Enabling
ZERO WASTE

Aberystwyth Fire Station

Noddir gan Lywodraeth Cymru
Sponsored by Welsh Government

ADEILADU ARBENIGRWYDD YNG NGHYMRU
CONSTRUCTING EXCELLENCE IN WALES

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Aberystwyth Fire Station

Executive Summary

Enabling Zero Waste (EZW) is a Constructing Excellence in Wales (CEW) initiative which aims to establish if and how, the construction industry can achieve the zero waste targets established in the Welsh Government's waste strategy document Towards Zero Waste.

CEW is working in collaboration with the industry to provide a detailed insight into the achievability of zero waste at present. CEW is also working to identify any associated barriers to achieving the targets, and disseminating best practice, solutions and opportunities.

Aberystwyth Fire Station was a £1.7 million, 48-week project undertaken by WRW Construction Ltd. It involved an eight-week programme of demolition of the former fire station, followed by the construction of a new fire station including community facilities.

The project has benefited from the knowledge and lessons learnt from the previous WRW/EZW project at Millbank Primary School. Significant improvements were shown at the fire station which benefited from a committed, enthusiastic and permanent site manager.

The project design team was led by Lawray Architects with other key design team members including Roger Casey Associates, McCann & Partners & Melin Consultants. The new Fire Station building was designed to achieve a BREEAM Excellent rating.

With support from the client, Mid-West Fire Service, the site team showed enthusiasm and commitment throughout the demolition phase by segregating the waste at source. CB Environmental Ltd (A Green Compass Company), the chosen waste management company for the demolition phase, played a key role in helping the project team to analyse the waste produced from site. Although the exercise delayed the project programme by three weeks, all parties involved remained positive to the initiative throughout, which led to high recycling rates being achieved.

The demolition phase of the project produced 988.37m^3 (1131.36 tonnes) of waste. The majority being of an inert nature 838.25m^3 (1064.58 tonnes). The demolition phase achieved 99.2% diversion of waste from landfill, close to achieving the target of zero waste to landfill. It exceeds the Welsh Government's current target of 70% of all waste, by weight, shall be prepared for reuse, recycled or recovered by 2015/16, as well as the target of 90% waste diverted from landfill ahead of 2019/2020.

The construction phase of the project produced 105.78m^3 (42.16 tonnes) of waste. This figure includes waste managed through take back recycling schemes.

The construction phase achieved 99.6% diversion of waste from landfill. Although diversion rates from landfill are high, 45.7% of waste was recycled with 53.9% of the waste produced (the majority of which was mixed waste) was sent for energy recovery, the efficiency of which is not known. The ambition of Welsh Government is that by 2020 less than 10% of all waste produced will be sent for energy recovery/landfill. For the construction phase of the project this was not achieved.

The aggregated landfill diversion rate for all phases is 99.4%.

It should be highlighted how having a committed client, contractor, architect and waste management company on a project is key to success. All parties in this instance were enthusiastic and committed to achieving zero waste which helped result in the successes achieved.

Other successes on the project include:

- Designing out waste, including 203kg of cladding & 1.02 tonnes of brickwork.
- Successful collaboration and negotiation between the contractor and client, to extend the project programme for demolition works, enabling improved segregation and recovery of materials without penalties for delays.
- 1.7 tonnes (9m^3) of material was reused as a result of the pre-demolition survey.
- No general waste skip within the first eight months of construction.
- Good initiation of take back schemes for off cuts of material.
- A site team dedicated to segregating waste on site.
- 455 tonnes of crushed aggregate recycled on site.
- Successful canteen waste removal initiative.
- 28.42% saved from overall waste costings due to site waste segregation.

The report makes the following recommendations:

Client recommendations:

- Review infrastructure currently available for dealing with wastes that will be affected by the upcoming landfill and incineration material bans.
- Ongoing communication with design consultants and contractors is important.
- Consider using any existing features and fittings for reuse in the new build, as reuse and re-manufacture can lead to a quality and cost effective option.

Designer recommendations:

- Consideration of the standard sizes of materials during design.
- Engagement with contractors to improve material understanding.
- Awareness of how intricate design affects waste.
- The importance of designing for deconstruction.
- The importance of using Building Information Modelling to identify and prevent clashes from occurring and consequently saving time, resources and money.
- Continue best practices learnt from the EZW initiative.

