement officer.
- **Programmable audio device:** This is a preventative technology designed for litter hot spots such as bring centres. It is intended to radically reduce incidents of illegal dumping.
- **UAVs:** This technology followed on from the analysis of satellite imaging. The intent is to investigate a flexible and cost-effective solution that can be used to gather aerial images.

- **Universal Purpose Environmental Enforcement (UPEE) board:** Following a number of months of monitoring remote areas this technology was identified to address many of the common issues experienced.

3.2 Technologies identified

The following sections examine each of the technologies deployed and outline cost, functionality, advantages and disadvantages and where they were deployed. A total of 37 deployments were completed across NUIM, Cavan, Fingal and Westmeath in order to evaluate specific technologies in real-life situations. The list of deployments can be seen in section 3.3.

3.2.1 Satellite imaging

The use of satellite imaging for environmental enforcement was proposed in the initial project proposal. Potential applications could include monitoring of licensed landfills, illegal landfills and object detection in specific areas.

Experts in satellite imaging from Enterprise Ireland, the ESA and Maptec visited NUIM to discuss potential applications. The advantages of this technology included the fact that it is a covert solution enabling monitoring to be carried out from a distance and yet image resolution can reach 0.5m.

In Ireland satellite images are taken by ESA satellites or those of third parties, such as Astrium or the National Aeronautics and Space Administration (NASA). Images may be optical, radar or thermal. The main disadvantages of satellite as an environmental enforcement technology include the following:

- Ireland has cloud cover 88% of the time, so optical satellite is not dependable.
- Historical low-resolution images are relatively cheap, but images with resolution less than 1 m are very expensive. For example, one picture per day for 7 days costs approximately €10,000.
- Radar and thermal imaging are more expensive and require very specific expertise for data processing.

- Satellite imaging cannot capture a sequence of events over a short-time period.

Project findings indicated that satellite imaging does not offer a cost-effective environmental enforcement solution for local authorities. It was decided that other technologies for gathering aerial images should be explored. Significant advances in UAVs, in terms of capability and cost, resulted in them being included in the scope of the project. They will be discussed later in this section.

3.2.2 CCTV monitoring

All local authorities are using some level of CCTV, which is deployed either internally or through a contracted service. Therefore, this was considered a baseline technology that all stakeholders are familiar with and also one where all share some common issues. In most cases, standard CCTV systems, which are typically used for security applications, are being deployed for environmental monitoring even though they are not designed for environmental requirements.

The main issues highlighted by local authorities were:

- night-time CCTV solutions;
- CCTV for derelict and problematic areas;
- covert CCTV systems;
- CCTV systems for remote areas where no mains power supply is available (this is discussed in section 3.2.3).

3.2.2.1 Night CCTV solutions

Night-time CCTV solutions create a much higher challenge than daytime systems since the low-light conditions and vehicle headlights make it difficult to identify both the illegal actions and licence plates.

In this respect, two technology solutions were deployed and tested for night CCTV systems:

- an analogue system consisting of a high-end Samsung camera with infrared light and 600 television lines (TVL), a licence plate recognition (LPR) camera and a digital video recorder (DVR) with 500GB hard drive (approximate cost €900);
- a digital system consisting of an internet protocol (IP) 3.1 MP (megapixel) digital camera, an infrared illuminator and a network digital video recorder (NVR) (approximate cost €1200).

3.2.2.1.1 Analogue CCTV system

The first system, formed of the Samsung infrared 600 TVL camera (SCO-2080RP, Samsung, Seoul, South Korea), the Smartwatch LPR camera (V11ANPR215, Smartwatch, Dublin, Ireland) and the Smartwatch 500GB DVR (I23SWEC04F500), was tested in two different locations, namely the NUIM north campus students' union car park (deployment reports 8 and 9) and the bottle bank situated in the premises of the Lusk Football Club, Lusk, County Fingal (deployment reports 2 and 3).

In Lusk, the objective was to determine if dumping and littering at the bring bank could be detected. The Samsung analogue camera is a 600TVL "high end" outdoor camera with good infrared functionality. The camera was powered from a mains supply in the clubhouse and all footage was recorded on a Smartwatch four-channel DVR, which was kept in the clubhouse. This technology was used in conjunction with an LPR camera. The intent of the Samsung camera was to monitor general activity, such as cars approaching and people depositing bottles, while the LPR camera could be used to read licence plates. The cameras were set up to record only when motion was detected in the area immediately surrounding the bring bank.

The system showed positive and negative points in terms of performance. The positive points were:

- Motion triggering worked effectively in both cameras.
- The Samsung infrared camera achieved what it was set up to do. All activity around the bring bank was captured. Two incidents of illegal dumping at the bring bank were captured during the deployment.
- The Samsung camera software was set up to block out bright lights (car headlights) at night-time – this worked effectively.

On the other hand, the negative points were:

- Licence plates could not be read at distances greater than 15m using the Samsung analogue camera. This was expected and was the reason for deploying a LPR camera at the same time.
- Night-time footage of the Samsung camera: The infrared on the camera was reasonably good, but did require a low level of background light to work (car lights, distant street lights).

- The LPR camera did not achieve what was needed. It could read licence plates up to 10–15m away in daylight, but it was very poor at distances greater than 15m. The number plate glare was a problem at night-time.

For the tests carried out in the car park at NUIM, the same setup was carried out as for Lusk, but the cameras and the DVR were battery powered. The car park is considerably well illuminated at night by lamp posts.

For this deployment, the positive points were:

- The LPR camera was able to read licence plates from a distance of about 15m during the day. The plate can be read even if the car is not facing the camera head-on (small angle). At night-time, the distance was reduced to about 10–12m. In this case, it is completely necessary that the car face the camera. The licence plate can be read even if the car headlights are on. The actions of the individuals caught on camera could be observed only during daylight hours. At night-time only the car licence plate can be seen – everything else is completely dark.
- The Samsung camera provided colour images both during the day and at night. The bright light function of the camera worked correctly, blocking strong sources of light so that the wider scene could be observed.

The negative points were:

- The LPR camera was expected to recognise licence plates from a greater distance than the Samsung infrared camera. At night-time, if the car was facing the camera at an angle, the plate could not be read.
- The Samsung camera did not allow the recognition of licence plates during the day or at night.

In conclusion, the performance of this system was worse than expected. The LPR camera captured licence plate numbers both during the day and at night-time. However, the distance range within which the plate could be actually recognised was smaller than expected, especially at night-time. The Samsung infrared camera provided colour images for both daytime and night-time with a reasonable level of background light. Plate recognition was not possible for the distances considered in the deployments (10–15m). In summary, both cameras did not provide a solid solution for daytime and night-time CCTV.

3.2.2.1.2 Digital CCTV system

The second system, formed of a digital 3.1MP IP camera from IC Realtime (ICIP-3000B-IR, IC Realtime, Dublin, Ireland), a four-channel 1TB NVR from IC Realtime (NVR-041n/1000) and the GJD 19m 60° low-glow illuminator (GJD Manufacturing, Heywood, Lancashire, UK), was tested at the Lusk Football Club (deployment report 4) and in NUIM (deployment reports 10 and 13).

In Lusk, the IP camera and the NVR were set up together with the LPR camera to compare its performance with the analogue Samsung infrared camera. Unlike the Samsung camera, the quality of the IP camera was excellent and licence plates could be easily read in the area of interest between 20m and 30m away. The motion triggering worked effectively, allowing all activity around the bins to be recorded.

The tests at the NUIM premises evaluated the capabilities of the IP camera, NVR and IR illuminator under very poor (or no) background light conditions. This test was found to be very successful, with the following main positive points:

- The brightness and exposure settings of the IP camera are crucial for correct licence plate and action recognition.
- The brightness settings need to be kept low in the configuration.
- For the exposure, values smaller than 1/500 do not allow licence plates to be read, since they reflect too much light. Ideal values of 1/120 and 1/250 were found.
- Both the illuminator and the camera performed in a satisfactory way for distances varying between 10m and 33m.
- For shorter distances, between 10m and 20m, the camera and the illuminator were able to correctly display the licence plate of the car even though the headlights of the car were on. The actions of people passing by the scene could also be seen. When the camera was working alone with no illuminator, it could pick up the plates and the actions of individuals in darkness, but not the plates with the headlights of the car on.
- For both configurations, with and without illuminator, the camera was able to clearly display a licence plate as far as 33m away. When the test was carried out with a car, the camera plus illuminator provided slightly better images than just the camera. For the

camera-only configuration, the plate was read even with the car lights on, except when the headlights were on, in which case the plate could not be seen.

The only negative point found was that licence plates could not be read without the external illuminator when the camera was used at night if the vehicle headlights were pointing at the camera.

As a final test, the IP camera had to be tested during daylight hours with the same configuration used at night-time to ensure its 24-hour performance (deployment report 13). The conclusions of this test are:

- A low brightness configuration and an exposure equal to 1/250 are the ideal parameters for a 24-hour CCTV system formed by the IP 3.1MP camera and the illuminator. This system would allow recognition of both the actions of individuals and licence plates during the day and under very dark conditions, providing an excellent permanent solution.

As a final conclusion for the night-time CCTV systems, the second option formed by the megapixel IP camera, NVR and illuminator completely outperformed the analogue system. However, it is a “power-hungry” solution and therefore is really feasible only if it has a mains electricity supply.

3.2.2.2 CCTV for derelict and problematic areas

CCTV equipment is very often a target for vandalism. This threat is heightened when the area being monitored is considered at high risk for vandalism. Westmeath County Council had such an area in Athlone where significant levels of illegal dumping were frequent in the gardens of unoccupied houses. Previous attempts to monitor the area had limited success. The researchers proposed an alternative solution whereby the area could be monitored from a safe distance (deployment report 7).

In this deployment a Samsung 600TVL analogue camera with 37× optical zoom was employed (SCZ-2370P) together with the Smartwatch 500GB DVR. This camera is not waterproof so it requires a protective housing. The approximate price for the set is €600.

The 37× camera was capable of monitoring the activity in the area from a distance. However, the unavailability of a stable position for the camera bracket (stable pole

or wall) produced camera shake effects in the image because of the weather conditions. This fact did not allow successful identification of the licence plate, recorded at distance, from the video. The more zoom used, the greater the effect of the camera shake on the image quality. In addition, even if the camera had been stabilised, only the maximum zoom would have given a licence plate reading. Therefore, the motion detection and intelligent zoom capabilities of the camera would need to be used. Primarily, the camera films a wide area (set of two or three houses), but using motion detection and intelligent zoom causes the camera to automatically zoom in to a point when motion is detected, which captures the action in detail.

To demonstrate the capability of reading a licence plate at a distance similar to the test in Athlone another test was set up in a NUIM car park (deployment report 12). In this case, the camera was secured to a very stable light post to avoid camera shake. Under these conditions, the camera was able to correctly display licence plates up to a distance of approximately 175m using the 37× optical zoom. The autofocus of the camera was used so that image quality would adjust automatically when small vibrations were received from the post. In addition, when the intelligent focus of the camera was tested, initially the camera was set with a zoom of 20×, which provided a wider view of the scene. When movement was detected in the scene, the camera zoomed in to 37×, displaying a readable car plate. After a selectable period of time (e.g. 5 seconds), if no more movement is detected, the camera goes automatically back to the 20× wider view until a new movement is detected.

In conclusion, the 37× optical zoom was capable of reading a car licence plate from a distance of around 175m when a stable mounting post is provided to avoid camera shake. The setup proved that the intelligent focus capability of the camera could be used for showing wider scenes, and that the maximum optical focus should be used only when movement is detected and a licence plate needs to be read. In general, CCTV cameras with powerful optical zooms are a good option for remote monitoring of conflict areas where an *in situ* equipment installation would be at risk.

3.2.2.3 Undercover CCTV system

Westmeath County Council also requested some research to develop an undercover CCTV system which

could be randomly hidden in different locations. Owing to the temporal nature of the system, it was required to be battery powered.

For battery-powered CCTV systems, the power consumption of both cameras and video recorders dictates how long the equipment will operate before the battery is discharged. Cameras and DVRs/NVRs, used to date, would last only 24 hours running from a standard 12V car battery with a capacity of 40Ah.

As an alternative, the system formed by a mini analogue 600TVL camera and a mini DVR was found to have the lowest power consumption, around 250mA when both are connected to a 12V battery. In this way, a system was built into a metallic box formed by the mini analogue camera, the mini DVR and two 12V DC and 7Ah batteries.

The mini Twilight camera (CCTV Direct, Leeds, UK) is an analogue 600TVL camera with no infrared that has a very low power consumption in comparison with other analogue CCTV cameras (around 80mA). The K-Ding mini DVR (CCTV Direct, Leeds, UK) is normally used in cars or bus CCTV installations. The video/images taken are recorded on a secure digital (SD) card with a maximum capacity of 32GB, instead of a hard disc drive. Like the mini camera, the mini DVR has a low power consumption in comparison with other DVRs (around 170mA). For Phase Alternating Line (PAL) video system, the mini DVR allows two types of video quality to be used, D1 (720×576) and Quarter Video Graphics Array (QVGA) (360×288), with a maximum of 25fps. Two 12V DC 7Ah batteries connected in parallel were used to power the system. Considering the power consumption of the camera and mini DVR, the system was calculated to work for around 50 hours continuously. The approximate cost of the system is €200.

The mini DVR allows a motion detection area to be set up, which can be the whole scene, one-quarter of the scene or one-sixteenth of the scene. When the camera is triggered, a video sequence of 5 or 10 seconds can be taken. It also allows 5 or 10 seconds of video to be recorded before the triggering instance.

The hidden system was set up behind a traffic sign in Patrick Street, Mullingar, in order to catch illegal dumping, which had been occurring next to a rubbish bin on a regular basis (deployment report 6).

The positive points of this deployment were:

- The system was easy to install on a sign post in the street because of the box enclosure.
- The triggering area was set to one-sixteenth of the scene, centred on the target rubbish bin where the subject normally deposited the rubbish bag. A 10-second video configuration was set up to record the scene every time movement was detected in the selected area. The motion detection and video recording were performed correctly by the DVR.
- The camera provided an acceptable image quality.
- The system was successfully powered by the batteries and allowed the devices to perform correctly.
- The camera has a wide angle field of view.
- The setup was covert.

On the other hand, the negative points of the deployment were:

- The necessity of the DVR to write images to an SD card does not allow continuous videos, produced by consecutive triggers, to be recorded. The DVR needs around 10 seconds to save a 10-second video on the SD card and start recording a new video.
- The busy location chosen for the deployment produced constant motion triggering, which resulted in almost constant recording. The 8GB camera installed in the DVR was able to save 631 videos of D1 quality. The overwriting function was not allowed, so it was not possible to check the total battery life of the system, since no videos were recorded after the SD card was full.
- The image quality of the small camera is not as good as other CCTV 600TVL cameras with higher specifications.
- The night-time performance of the camera could not be checked, since the memory card was full before this time.

In conclusion, among all the CCTV systems reviewed during the project, this configuration of camera and DVR provides the lowest power consumption for setups using battery power. In addition, its reduced size allows hidden deployment. The system provides good-quality daytime images but cannot read number plates further than 10m away.

3.2.3 Wireless remote environmental monitoring sensors

The intent of this section is to identify battery powered solutions that are suitable for environmental enforcement and monitoring in remote locations. While some of the solutions can be programmed to send images from the field to a personal computer or phone, other solutions store the footage on the device. Five solutions were analysed (all from Trailcampro, Springfield, MO, USA):

1. Ltl Acorn trail camera (€500–1000). Deployment reports 1, 11, 16, 17 and 21.
2. Reconyx Hyperfire trail camera (€500–1000). Deployment reports 18, 23, and 25.
3. Bushnell trail camera (<€500). Deployment reports 15 and 22.
4. Plotwatcher Timelapse camera (<€500). Deployment reports 41 and 42.
5. Reconyx SC950 Hyperfire Camera (€500–1000). Deployment reports 30 and 33.

All five solutions have different strengths and weaknesses. Choosing the ideal system will depend on requirements.

3.2.3.1 Ltl Acorn trail camera

The Ltl Acorn camera is a trail camera with Multimedia Messaging Service (MMS) functionality. High-quality still images at 2MP, 5MP or 12MP can be captured. The camera is very compact (5.5×3.5×3 inches) and has a “no glow infrared”, which makes it suitable for covert deployments. It is triggered by an internal passive infrared (PIR) movement sensor, which works up to 25m. It has a long battery life and can take an SD card up to 32 GB, which holds approximately 15,000 images at 5MP. Its easy installation and high-quality images mean it is good for use in remote areas with low footfall (up to 500 triggers per day).

This trail camera was used at five different locations across the three core local authorities. In the first two locations, Stockhole Lane in Fingal, County Dublin, and at the back of a public house in Mullingar, County Westmeath (deployment reports 1 and 11, respectively), the objective was to catch people carrying out illegal dumping. In both deployments the camera was set at 5MP and in a burst mode where two images were

captured once the PIR was activated. In addition, two images were sent to an email address every day so that changes to the site could be observed on a daily basis.

In both cases camera performance was similar. The positive points raised were:

- The camera was relatively easy to deploy covertly. No mains power or external battery was required so setup was relatively simple. The camera was housed in a box, sprayed black to help disguise it, for additional protection.
- The 5MP images were clear and number plates could be read in the area of interest.
- The camera PIR triggered when movement was detected within 25m, which covered the area of interest.
- Short Message Service (SMS) images: two images were sent on a daily basis to monitor the site for changes. This was an excellent feature, as it meant the site could be viewed without travelling to the location.
- The battery life is excellent. The 12 AA batteries took approximately 15,000 images over a 5-week period of deployment and were at 25% of life after the deployment.
- SD card capacity: the camera can take a 32GB card. During the first 2 weeks of deployment in Stockhole Lane, 5595 images were taken, consuming 6.1GB of storage space on the SD card. Therefore, the camera could operate in this environment for approximately 10 weeks before the 32GB SD card would be full.

On the negative side, the infrared illumination of the camera was found to be very limited. Therefore, the night-time pictures were very poor unless there was sufficient background light. In addition, similar to many trail cameras, the programmability is very limited.

The third deployment of the camera (deployment report 16) intended to test the Ltl Acorn camera as a CCTV system by setting it up so that a picture was taken every 3 seconds, independent of motion detection. This was used to monitor a rubbish bin in Patrick Street, Mullingar, where rubbish was regularly being left beside the bin. A schedule was set up in the camera to operate only between 8 a.m. and 6 p.m. in order to maximise the battery life by not using the infrared lamp, and to save memory card space by avoiding the hours with less activity in the street.

The camera took one picture approximately every 3 seconds between the hours specified in the schedule. A major issue with the sleep mode software of the camera was discovered. The camera was not reliable at shutting down and waking up at pre-programmed times. This issue was observed in deployments 17, 22 and 23. Deployment 23 was set up as a controlled experiment to gain a better understanding of the issue. The software sleep mode bug was confirmed and found to be independent of battery power.

Overall, the Ltl Acorn camera is a good camera for use in remote areas where there is low footfall. Image quality is very good and car registration plates can be read up to 30m away in daylight. The MMS function enables the site to be viewed remotely on a daily basis. The main weakness is its poor performance in complete darkness. Furthermore, there are some programming constraints. The camera is unreliable as a CCTV system; it takes pictures at constant time intervals during a programmed time schedule. Therefore, this camera would be recommended only for non-critical monitoring.

3.2.3.2 Reconyx Hyperfire trail camera

The Reconyx HC600 Hyperfire camera falls under the WREMS technology category. Unlike the Ltl Acorn trail camera, it does not have the MMS functionality. It can record video or high-quality still images at 1080p or 3.1 MP. It is larger than the Acorn or the Bushnell, but is still quite compact at 5.5×4.5×3 inches. Its PIR works very reliably up to 25m. It utilises a “no glow infrared”, which does not attract unnecessary attention in the field. Battery life is reasonable and it is rated to take approximately 40,000 images at 3.1 MP. In practice, on busy sites this would equate to 1.5–2 weeks of footage. Installation is relatively easy and high-quality images can be obtained. Therefore, it is good for use in a wide variety of places, including remote areas with low footfall and bottle banks that are relatively busy.

The Reconyx camera allows the time interval between pictures taken in the same burst to be defined (1, 3, 5 or 10 seconds) or to be as fast as possible (RapidFire mode). The number of pictures captured per trigger can be set to 1, 2, 3, 5 or 10. This function is very useful. In addition, a minimum time interval between bursts can be set up, if necessary, to 15 seconds, 30 seconds, 1 minute, 3 minutes or 5 minutes.

The Reconyx HC600 Hyperfire camera can be set up to work on a programmable schedule and to take pictures at constant time intervals independently of the PIR triggers. The picture interval can be set up equal to 1, 5, 15 or 30 minutes or 1 hour.

This model of Reconyx camera can use only AA lithium batteries or AA rechargeable nickel–metal hydride (NiMH) batteries. AA alkaline batteries must not be used.