Contractor recommendations:

- The importance of segregating waste at source. Discussing waste strategies throughout all stages of the project to all members involved on site. WRW and the site team refrained from using a mixed waste skip on site. As previously mentioned, this initiative has ensured a high standard of waste segregation.
- Ensure all skips are checked daily and inform site operatives to maintain waste segregation in the correct skips. This can be achieved through clear skip signage, maintaining a clean site and where possible fencing off all segregated skips. A waste champion can aid waste management practices through supervising segregation.
- Identifying end destinations of all waste types through early discussions with the waste management company, prior to engaging into a contract is important.
- Engaging with the supply chain at the earliest opportunity to include returnable packaging, take back schemes etc within procurement.

If the forthcoming Environment (Wales) Act landfill diversion requirements were applied to this project, approximately 36 tonnes of material would require an alternative disposal solution. This shows the need to research alternative disposal options, along with the appropriate infrastructure, necessary to enable the changes required by the legislation.

1 About

1.1 Enabling Zero Waste

Enabling Zero Waste is a Constructing Excellence in Wales (CEW) initiative which provides practical, positive and proactive assistance to construction, demolition and civil engineering projects in Wales. The aim is to establish if, and how, the construction industry can achieve the zero waste targets established in the Welsh Government's waste strategy, Towards Zero Waste.

CEW provides EZW project participants with technical advice, expertise and guidance on waste management and Building Information Modelling (BIM) to help overcome barriers to waste minimisation and design for deconstruction. Each project is provided with a bespoke and tailored package to best suit its needs.

CEW is working in collaboration with the construction industry to provide a detailed insight into the achievability of zero waste. The goal being to share best practice solutions and opportunities, along with identifying any barriers associated with achieving the Welsh Government's targets. CEW offers practical assistance to construction project design and site teams to explore viable solutions to achieving zero waste and EZW project objectives to;

- Understand and evidence when and how wastes occur during the construction process.
- Understand current strategies, methodologies and opportunities for the diversion from landfill of site wastes.
- Analyse the feasibility/viability of achieving zero waste to landfill in the current environment.
- Work to develop solutions to prevent and minimise the generation of on-site waste, leading to a reduction in waste management, disposal and landfill costs.
- Support changes to behaviour and processes that encourage prevention and minimisation of waste.
- Achieve site efficiencies from waste management opportunities/solutions.
- Minimise site traffic through reduction in supplies and materials allowing for cost savings.
- Disseminate solutions and opportunities from the development of effective waste management strategies.
- Provide learning and education opportunities regarding alternative waste management techniques which can be disseminated for future projects ensuring continual benefits.

1.2 About WRW Construction Ltd

Founded by current Group Chairman Robert Williams MBE and Group Director Debbie Williams in 1985, WRW has grown through playing a role in three decades worth of development in the education, commercial, civil, and residential areas of the construction industry.

WRW has held a close working relationship with Constructing Excellence in Wales and has previously collaborated with the EZW initiative with Millbank Primary School in Cardiff.

2 Project Background

The former Aberystwyth Fire Station built in 1962 comprised of a traditional brickwork façade, a two-storey office, canteen and living quarters. The east elevation held a large single-story vehicle storage and maintenance garage. The existing roof structure supported a metal truss design and timber joists at ceiling level. There were also buildings on site which had flat roofs, with an external composite felt roof finish. This proved to be problematic with regard to separation and disposal. The bitumen felt and timber was sent for recovery, (the efficiency of which is not known) as the material could not be reused or recycled due to its composite nature.

The service yard held a five-storey concrete and brick drill tower. The tower was demolished along with the former fire station.

Construction consisted of a steel frame, part face brick and external cladding. The new modern fire station holds three fire appliance bays, office accommodation and a community café open to the public. The gross internal floor area of the fire station is 828 m².

The contract began in July 2015 with a completion date of July 2016. The project programme was delayed by three weeks due to committed waste segregation practices during the demolition phase. The programme also experienced delays from adverse weather conditions.

At the start of the EZW project the fire station design had been finalised, the original planning permissions were in place, contactor, subcontractors, suppliers and waste management contracts had all been appointed.

2.1 Cost

The project value was £1.7 million.

2.2 Contract Type

The project programme allowed a forty-week build contract with eight weeks included for demolition from August 2015 to September 2015. The demolition work was carried out by L.G. Murphy of Swansea. Lawray Architects Ltd were the chosen designers for the project.

3 Methodology

Each Enabling Zero Waste project participant is provided with a tailored work plan/methodology. The content was developed with the project team and designed to enhance any existing measures being undertaken.