By default, the Reconyx HC600 camera cannot employ an external power supply. However, the camera can be adapted to use a 12V DC external power supply with a jack connector.

This camera was used in the following deployments:

- 18: Supervalu bring bank, Virginia, County Cavan, 26 October 2012 to 26 November 2012.
- 23: Tesco bring bank, Baileborough, County Cavan, 16 November 2012 to 7 December 2012.
- 25: Bring bank, Shercock, County Cavan, 26 October 2012 to 14 November 2012.

Positive points raised by all deployments included:

- The camera is relatively small and was easy to deploy covertly. No mains power or external battery is required so setup was relatively easy. The camera was housed in a box, sprayed black to help disguise it, for additional protection.
- The 3.1 MP images gave excellent clarity.
- The camera PIR triggered when movement was detected within 25m, which covered the area of interest, and performance was reliable.
- The battery life is good. The 12 AA NiMH batteries were installed fully charged. In deployment number 18, over a time interval of 11 days, the camera took 9.3GB of footage (23,000 images) and 60% of the battery life remained. Using this information, the battery life using rechargeable NiMH batteries can be estimated as greater than 3 weeks. This does not consider very cold weather conditions (under 0°C).
- At night, the infrared illuminator had a longer range than the Ltl Acorn trail camera.
- Licence plates could be read at 25–30m during the day, and approximately 15m at night.
- The large number of pictures per burst (10 pictures) and the time interval of 3 seconds between them allowed all action in the scene to be observed over

time, especially if the person moved away from the PIR range.

- Illegal dumping actions were captured both during the day and at night with car LPR.

Opportunities for camera improvements included:

- Although the infrared is quite powerful, some background light was necessary in order to distinguish the actions carried out at night.
- Car LPR at night depends on camera angle and if the car lights are on and pointing towards the camera. In most situations where the lights are directly pointing at the camera, or when the light for the licence plate on the back of the car is on, the licence plate cannot be read.
- The battery life is shorter than for the Ltl Acorn camera.

Overall, it is a good camera for overt or covert use. Image quality is very good and car registration plates can be read up to 30m away in daylight and around 15m away at night (depending on car angle and if car lights are on). Its infrared illuminator performance is better than other trail cameras, e.g. Ltl Acorn. In addition, the time delay programmability between pictures in the same burst makes it very useful for observing the evolution of an action. On the other hand, in comparison with the Ltl Acorn camera, the Reconyx HC600 Hyperfire does not allow time-lapse pictures to be taken at less than 1-minute frequency and it does not have MMS capability.

3.2.3.3 Bushnell trail camera

The Bushnell camera falls under the WREMS technology category. Unlike the Ltl Acorn trail camera, it does not have MMS functionality. It can record video or high-quality still images at 3, 5 or 8MP. It is very compact (6.5 × 4.5 × 2.5 inches) and its PIR triggers up to 15m, which is poorer than either the Acorn or the Reconyx. No-glow infrared is a function (but it is not very effective). The camera has a long battery life, between 5 and 6 weeks depending on the number of shots taken.

Like the Ltl Acorn camera it allows one, two or three pictures to be taken per burst. The time interval between pictures is not configurable.

The interval of time that the camera will wait until responding to another PIR trigger can be set between 1

and 59 seconds with a 1-second interval, or between 1 and 60 minutes with a 1-minute interval.

The Bushnell camera can be set up to work on a programmable schedule and to take pictures at a constant interval independently of the PIR triggers. The picture interval can be set at 1, 5, 15, 30 or 60 minutes.

This camera was used in the following deployments:

- 17: Centra bring bank, Millmount, Mullingar, 5 October 2012 to 17 October 2012.
- 22: Tesco bring bank, Baileborough, County Cavan, 16 November 2012 to 7 December 2012.

The positive points raised by all deployments included:

- The camera is relatively small and was easy to deploy. No mains power or external battery is required so setup was relatively easy. The small size and black colour did not attract attention when it was installed in a box mounted on a lamp post.
- The 5 MP images gave excellent clarity and number plates could be read in the area of interest.
- The camera PIR triggered when movement was detected within 15m.
- Licence plates could be read at 25–30m both during the day and at night. At night the distance depended on the orientation of the car lights with respect to the camera.
- The camera infrared together with the ambient background light enables reasonable-quality night pictures (similar to Acorn, but not as good as Reconyx).

Some of the weaknesses of this camera included:

- Car LPR at night depends on camera angle and whether or not the car lights are on and pointing towards the camera. In most situations where the lights are directly pointing at the camera, or when the rear licence plate light is on, the licence plate cannot be read.
- The detection distance of the PIR is shorter than for the Ltl Acorn and Reconyx cameras, at around 15m.
- Unlike the Reconyx camera, the small number of pictures per burst (only three) and the lack of configurability of the interval between pictures means action can be missed if the subject moves away from the detection area of the PIR.

Overall, it is a good camera for overt or covert use. Image quality is very good and car registration plates can be read at distances of 25-30m during the day and 15m at night (depending on car angle and if car lights are on). Its infrared illuminator performance was good considering the high level of background light. On the other hand, the shorter PIR range and the limited number of pictures per burst resulted in activity being missed when subjects walked outside the PIR range.

3.2.3.4 Plotwatcher Pro camera

Plotwatcher Pro (<€500), deployment reports 31 and 32.

The most significant difference between this camera and other cameras is the fact that this operates in a time-lapse mode only. It is not triggered with a motion sensor; instead it continuously captures images at the programmed time interval. It was deployed in two locations in Mullingar. In deployment number 31 the camera was set up to observe a bin on a public path. It was known that the same couple were regularly leaving their household rubbish beside the bin. The camera was set up to take images at 1-second intervals and power off at night to conserve battery life. The couple left rubbish on two occasions over a 2-week period between 13 February 2013 and 27 February 2013. The camera caught both incidents clearly.

This solution is an alternative to the mini camera tested in deployment number 6 and was certainly a more effective solution.

The main advantages of this camera include:

- A very long battery life: the camera specifies that it can take up to 1,000,000 images on a set of eight AA batteries. In our testing we captured up to 300,000 images over a 1 week period.
- It saves images as a "TRU Video" file and has reasonably good software for reviewing images.
- There is no reliance on PIR sensor so all activity is captured.
- The time lapse can be set from 1 second up to 1 hour.

However, there were also some weaknesses associated with this camera such as:

- It is not good for reading licence plates; only plates up to 15m away were readable.

- It has no infrared, so is useful only during daylight hours.
- It captures only 1 MP images.
- The image clarity is often blurred when an object is moving across the lens, but is clear when the object is stationary or moving towards the lens.
- When the timer function was used to power it down at night, the images "froze" 3 hours before power down. This happened every day.
- All the footage needs to be reviewed; however, the software is quite good.

Overall, this camera is a good solution for certain applications. It is relatively cheap and, while the quality of the images is not outstanding, it delivers lots of images.

3.2.3.5 Reconyx SC950 Hyperfire Camera

Cost: €500–1000, deployment reports 30 and 33.

Although the time-lapse function in the previous Plotwatcher camera was good, the image quality was not great. This Reconyx camera was tested in a time-lapse mode, but with 3MP images being taken, and was therefore aimed at applications where it could read licence plates. Its main deployment was at the Lusk United Football Club between 6 March 2013 and 9 May 2013. It was set up a long distance from a bring bank and therefore needed to be in a time-lapse mode in order to capture images. However, it is power-hungry so was modified to accept an external 7Ah battery. It was set up in a 5-second time-lapse mode, powering off at night to conserve energy. Each week it would take approximately 65,000 images. Under these conditions a 32 GB card would last approximately 10 days.

During the period from 29 March 2013 to 9 May 2013 this camera was deployed with a second camera and between them 41 cases of illegal dumping were captured and presented to Fingal for follow-up.

Some of the main advantages of this time-lapse system with an external power supply included:

- It gives high-quality images and has a long battery life. It could read licence plates at 25m.
- The time lapse is 3, 5, 10, 15, 30 seconds, 1, 2, 3, 5, 10, 30 minutes, 1 hour, etc.
- The infrared was reasonable, but power-hungry – it was turned off in our deployment.

Some of the weaknesses of this system include:

- It is expensive.
- The camera needs to be modified and housed in a box with an external battery.
- The solution is larger and harder to disguise than it would have been if it did not have an external battery.
- Lots of footage is gathered, the review process is long and there is no software to simplify it.

In summary, this is an excellent solution for capturing activity from a distance or in situations where the PIR trigger may not work reliably. However, it is expensive and therefore may be suited to relatively only “safe” deployments.

3.2.4 Programmable audio device

3.2.4.1 NUIM programmable audio device

The programmable audio device for bottle banks is a device fully developed by the research team. It was conceived as a preventative solution to minimise illegal dumping at bottle banks. The device plays a message when motion is detected in the area of interest. The message is fully customisable and, in the case of bottle banks, it reminded users not to leave any rubbish behind. The device can also be customised so that it will not repeat the message until a programmable time delay has elapsed and it receives a new trigger. A working time schedule can be programmed so that the device operates only between specific hours of the day. The device offers four different volume-intensity levels. It is battery powered and battery life depends on volume and number of triggers per day. It has been deployed in applications where the device triggered 7000 times over a 5-week period on a single battery charge.

As with all trail cameras, the programmable audio device has been installed in different locations across the three core local authorities (deployment reports 5, 14, 19, 20, 24 and 26). From the first deployments, different bugs were identified and corrected, which resulted in the device being continuously improved.

The first prototype of the programmable audio device was deployed in the bring bank at the Lusk Football Club premises (deployment report 5). This prototype was set up with a working interval between messages of 3 minutes and working schedule between 8 a.m. and

10 p.m. daily. However, a technical bug caused the device not to restart following an overnight shutdown. Therefore, the effectiveness of the device was not measured in deployment number 5.

After the bug related to the working schedule was fixed, the second prototype of the programmable audio device was tested at the Millmount bottle bank, Mullingar (deployment report 14). The objectives of this deployment were to test the performance of the device and observe if there was any reduction in the amount of dumping. As a result, the programmable audio device worked according to the schedule previously set up. The manager of the supermarket situated next to the recycling area noticed a reduction in the amount of rubbish dumped at the recycling area during the audio device deployment. In addition, no complaints from adjacent neighbours were received.

Subsequently, the programmable audio device was deployed in three different bring banks in County Cavan: Virginia, Shercock and Baileborough (deployment reports 19, 20, 24 and 26). Initially, in Virginia and in Shercock, the first prototype of the audio device was deployed with a working schedule between 9 a.m. and 9 p.m. Later on, the device in Virginia was improved by adding a second PIR situated approximately 10m away from the audio device to maximise the detection area and the probability of detecting everybody using the facilities. As a result, a reduction in the number of illegal dumping cases was observed in both places during the hours that the audio devices were working. The study compared the number of illegal dumping cases versus the total number of users who used the facilities before the programmable audio device was installed and after it was installed. Finally, the results obtained from the deployment in Baileborough showed the highest reduction in the number of illegal dumping cases, with an 86% reduction.

Following the successful results in Cavan, deployment of the programmable audio device at the bottle banks in Lusk United Football Club was repeated. The intention was to validate the positive results from Cavan and also determine if it would be as effective in an urban area. Deployment number 34 in Lusk confirmed the excellent results from Cavan: an 83% reduction in littering at the bottle bank was observed during its deployment based on an analysis of 1967 visitors to the site over a 9-week period.

Table 3.1. Effectiveness of audio device at bring banks

		Virginia	Shercock	Baileborough	Lusk, Dublin
		October/ November 2012	October/ November 2012	November/ December 2012	March–May 2013
No audio device	Number of users	1044	382	750	983
	Number of dumping cases	30	12	38	54
	Percentage dumpers	2.87	3.14	5.07	5.49
Audio device	Number of users	1363	136	599	984
	Number of dumping cases	31	2	4	9
	Percentage dumpers	2.27	1.47	0.67	0.91
% reduction with speech device		20.9	53.2	86.8	83.4

Table 3.1 summarises the effectiveness of the programmable audio device across different locations. The bring bank in Virginia is very large and the audio device would trigger only when a user visited the glass recycling. However, many users recycled only cardboard and did not trigger or hear the device. This deployment highlighted the need to upgrade the audio device so that it could be triggered from multiple sensors spread over a broader area. The upgraded device was used in Baileborough and significantly changed behaviour based on an analysis of 1349 visitors to the bring bank. There was also a significant behaviour change observed in Shercock. However, there was relatively low footfall at this site. The deployment in Lusk validated that the audio device is a robust solution for significantly reducing illegal dumping at recycling bring banks.

3.2.4.2 *Takex Speaker Sensor, model PV-12E*

Following the significant results achieved with the NUIM programmable audio device, the research team explored the marketplace for off-the-shelf devices that may achieve similar results. They were seeking a battery-powered solution that could play a customisable message. The first device trialled was the Takex Speaker Sensor, model PV-12E (Takex, Kyoto, Japan). This unit is an outdoor enunciator costing approximately €200. It is quite compact on first impression, but the unit does not include an external battery pack. Therefore, this would need to be added in a separate enclosure and be wired to the speaker sensor. The unit consumes 50 mA when on standby and a maximum of 500 mA when a message is playing.

On the positive side, it was quite easy to record a message onto this device and the PIR sensor triggered

at a range of 8–9 m. It had a broad volume range, but the sound quality deteriorated significantly as volume increased. In addition, on the negative side, the unit had no programmability function. There was no timer for powering it off at night or at designated times. Furthermore, the message played every time the PIR was triggered, which could be very annoying. There is no provision for monitoring the unit remotely and the sound quality is quite poor. The maximum message length is 8 seconds.

In conclusion, this unit would not be recommended as a preventative solution for illegal dumping because of its poor sound quality and lack of programmability.

3.2.4.3 *Takex Speaker Sensor, model PVW-12TE*

The second off-the-shelf enunciator tested was the Takex Speaker Sensor, model PVW-12TE (Takex, Kyoto, Japan). This is an indoor/outdoor device which costs approximately €200. Like the model PV-12E above, it requires an external battery pack to be connected and this is not included. It consumes 55 mA when on standby and a maximum of 300 mA when a message is playing.

Similarly to the PV-12E, message recording was relatively simple. The message could be recorded directly onto the unit or it could be downloaded from another device. A significant advantage it has over the PV-12E is that two messages may be recorded: one plays during hours of brightness and the other plays in hours of darkness. The PIR triggered at a range of 8–9 m and the sound quality was better than the PV-12E. However, its maximum volume is significantly less than the PV-12E. It may be more suited to indoor applications, as dampness or frost may damage the inbuilt speaker (it is not

a horn like in the PV-12E). Again programmability is quite poor: there is no timer function for controlling its on/off time, the message plays every time the sensor is activated and the unit cannot be monitored remotely. The maximum message length is 8 seconds as with the previous unit.

In conclusion, this unit is more suitable than the PV-12E, but is not suitable for long-term outdoor applications in its current configuration. It is more suited as a solution for some indoor applications, but programmability is quite limited.

3.2.5 Active infrared beams

Active infrared beams are generally used for perimeter or boundary protection of an area. The beam transmitter and receiver may be placed up to 200 m apart provided there is a direct line of sight between them. They are generally used in conjunction with other devices that are triggered by the infrared beams when movement is detected, such as GSM (Global System for Mobile communication) transmitters, alarms, audio devices, etc.

The research team demonstrated the application of one type of these active infrared beams at the bring bank in Shercock (deployment report 27). The model used was the Optex battery-powered infrared beams (AX200TFR-TI; Optex, Shiga, Japan), which can cover an outdoor distance up to 100 m. The approximate price of the battery-powered beams and batteries is €800. This represents a much more expensive option than the mains-powered beams but it provides the flexibility of battery-powered devices for temporary deployments.

During the Shercock deployment, the transmitter and receiver were situated 32 m apart, providing a detection line directly in front of the bring bank, so any user would have to cross the line when approaching the bins. In this case, the beams receiver device was connected to the audio device in order to trigger an alert every time the beams were broken. Once installed, the triggering of the audio device occurred each time the beams were crossed.

The infrared beams provide a reliable method for triggering devices such as the audio device or a GSM text unit. However, they are expensive and are also susceptible to vandalism, as they are mounted relatively low. They are suited to protecting high-value assets in an area where a trigger can be investigated immediately when it occurs.

3.2.6 Environmental Enforcement App for field officers

The Environmental Enforcement Application for tablets was presented as a versatile and useful tool for field officers. In addition, it offered a quick and organised way to store and access field reports. During the first workshop in June 2012, Fingal pointed out that it was already working on a project involving an app development for their officers. However, this app was scoped for use within Fingal only and not as a nationwide tool.

The Environmental Enforcement Officer App prototype initially designed by the research team was scoped as a tool that, when used by any local authority, would allow information related to environmental enforcement to be shared with any other local authority using the same app. Thus, collaboration and efficiency would be achieved not only within one organisation, but also in the information exchange process between multiple local authorities.

The research team proposed that we could develop this application with Westmeath County Council. However, Westmeath was already working on a similar project and developing its own app, which was designed to be fully compatible with its Environment Management System (EMS). The intention was that this application, when developed, would be rolled out to other local authorities in the midlands, including County Cavan.

Based on the evidence that much work was already being carried in this area the research team decided to cancel the development of the Environmental Enforcement Office App prototype and focus on other areas that could prove more beneficial.

3.2.7 Quadcopters for aerial photography (unmanned aerial vehicles)

Quadcopters were presented at the first workshop as a feasible alternative to satellite imaging. The use of UAV for aerial photography is a relatively new area and is gaining lots of interest, as there are many applications for the technology. A Gaii 500X quadcopter (Gaii, New Taipei City, Taiwan) with a GoPro camera (GoPro, San Mateo, CA, USA) was purchased towards the end of 2012. Although this package was relatively cheap (approximately €1500), it offered great potential.

Field trials for the UAV were carried out in NUIM. Inexperience in the beginning resulted in the Gaii

500X being crashed each day it was tested. As a consequence, the frame of the Gaui was redesigned so that it would click apart on impact without breaking parts and therefore could be reassembled easily. With each breakage an improvement was implemented and therefore the testing was an iterative process. The Gaui was flown up to 200m from its base at a height of 80m, approximately. Good aerial footage was recorded using the GoPro camera.

The Gaui has a programmable GPS unit on board. However, despite significant effort, we have yet to be successful in programming it. In order to have full control and confidence flying the Gaui, the GPS unit must be operational.

Initially, it was felt that a few local authorities could share a UAV and have one expert user to deploy it across several authorities. However, based on experience this approach would not be recommended. Flying a UAV is a very skilled task and requires significant expertise. In addition, on-going maintenance and repairs are necessary and are a large investment in both time and money. The recommendation for this technology would be to contract it in from an expert in the field.

3.2.8 Universal Purpose Environmental Enforcement Board

During September, October and November 2012, the research and deployment of the different technologies demonstrated the lack of desirable functionality in the devices deployed. Many of the technologies had weaknesses in common, so the research team identified opportunities to introduce new functions for CCTV and WREMS technologies. Some of these functionalities included:

- timing control for CCTV and WREMS systems;
- system status transmission via SMS;
- alarm detection from external devices such as passive infrared (PIR) or active infrared devices;
- communication with other type of sensors using wireless communications;
- saving information onto a memory card.

Under these requirements, the decision to design a UPEE board was taken to fulfil those necessities. In addition, considering the broad functionalities given above, this board could also be applied to other types

of deployments, such as a bin-level sensor system in a bring bank. Consequently, a first technical specification for the UPEE board was created based on three different working scenarios: CCTV system, WREMS camera system and sensors system.

Depending on the applications for the UPEE board, different modules and functionalities of the board would be employed. It is important to note that several scenarios could take place simultaneously. For example, the board could be simultaneously used to control a CCTV system and retrieve information from wireless sensors.

The intent of this board was to provide an interface across existing technologies that would make them more suited for environmental monitoring applications. The three different working scenarios considered were:

1. CCTV system:

- (a) The board is powered using a 12V or 24V DC battery or 220–240V AC mains power.
- (b) Up to three of the power outputs can be used, normally at 12V DC.
- (c) A timer function is implemented to set up the operational hours of the devices. Each output could require an independent timer.
- (d) One or more SMS could be sent every day containing information on temperature, battery life, GPS location, local time and SD card capacity.
- (e) The configuration of the timers could be changed via SMS with a particular command.
- (f) If a battery is used as a power source, a solar cell could be used to recharge the battery.
- (g) An accelerometer could be used to detect any tamper attempt. If a tamper attempt is detected an SMS would be sent containing the alert.
- (h) Certain information could be saved in the memory card; a log of the temperature values, accelerometer triggers, battery life, GPS location, etc.
- (i) Alternatively, the device could be set up in constant sleep mode until motion is detected by the external sensors. Then, the devices would be powered up for a certain amount of time. It could also send an SMS informing that motion has been detected.

2. Trail cameras or WREMS system:

- (a) The board is powered using a 12V or 24V DC battery or 220–240V AC mains power.
- (b) Up to three of the power outputs can be used, normally at 6V DC.
- (c) A timer function is implemented to set up the operational hours of the devices. Each output could require an independent timer.
- (d) One or more SMS could be sent every day containing information on temperature, battery life, GPS location, local time and SD card capacity.
- (e) The configuration of the timers could be changed via SMS with a particular command.
- (f) If a battery is used as a power source, a solar cell could be used to recharge the battery.
- (g) An accelerometer could be used to detect any tamper attempt. If a tamper attempt is detected an SMS would be sent containing the alert.
- (h) Certain information could be saved in the memory card; a log of the temperature values, accelerometer triggers, battery life, GPS location, etc.
- (i) Alternatively, the device could be set up in constant sleep mode until motion is detected by the external sensors. Then, the devices would be powered up for a certain amount of time. It could also send an SMS stating that motion has been detected.

3. Sensors system:

- (a) The board is powered using a 12V or 24V DC battery or 220–240V AC mains power.
- (b) The Wi-Fi module is used to communicate with wireless sensors (CO₂, noise, bin capacity) and retrieve some type of information from them. The amount of information would generally be small.
- (c) The information received would be stored in the SD card.
- (d) The information could be transmitted using SMS together with other information on temperature, battery life, GPS location, local time and SD card capacity.

- (e) A timer function could be used to set up the operational time of the Wi-Fi module, e.g. the module may need to retrieve information from the sensors only once a day.
- (f) The configuration of the Wi-Fi timer could be changed via SMS with a particular command.
- (g) If a battery is used as a power source, a solar cell could be used to recharge the battery.
- (h) The accelerometer could be used to detect any tamper attempt. If a tamper attempt is detected an SMS would be sent containing the alert.

A UPEE board was conceived in order to address these common challenges. A board requirements document was developed with specifications for the board so that a quote for its development could be attained. A hardware consultant, Stephen Hughes, reviewed the requirements document and believed all requirements could be achieved. The cost to develop both the hardware and the software was quoted at approximately €25,000, which far exceeded the available budget. A process to reduce the specification of the board so that it would cost <€8000 was not successful.

In conclusion, the UPEE board is a good concept to address many of the common issues related to CCTV and WREMS deployments. However, the cost of developing the solution falls outside the financial scope for this project. Therefore, this was not pursued. However, the scoping exercise was very valuable and this board is worth considering for future projects.

3.2.9 *Wireless remote sensor*

While cameras that are triggered using an integrated PIR sensor are often suitable for remote monitoring in areas where no mains power is available, they also have many practical issues associated with them that create challenges for field deployments. The main challenges are:

- They need to be positioned close to the area of interest so that people will trigger them; however, this may mean that they are too close to read vehicle licence plates and capture the entire scene.
- A covert solution is harder to achieve, as they are located in the area of interest.
- The camera is exposed, as its PIR needs to detect movement.
- The equipment is susceptible to vandalism.

The concept here was to implement a solution whereby a camera could be triggered from an external standalone wireless PIR sensor. Although the technology is available for various applications, there was not a cost-effective solution for wirelessly triggering cameras. Therefore, the research team looked to develop a solution that could be integrated with cameras already tested during the project.

The objective of the wireless PIR sensor was to address the challenges identified above. The requirement was to have a standalone wireless sensor placed in the area of interest that triggered a camera up to 50m away from the sensor. Therefore, the camera would be situated in a “safe” location, with the wireless PIR sensor as the only technology at risk. A sensor is more compact than a camera and is therefore easier to hide and also has a much lower cost.

Development of this solution was completed in August 2013, so field deployments to test its effectiveness were completed in NUIM. Results from the testing found that:

- The wireless PIR sensor could trigger the camera at any distance up to 120m away with a direct line of sight, and up to 50m away without a direct line of sight. This was much better than expected.
- The range of the wireless PIR sensor was a maximum of 12–13m, which is less than our target of 20m. However, it is still an excellent solution for most scenarios. The range here refers to how close a person needs to be to the sensor in order for it to trigger. The distance in the point above refers to how far the camera may be positioned away from the sensor.
- The power consumption of the wireless PIR sensor is relatively small and the transmitter is expected to last for 3–4 months on a battery, while the receiver will be integrated into the camera and be powered by the camera power supply.

Development of this solution had a non-recurring engineering cost of €3500. The cost for future implementation is an additional €200 per camera. This

solution is suitable for areas where cameras are at high risk of being stolen or vandalised

3.3 Summary log of technology field deployments

A total of 37 technology field deployments were completed over the course of the project. The intention of the deployments was to investigate the effectiveness of various technologies in real-world situations. To that end, the core local authorities of Fingal, Cavan and Westmeath identified problem areas where the technologies could be trialled. In addition, a number of field trials were also completed in NUIM.

A summary log of all technology field deployments is shown in Figure 3.1.

3.4 Cost–benefit analysis of technologies

As budgets for waste enforcement are getting tighter, local authorities are looking for opportunities to provide effective services at reduced costs. This project focused on identifying new and emerging technologies to support waste enforcement at competitive costs.

There is not a one-size-fits-all technology solution that satisfies all requirements in all situations. However, there are common issues experienced across all local authorities. The cost–benefit analysis outlines:

- the technologies investigated;
- typical applications or issues that the technology addresses;
- the strengths and weaknesses of the technology;
- the cost of purchasing the technology with accessories for installation;
- whether the equipment is mains or battery powered;
- how well cameras can read licence plates;
- effective day/night solutions;
- whether the technology can be monitored remotely;
- recommendations on the effectiveness of the solution based on the researchers’ experience.

The cost–benefit analysis is detailed in Table 3.2.

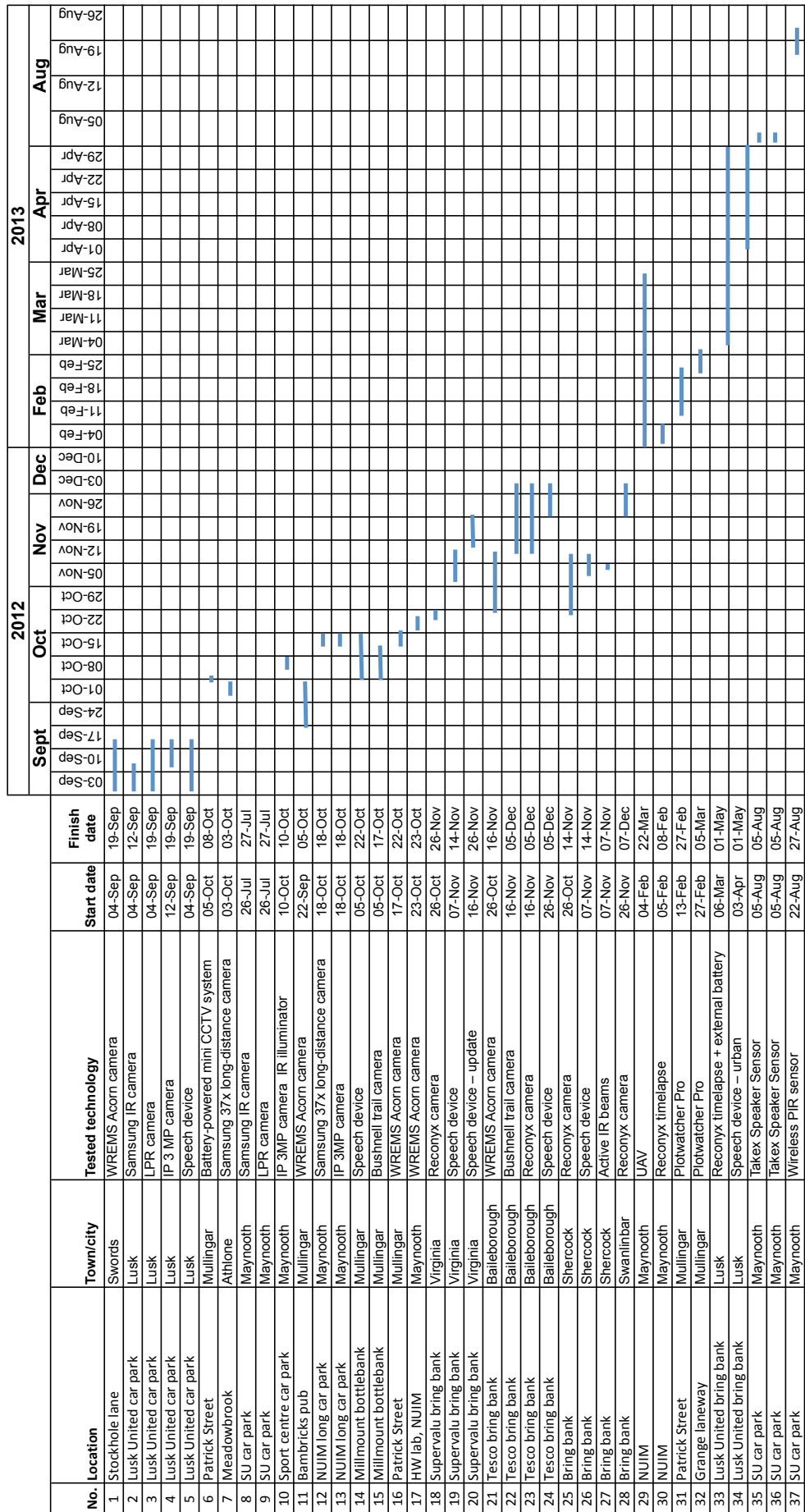


Figure 3.1. Log of technology field deployments.

Table 3.2. Cost–benefit of technologies

Technology	Applications/issue	Strengths	Weaknesses	Cost (€)	Needs mains power	Reads licence plates	Day solution	Night solution	Remote monitor	Covert	Comment
CCTV monitoring											
Night CCTV solutions											
Analogue CCTV	Monitoring illegal dumping hot spots, bottle banks, etc. using mains-powered solutions	Motion triggering Bright light blocking Samsung good for “general” monitoring. Good colour night images where street lighting present	Licence plate can be read only up to 15m in day and <10m at night on Samsung LPR camera was similar to Samsung Image quality poor with LPR camera	500–1000	Yes	Poor	Poor	Poor	Yes	No	Would not recommend this system
Samsung 600TVL camera, model SCO-2080RP											
Licence plate recognition (LPR), model Smartwatch V11ANPR215											
4-channel DVR model Smartwatch 123SWEC04F500											
Digital IP CCTV	Monitoring illegal dumping hot spots, bottle banks, etc. using mains-powered solutions	Excellent solution Camera can read plates up to 33m by day and night Illuminator allowed licence plate reading even when car headlights were directed at camera	Power “hungry” solution For battery developments, battery would only last 24 h	1000–1500	Yes	Very good	Very good	Very good	Yes	No	Would recommend this system. Infrared illuminator may not be necessary in most cases
3.1MP IC Realtime camera, model ICIP-3000B-IR											
4-channel NVR, model IC											
Realtime NVR-041n/1000											
Infrared illuminator, model GJD 19m											
Problem/hostile areas											
Samsung 600TVL analogue camera with 37x zoom, model SCZ-237OP	Monitoring hostile/problem areas from a “safe” location/distance	Reads licence plates up to 180m during day Can monitor from safe location/distance Motion zoom mode	No infrared Needs very stable mounting (not a pole)	500–1000	Yes	Very good	Very good	No	Yes	No	Would recommend this system for monitoring from a safe distance
4-channel DVR, model Smartwatch 123SWEC04F500											
Covert											
600TVL mini twilight camera, model K-Ding mini DVR	Covert monitoring	Small form factor covert design Battery life up to 50h recording	No infrared Only records in 10s bursts so some action is missed Poor image quality	<500	No	Poor	Yes	No	No	Yes	Would not recommend this system

Technology	Applications/issue	Strengths	Weaknesses	Cost (€)	Needs mains power	Reads licence plates	Day solution	Night solution	Remote monitor	Covert	Comment
<i>Wireless Remote Environmental Monitoring Sensor (WREMS)</i>											
Ltl Acorn camera	Monitoring illegal dumping hot spots, bottle banks, etc.	High image quality, 5 MP or 12 MP Triggers range to 25 m Small form factor Sends SMS images to phone Time lapse from 1 s intervals Reads licence plate up to 30 m	Infrared very poor Poor programmability Reliability issues	500–1000	No	Very good	Very good	Poor	Yes	Yes	Good camera, but because of reliability issues would only recommend for non-critical work
Reconyx HC600 camera	Monitoring illegal dumping hot spots, bottle banks, etc.	Good image quality, 3 MP Triggers range to 25 m Small form factor Good programmability Reasonable infrared Reads licence plate up to 30 m	Expensive No remote monitoring Minimum time lapse of 1 min	500–1000	No	Yes	Very good	Good	No	Yes	Good camera – would recommend
Bushnell camera	Monitoring illegal dumping hot spots, bottle banks, etc.	High image quality, 5 MP and 8 MP Small form factor Reads licence plate up to 30 m	Triggers range to 15 m No remote monitoring Minimum time lapse of 1 min Infrared very average	<500	No	Yes	Very good	Poor	No	Yes	Reasonable camera – would recommend for some applications
Plotwatcher Pro camera	Monitoring illegal dumping hot spots, bottle banks, etc.	Time-lapse mode from 1 s Good software for reviewing footage Excellent battery life No reliance on PIR sensor	Image quality poor – not for licence plates No infra red Software issues	<500	No	Poor	Very good	No	No	Yes	Reasonable camera – would recommend for some applications

Technology	Applications/issue	Strengths	Weaknesses	Cost (€)	Needs mains power	Reads licence plates	Day solution	Night solution	Remote monitor	Covert	Comment
Reconyx SC950 Camera	Monitoring illegal dumping hot spots, bottle banks etc.	Good image quality, 3MP Trigger range to 25m Small form factor Good programmability Reasonable infrared Reads licence plate up to 30m Time lapse from 3s	Expensive No remote monitoring No software for reviewing footage	500–1000	No	Very good	Very good	Good	No	Yes	Good camera – would recommend
Active Infrared beams											
Optex battery-powered infrared perimeter protection (AX200TFR-T1)	Used to protect the boundary or perimeter of an area or to trigger a device when the beam between the transmitter and receiver is broken	AX200TFR-T1 covers a range of 100m Very reliable trigger for devices such as GSM text transmitter, cameras, alarms, audio devices, etc. Works in darkness and fog Battery-powered, flexible	Expensive Powered versions are much cheaper than battery Can be vandalised as they are mounted low	500–1000	No	n/a	Yes	Yes	No	No	Good solution – would recommend
Sensor technology											
Programmable audio device – NUM	Programmable audio message played when person approaches target area Proven to reduce illegal dumping at bring banks by 80% Also used for dog fouling	Reduced illegal dumping by 80% Battery-powered Preventative Remote monitoring Programmability Power efficient	Overt solution – needs to be vandal proof	Not available off the shelf Available through start-up company	No	n/a	Very good	Very good	Yes	n/a	Good solution – would recommend

Technology	Applications/issue	Strengths	Weaknesses	Cost (€)	Needs mains power	Reads licence plates	Day solution	Night solution	Remote monitor	Covert	Comment
Takex Speaker Sensor PV-12E	Programmable audio message played when person approaches target area	Battery-powered Preventative	No battery pack included No programmability options Always triggering	<500	No	n/a	Poor	Poor	No	n/a	Would not recommend this system
Takex Speaker Sensor PVW-12TE	Programmable audio message played when person approaches target area	Battery-powered Preventative	No remote monitoring No battery pack included No programmability options Always triggering	<500	No	n/a	Poor	Poor	No	n/a	Would not recommend this system
Wireless sensors	Wireless sensor developed to remotely trigger CCTV. Purpose is to keep CCTV safe away from trigger area	Battery wireless trigger for CCTV Triggers camera up to 100m away Asset protection	PIR trigger range of 13m is relatively short	n/a	No	n/a	Very good	Very good	n/a	n/a	Good solution – would recommend
Satellite imaging											
	Monitoring of licensed landfills, illegal landfills and object detection in specific areas	Broad aerial view – visibility without going to area	88% cloud cover in Ireland Expensive Historical – not live	10,000 for one image/day over 1 week	n/a	No	Poor	No	No	Yes	Would not recommend based on cost and cloud cover
Unmanned aerial vehicles											
Gauai 500X with GoPro camera	Aerial monitoring of unsafe/difficult to reach areas	Relatively cheap Aerial images	Technology not robust Continuous fixing Difficult to learn to use	1500–2000	No	No	Yes	No	No	No	Would not recommend this as a solution for local authorities – if they require aerial imaging, bring in a specialist

4 Recycling bring bank analysis

According to the EPA National Waste Report 2011 (McCoole et al., 2013), local authorities reported 1891 bring banks in operation in 2011. Civic amenity centres and bring banks account for 16% of all household waste collected in 2011 and are therefore a valued facility. Bring banks offer a facility where glass bottles/jars can be recycled free of charge. Many bring bank locations also offer clothes and cardboard recycling. However, as highlighted by the survey completed during this research, bring centres are the third worst hot spot for illegal dumping in urban areas. Therefore, they can be very unsightly, attract vermin and pose a health risk to users. Although communities want the service offered through bring banks, nobody wants them located beside their home or business. Since all local authorities grapple with similar issues at bring banks, insights discovered during this research project were compiled as detailed in the sections that follow.

4.1 Design and planning of bring bank centres

4.1.1 Location

Historically, bring banks were very often located in areas where they were available, but “out of the way”, for example in the back corner of a car park where there is no passing traffic. Bring bank location influences human behaviour with regard to their use.

4.1.2 Layout

Given that there are 1891 bring banks in operation, it would be expected that there are best practices in place for their layout. However, this is not the case. Differences in layout across and within local authorities are evident. Layout scenarios include the bins in a straight line, in an L-shape, in a U-shape, in rows or standing independently. There may be gaps left between bins or at the corners of a row of bins. The layout of a bring bank is extremely important for influencing behaviour and also for effective monitoring and management of the area. For example, users have been shown to dump in gaps between bins, behind bins or at the end of a row of bins. In cases where a local

authority wants to monitor an area using CCTV, blind spots must be eliminated by design in order to achieve effective monitoring. Areas for potential dumping must be visible using a single camera, rather than requiring multiple cameras, in order to minimise cost and improve effectiveness. Furthermore, this design offers easier solutions for cleaning and maintenance.

4.1.3 Bin design

The type of bin used bears some influence on the layout. Many different types of bins are in use. Problem bins are wider at the top than at the base, so when positioned side by side they offer a gap at the bottom where rubbish can be deposited. Other bins have loading orifices on all four sides and therefore some local authorities leave a gap between the bins for loading access. This design is poor, as these gaps encourage illegal dumping. Furthermore, when bins are laid out in an L-shape there is always a gap left in the corner, which leads to dumping. There is an opportunity for a “corner access” bin to fill this gap.

4.1.4 Immediate surroundings

The area around the bring bank should be laid out so that traffic is managed, whereby vehicles should approach, park and leave area in a predetermined manner. This can be achieved through road markings and guide rails. Installing a boundary around bring banks has been observed as a best practice for their appearance and maintenance. Much could be done to enhance the road/path surfaces around and under the bring banks. Too often they are located on a loose surface, which is very difficult to maintain. There is significant opportunity to create an aesthetically pleasing surface, which also goes to support monitoring effectiveness.

4.1.5 Health and safety

Common issues such as odour, broken glass, trip hazards and vermin have been observed at bring banks during this research. Other issues observed included theft from clothes banks. One area of concern is bin fatigue as they get older. In many designs, the base

of the bin opens by releasing a chain when emptying its contents into a truck. These mechanisms may fail over time when the bin is elevated and full, resulting in a serious risk to anyone in the vicinity below.

4.1.6 Monitoring/cleaning

Monitoring, cleaning and sustainability of bring banks are often overlooked while they are being installed. Considerations outlined above in terms of location, layout, type of bin and surrounding environment have a significant impact on how effectively they can be monitored.

4.1.7 Alternative designs

There are some alternatives to the standard bring bank in Ireland. Underground bring banks have been installed in Coolagown, County Cork, and Ballinahown, County Westmeath. These have been effective from a dumping perspective, but are significantly more expensive to install. Another alternative is the “hole in the wall” type design where the bring banks are enclosed. In the UK, Tesco has started to implement and manage bring banks in its car parks to gain the income from recycling. Although many have criticised Tesco for corporate greed, perhaps local authorities can learn from its infrastructure.

4.2 Technology deployed at bring centres

Traditionally, no technology was deployed at bring banks. However, once they were recognised as a major source for illegal dumping many local authorities deployed CCTV cameras at random locations to catch those that flout the law. However, this has been quite costly, as deployments are temporary, many areas do not have mains power and equipment is at a high risk of being damaged or stolen. In some cases dummy CCTV is used and can have a short-term benefit.

However, CCTV deployed in a bring bank is a reactive technology. During this project the programmable audio device was developed as a preventative technology to stop illegal dumping from happening in the first place. It proved very successful, achieving over 80% reduction in illegal dumping at bring banks in both urban and rural areas.

Installing wireless bin-level sensors in all bins is also a preventative technology that could be used to remotely monitor trigger points for when bins need to be emptied and therefore ensure that cases of overflowing bins do not occur. It would also mean that the collection service could be more efficient, as the bins would be emptied only when they are close to full.

In Sweden no money is awarded for recycling glass, and recycling rates are much lower than for recycling cans. Volkswagen introduced an arcade-type bottle recycling bank, and using the “fun theory” demonstrated a significant increase in glass recycling.

If footfall/usage trends were profiled across bring bank centres, then local authorities could proactively schedule some presence at peak times to influence behaviours and practices.

4.3 Human behaviour at bring centres

Analysis of a bring bank in Lusk, County Dublin, over a 9-week period yielded the following results:

- 61% of users are male, 39% female;
- 5.5% of bring bank users leave rubbish behind and the “norm” at an untidy site is that approximately 5% of users leave rubbish behind;
- men are 60% more likely than women to leave rubbish.

It was also found that dumping would start at the end of the bring banks, between the bins or behind them, all of which are out of sight. In all cases studied over the 2-year duration of the project the overwhelming finding was that rubbish attracts rubbish. A clean bring bank could remain clean for many days, but once the first box or bag was deposited many more would follow in the subsequent days.

There was also the finding of the “tidy dumper”. This is the person who neatly places their box along with other rubbish. They feel this is acceptable if rubbish is there already. However, this person would never be the first person to leave rubbish.

The opportunity to reduce illegal dumping at bring banks can be supported through education and awareness of what is acceptable. Preventative measures such as signage and the programmable audio device are important as a foundation but opportunity exists to improve education and awareness in many other ways.

5 Dissemination of research

The researchers used the approaches outlined below to publicise their work and share findings throughout the project duration:

- Project team workshops: Two workshops were held in NUIM involving the project core and extended teams including NUIM, EPA and Fingal, Westmeath and Cavan local authorities. In addition, three EPA progress meetings were hosted at NUIM.
- EPA Research conference, 28 June 2012, Trinity College, Dublin: The research plan for the project was presented.
- ENVIRON 2013, 30 January to 1 February 2013, NUI Galway, “Environment: From Ecosystem Functioning to Human Health”. The ENVIRON colloquium is the largest annual gathering of environmental researchers across the island of Ireland, with over 300 delegates attending the event each year. It provides a vehicle for PhD students and postdoctoral fellows to exchange information on their most up-to-date findings with a large and diverse audience made up of academics, industry members and policymakers.
 - The research team submitted a proposal for a presentation at this conference, which was accepted. The title of the presentation was “National survey on environmental waste enforcement: issues, best practice and technology”. The aim of the presentation was to share the key findings from the environmental survey completed with all local authorities in 2012.
- Information and Communications Technology and Environmental Regulation: Developing a Research Agenda, 20–21 June 2013, NUI Galway:
 - The aim of this workshop was to build a network of researchers dealing with these issues in order to prepare joint projects and funding applications and work towards an international conference dealing with this topic. The workshop discussed the development of a coherent but multi-disciplinary research agenda for ICT and environment regulation and agree detailed proposals for future work in the area, such as the publication of an edited collection, funding applications or an international conference.
- The researchers submitted a proposal for a presentation entitled “Identification of dumping behaviour at bring centres in Ireland and their multi-disciplinary solutions”, which was accepted. This presentation focused mainly on the issues associated with bring centres in terms of (1) design/planning, (2) technology and (3) human behaviour.
- Ninth International Conference of Ecosystems and Sustainable Development (ECOSUD), 18–20 June 2013, Bucharest, Romania:
 - The conference was held in June 2013 in Bucharest, Romania. A paper entitled “New CCTV approaches for environmental enforcement in Ireland” was submitted and subsequently accepted for presentation at the conference. The paper discusses the main issues associated with using CCTV for environmental enforcement and offers solutions to address these issues. This paper will be published in the Sustainable City 2013 Conference Proceedings as one volume of the journal *WIT Transactions on Ecology and the Environment*.
- *Irish Geography*, ISSN 0075-0778 (print), 1939-4055 (online):
 - The researchers submitted a paper for publication in the *Irish Geography* journal entitled “An investigation into environmental waste enforcement in Ireland”. This was accepted in December 2013 for publication. The paper presented the national environmental enforcement survey carried out across all Irish local authorities in 2012. The results gathered were compared with similar national and international studies. Final conclusions and their implications on Irish and European legislation were presented.

6 Conclusions

Illegal dumping and fly-tipping of waste is well recognised as one of the major waste enforcement issues facing local authorities across Ireland. Each jurisdiction has many dumping hot spots that authorities manage on a daily basis. This research project identifies novel technologies and procedures for environmental waste enforcement across Ireland that are cost-effective solutions for local authorities.

The national survey of local authorities highlighted that the main environmental enforcement issues were illegal dumping and fly-tipping of waste. In rural areas this happened mainly along the roadside, in forest areas and in bogs. These areas are quite difficult to manage from a monitoring and clean-up perspective, as they are very dispersed. In urban areas illegal dumping and fly-tipping was most common in derelict areas, along the roadside and in recycling bring banks. Many local authorities use monitoring technology in some bring banks on a temporary basis and, although it is effective, the associated costs are quite high.

Best practices highlighted by local authorities included the use of CCTV coupled with visible patrols. Education and increasing public awareness to issues related to illegal dumping were thought to be fundamental to changing behaviours. Aligning themselves with the polluter pays principle, local authorities that actively used section 56 of the Waste Management Act (1996) to recover the cost of waste enforcement actions were thought to be following best practices. International best practices identified included (1) having waste enforcement staff on a round-the-clock basis, as much enforcement is required outside normal working hours, (2) introduction of an environmental court to specialise in environmental cases, (3) having permanent CCTV in all bring centres, (4) including waste disposal charges in the household charge and (5) introducing legislation requiring households to demonstrate how they dispose of waste. It was thought that breaches of the Waste Management Act (1996) could be processed more effectively through the introduction of greater administrative sanctions for local authorities rather than dealing with them as criminal sanctions.

All local authorities were interested in exploring new technologies and techniques for environmental

enforcement. As all local authorities had experience in the use of CCTV, the report identifies cost-effective solutions to address current issues faced. These included challenges such as (1) clarity of night-time monitoring, (2) monitoring of derelict and problem areas, (3) covert monitoring and (4) monitoring of remote areas where no mains power supply is available. In terms of sensor technology, boundary infrared beams and wireless sensors were used to trigger remote devices. While the challenges of aerial imaging through the use of satellite imagery and UAVs were discovered, a very successful preventative technology for illegal dumping was developed and proven with the programmable audio device.

Although illegal dumping patterns were found to be similar across local authorities, each scenario is different and unfortunately there is not a universal monitoring and enforcement solution to satisfy all scenarios. Therefore a cost-benefit analysis was completed for each of the technologies, highlighting costs, typical applications, strengths and weaknesses, and recommendations, among other factors. This analysis provides direction to local authorities when evaluating the most appropriate solution for their situations.

This research found that approximately 5% of visitors to recycling bring banks analysed left rubbish behind. Once the initial box or bag of rubbish is deposited, more follows quickly, as if it were an acceptable behaviour. Some bring banks are more prone to illegal dumping than others, which is influenced by factors such as the bring bank location, its layout, the bin design used and the immediate area surrounding the bins. Bring banks were installed without planning how technology, such as CCTV or preventative programmable audio devices, could be integrated into their management. Recommendations for a standard best practice bring bank can be drawn from the research.

Research findings have been disseminated in both national and international conferences throughout the project and two papers have been accepted for journal publication. Each local authority will have access to the entire project report, which will act as a reference and guide for investing in environmental enforcement technologies.

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Abbreviations

App	Application	NECL	National Environmental Complaints Line
CCTV	Closed-circuit television	NIECE	Network for Ireland's Environmental and Compliance Enforcement
DC	Direct current	NiMH	Nickel–metal hydride
DVR	Digital video recorder	NUIM	National University of Ireland Maynooth
EEN	Environmental Enforcement Network	NVR	Network digital video recorder
ELV	End-of-life vehicle	OECD	Organisation for Economic Co-operation and Development
EMS	Environment Management System	OEE	Office of Environmental Enforcement
EPA	Environmental Protection Agency	PIR	Passive infrared
ESA	European Space Agency	RMCEI	Recommendations for Minimum Criteria Environmental Inspections
EU	European Union	SD	Secure digital
GSM	Global System for Mobile communication	SMS	Short Message Service
ICT	Information and communications technology	TVL	Television lines
IMPEL	European Union Network for the Implementation and Enforcement of Environmental Law	UAV	Unmanned aerial vehicle
IP	Internet protocol	UPEE	Universal Purpose Environmental Enforcement
LPR	Licence plate recognition	WREMS	Wireless Remote Environmental Monitoring Sensor
MMS	Multimedia Messaging Service		
MP	Megapixel		
NASA	National Aeronautics and Space Administration		

Appendix A Environmental Waste Enforcement Research Survey



ENVIRONMENTAL WASTE ENFORCEMENT RESEARCH SURVEY

An initiative to identify novel technologies and procedures to support environmental waste enforcement has recently been initiated by the EPA (Project # 2011-ET-MS-11). Research on this project is being led out of the National University of Ireland, Maynooth.

The intent of this project is to investigate novel technologies and practices to support local authorities in their environmental waste enforcement challenges. Input from each local authority is important to ensure the research is directed at resolving 'real issues'. To that end, each local authority is being asked to complete the 'Environmental Waste Enforcement Research Survey'.

Notes on survey:

1. Please submit completed surveys by Wednesday 23rd May 2012.
2. All information shared is confidential. Data from survey will be aggregated across local authorities – not used for comparisons across local authorities.

3. Please use data from RMCEI returns report where relevant/available.
4. The terms 'you' and 'your' in the survey refer to the local authority in question.
5. Please complete all questions and do not leave blanks. Use n/a if question is not applicable.
6. Time to complete survey is approximately 30 minutes.
7. Link to additional project details...<< <http://www.callan.nuim.ie/eer/>>>

Support/Queries:

If you have any queries regarding content in the survey please do not hesitate to contact project researchers....

- Dr Alvaro Palomo: 085-8236957; apalomo@eeng.nuim.ie
- Aidan McDermott: 087-1481894; aidan.mcdermott@nuim.ie

Environmental Waste Enforcement Research Survey

Section 1: Current Situation

- Q1.1 What are the top 5 waste enforcement issues in your jurisdiction (1 being the largest issue, 5 being the smallest)?
What is the main cause for each issue?

	Waste Enforcement Issue	Cause of Issue
1		
2		
3		
4		
5		

- Q1.2 What 'preventative' practices are used to address illegal waste activities in your area?

- Q1.2.1 Rate your satisfaction with the outcomes of 'preventative' practices

☐ Not Satisfied ☐ Partially Satisfied ☐ Satisfied ☐ Very Satisfied ☐ Totally Satisfied

- Q1.3 What "reactive" practices are used to address illegal waste activities in your area?

- Q1.3.1 Rate your satisfaction with the outcomes of "reactive" practices

☐ Not Satisfied ☐ Partially Satisfied ☐ Satisfied ☐ Very Satisfied ☐ Totally Satisfied

- Q1.4 What best practices are used in your area for waste enforcement?

- Q1.5 What best practices are you aware of that are not used in your area? (Due to budget/resource/expertise/etc. constraints)

Best Practices – National:

Best Practices – International:

- Q1.6 Are you aware of other waste enforcement solutions that you would like to try?

- Q1.7 Please rank the following waste/litter 'hot spots' in **rural areas** from 1 to 9 (1 being the most severe, 9 being the least severe). Mark as n/a if area does not apply in your jurisdiction

- | | |
|--|---|
| <input type="checkbox"/> Roadside | <input type="checkbox"/> Beach/Coastline |
| <input type="checkbox"/> Picnic Areas/Lay-By | <input type="checkbox"/> Field Gateways |
| <input type="checkbox"/> Forest Areas | <input type="checkbox"/> Bogs |
| <input type="checkbox"/> Rivers/Lakes | <input type="checkbox"/> Quarries |
| | <input type="checkbox"/> Other Please explain |

- Q1.8 Please rank the following waste/litter "hot spots" in **urban areas** from 1 to 9 (1 being the most severe, 9 being the least severe). Mark as n/a if area does not apply in your jurisdiction

- | | |
|---|---|
| <input type="checkbox"/> Roadside | <input type="checkbox"/> Residential |
| <input type="checkbox"/> Parks/Amenity Areas | <input type="checkbox"/> Derelict Areas |
| <input type="checkbox"/> Bring Banks | <input type="checkbox"/> Industrial Areas |
| <input type="checkbox"/> Beach/Coastline/Rivers | <input type="checkbox"/> Retail Areas |
| | <input type="checkbox"/> Other Please explain |

- Q1.9 Is there an Environmental Complaints Coordinator in your organisation? ☐ Yes ☐ No

Q1.10 What environmental enforcement issues do you have in relation to...

Q1.10.1 Water

--

Q1.10.2 Air

--

Q1.10.3 Noise

--

Q1.10.4 Other

--

Section 2: Waste Enforcement Technology

Q2.1 What waste enforcement technology are you using and what aspect of waste enforcement is it used for?

--

Q2.2 Effectiveness of technology:

Q2.2.1 What works well?

--

Q2.2.2 What doesn't work well?/What problems do you experience?

--

Q2.3 Are you open to using new technologies?

☐ Definitely Yes ☐ Yes ☐ Maybe ☐ No ☐ Definitely Not

Q2.4 In what areas (if any) would you like to see new/improved technology or tools to support waste enforcement?

--

Q2.5 Do you utilise contractors for waste enforcement?

☐ Yes ☐ No

Q2.5.1 If yes, in what areas do you use waste enforcement contractors?

[illegible]

Q2.6 What waste enforcement technologies are used by the local authority themselves (as opposed to contracted in)?

Q	Q	Q	Q	Q	Q

Q2.7 Please indicate (tick) what waste (litter related) technologies have been used in **'rural areas'** in the table below

[illegible]

Q2.8 Please indicate (tick) what waste (litter related) technologies have been used in 'urban areas' in the table below

	Roadside	Parks/ Amenity Areas	Bring Banks	Beach/ Coastline/ Rivers	Residential	Derelict Areas	Industrial Areas	Retail Areas
CCTV	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Satellite	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sensors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Arial (Helicopter, Aeroplane)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Enforcement Officers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Section 3: Prosecutions

Q3.1 How can the public make waste complaints in your area?

- ☐ National Hotline
 ☐ Local Hotline
 ☐ Direct Phone
 ☐ On-line Form
 ☐ Postal Form
 ☐ Other Please explain 'other':

Q3.2 How many complaints were raised by the public in 2011? (RMCE Returns Section 4) related to...

Waste (litter)? Waste (non-litter)? Water? Air? Noise? Illegal dumping line?

Q3.3 How many waste enforcement actions were initiated by the officers in 2011? (RMCEI Returns Section 7.1)

Q3.3.1 How many of them were warning letters?

Q3.3.2 How many of them led to the prosecution of the offender? (RMCEI Returns Section 8.1)

Q3.3.3 How many of the prosecutions were successful?

Q3.4 Please provide the same data requested in Q3.2 and Q3.3 for the years 2010 and 2009 (Note: data already populated where available)

	Total No. Complaints	No. Waste Enforcement Actions	No. Warning Letters	No. Court Cases	No. Successful Prosecutions
2010					
2009					

Q3.5 What is the average cost of bringing a waste enforcement case to court?

Q3.5.1 If prosecution is successful, who typically covers costs involved?

- ☐ Local Authority
 ☐ Defendant

Q3.6 Have any prosecutions been unsuccessful? Why?

Q3.6.1 Do you see any problems in the current legislation that leads to unsuccessful prosecutions?

Q3.7 Please recommend any suggestion you have to improve the prosecution process?

Q3.8 Do you have a waste enforcement policy document?

- ☐ Yes
 ☐ No

Q3.8.1 Is this document available to the general public? How?

Section 4: Financial

Q4.1 Do you feel you are getting value for money with current waste enforcement solutions?

☐ Yes

☐ No

If no, please explain

Q4.2 How many full-time employee equivalents are dedicated to waste enforcement in your organisation?

Q4.3 How much was spent on clean up after litter/waste incidents in...

2011

2010

2009

Q4.4 How much would you spend per year on a waste/litter enforcement solution for your most severely ranked...

rural area hot-spot (Q1.7)

urban area hot-spot (Q1.8)

Q4.5 What is your 2012 annual budget for waste enforcement?

Q4.5.1 What is your 2012 budget for deployment of waste enforcement technology?

Q4.6 How much is spent on contractors vs internally for waste enforcement p.a. (use 2011 data)?

Q4.7 What areas of waste enforcement have been affected by budget cuts in 2011?

Q4.8 What areas of waste enforcement may be impacted from reduced budgets in 2012/2013?

Section 5: Networking & Improvement Ideas

Q5.1 Have you ever run public training programmes on waste enforcement?

☐ Yes

☐ No

Please provide details:

Q5.2 Do you share waste enforcement best practices across other local authorities? Examples?

Q5.3 If you could improve one area of environmental waste enforcement, what would that be?

Q5.4 What other ideas do you have for improving waste enforcement in your area?

Q5.5 The objective of the Environmental Enforcement Network (EEN) in Ireland is to achieve improved cooperation and coordination between the various agencies involved in environmental enforcement so that a higher and more consistent standard of environment protection is achieved.

Q5.5.1 Please rate EEN effectiveness to date from 1 to 10 (1 not effective at all, 10 extremely effective)

Q5.5.2 What improvements would you suggest for the EEN?

Q5.5.3 Do you see value in a tool to enable real-time sharing of information among enforcement officers?

☐ Yes

☐ No

Please explain

Q5.6 Please provide any further information you may consider relevant.

Q5.7 What is your role within your organisation?

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL

Tá an Gníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaoil a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaoil a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gclóíonn leis na córais sin.*

Eolas: *Soláthraimid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírthe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bimid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaoil atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaoil inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú

- Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaoil:
- saoráidí dramhaíola (m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- an diantalmhaíocht (m.sh. muca, éanlaith);
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe (OGM);
- foinsí radaíochta ianúcháin (m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha);
- áiseanna móra stórála peitрил;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaoil.

Bainistíocht Uisce

- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuisc; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaoil

- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil (m.sh. tuairisciú tréimhsiúil ar staid Chomhshaoil na hÉireann agus Tuarascálacha ar Tháscairí).

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn

- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn

Taighde agus Forbairt Comhshaoil

- Taighde comhshaoil a chistiú chun brúnna a shainaitheint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeraíde, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta

- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaoil in Éirinn (m.sh. mórfheananna forbartha).

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas

- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaoil ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaoil (m.sh. Timpeall an Tí, léarscáileanna radóin).
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta

- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlacha a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Measúnú Comhshaoil
- An Oifig um Cosaint Raideolaíoch
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

**Aidan McDermott, Alvaro Palomo,
John Dooley & Ronan Farrell**

Illegal dumping and fly-tipping of waste are major waste enforcement issues facing local authorities across Ireland. This research project identified novel technologies and procedures for environmental waste enforcement in Ireland that are more cost-effective for local authorities. The report carried out a national survey of local authorities which highlighted the main environmental enforcement issues for both rural and urban settings.

Identifying Pressures

This research found that approximately 5% of visitors to recycling bring banks analysed left rubbish behind. Once the initial box or bag of rubbish is deposited, more follows quickly, as if it was an acceptable behaviour

Informing Policy

On the one hand, many local authorities have used monitoring technology on a temporary basis, and although it is effective, the associated costs are quite high. Aligning to the polluter pays principle, local authorities that actively used section 56 of the Waste Management Act (1996) to recoup the cost of waste enforcement actions were thought to be following best practices.

However, on the other hand, education and increasing public awareness to issues related to illegal dumping are accepted to be fundamental to changing behaviours. Informing people clearly of their options, very often will lead to them making the decision not to litter and in turn helps to minimise expenses on the part of the local authorities both in following up on prosecutions and the clean-up of the litter.

Developing Solutions

The report sets out cost-effective solutions to address issues faced by local authorities in preventing illegal dumping and enforcing environmental laws. Challenges addressed include

- (1) clarity of night-time monitoring,
- (2) monitoring of derelict and problematic areas,
- (3) covert monitoring,
- (4) monitoring of remote areas where no mains power supply is available.

The latest commercially available technology was tested along with proprietary hardware. Among these trials, a very successful preventative technology, a programmable audio device, was developed and demonstrated in practice. The research team identified that illegal waste dumping preventative solutions in the first place are more effective than prosecutions and help to limit illegally dumped waste. Making an extra effort to remind the public of their options helps to limit offences, and can also help to focus resources to prosecute offenders that despite being given every opportunity not to do so, still offend.