1. For the duration of the project, the WRW project team was provided with technical waste management support and guidance to assist with the achievement of zero waste to landfill.
2. A specific waste management resource was allocated to provide hands on support with site waste management and to deliver potential zero waste options/solutions for site waste issues. Assistance included:

- Onsite visits.
- Waste management support advising upon increased segregation.
- Identification of problematic materials used on site.
- Reduction in waste by encouraging good housekeeping to reduce damage and over ordering of materials.
- Reduction of waste through reuse or finding alternative solutions to disposal.
- Assistance working with the site supply chain, client and waste management companies to encourage take back schemes, wider education and increase waste data quality.
- Preparation, monitoring and update of a Site Waste Management Plan (SWMP) using BRE SMARTWaste.

Support was also provided to the site team with regard to recording data onto SMARTWaste. After every site visit, recommendations were issued to assist in improving waste management practices.

The principal waste management recommendations were to:

- Improve signage, segregation and storage of materials.
- Set up a dedicated waste compound.
- Identify a waste champion to review and ensure that legal compliance and waste management best practices were met.
- Prevent the spoilage of materials on site by keeping them dry and stored in a secure place.
- Undertake toolbox talks to raise awareness with regard to waste prevention and reduction.
- Identify possible supply chain take back schemes.
- Bring a concrete crusher on to site for material reuse and recycling.

Waste management training was carried out prior to work starting with the contracts manager and WRW staff. The training involved detailing waste minimisation opportunities, compliance issues, forecasting and recording of waste.

Associated documentation and guidance regarding the above was also provided. Aerial drones were used throughout the demolition phase. Communications involved regular updates via twitter, update events, webinars and presentations.

Pre-demolition

Post-demolition

4 Demolition Data Analysis

4.1 Pre-Demolition survey

The former fire station building was demolished by L.G. Murphy Demolition Ltd (Swansea). Prior to any demolition work commencing, a pre-demolition survey was undertaken by BRE as part of the EZW initiative. The survey was the first stage towards assessing the materials present and their likely options and alternatives to landfill disposal. The pre-demolition survey aim was to identify areas for material reuse, reclamation or recycling. The information was then used to:

- Reduce the cost of disposal of the building
- Realise financial benefits of diverting materials from landfill
- Quantify the environmental rewards of reuse, reclamation and recycling

A breakdown of individual waste streams and alternative end destinations chosen, are as follows:

4.1.1 Metal

Metal items identified throughout the survey were reused on site and throughout the local community as follows:

- The fire station's old steel lockers were utilised in the site's drying room in line with Considerate Constructor recommendations.
- A stainless-steel cooker was donated to a member of the public that was starting a catering business.
- A mesh fence was given to a fireman for use in his garden.
- A waste oil tank was used in the sub contractor's yard.
- A diesel generator reused in the new warehouse/ stores.
- Stainless steel coat hangers to be reused in new fire station.

100% recycling rates were achieved for other metal products such as radiators (23no), heating pipework, external down pipes, kitchen extractor hood, splashback, metal shelving and structural steel. It is significant that all metals were recycled as one tonne of recycled steel saves two tonnes of raw materials and 70% of the energy required to produce virgin material. Just under 30 tonnes of scrap metal was generated, 2.68% of the overall demolition waste. (BRE, 2017*)

BRE, 2017, Stoneyhall housing estate predemolition audit, Available at www.bre.co.uk, Accessed 15/09/2017

4.1.2 Timber

CEW recommended that timber waste was segregated from mixed waste so that it could be collected for recycling, and assist in reducing the number of mixed skips leaving the site. Additional timber products noted from the survey consisted of:

- 2 x garage/workshop doors; it was assumed that the original fire station appliance doors could be reused, however, due to the danger of removing and reloading the mechanical loading springs, the doors were sent for recycling.
- Stair treads.
- Built in shelving.

Other timber items were distributed as follows:

- Desks to a local sub-contractor for use in their offices along with WRW site offices.
- Internal doors used in sub-contractor offices.
- Window frames used in new allotment sheds.
- Benches from the mechanical workshop used at a sub-contractor's yard.

Excluding the above, 14.26 tonnes of timber waste (1.26%) was produced from the demolition phase. All of which, was sent for energy recovery.

4.1.3 Brickwork/Concrete/Inert materials

As recorded from the data provided by CB Environmental Ltd, 94% of the demolition waste was brick and concrete, produced from the structure of the former fire station from external walls, internal partition walls and a five-storey drill tower. It was suggested by CEW to bring a crusher onto site, crush the material and reuse as recycled aggregate. 455 tonnes of crushed material remained on site for sub base. However, the crushed material specification did not suit the specification of the permeable drainage system installation, so clean virgin material was imported onto site with the remaining crushed aggregate being sent off site to another location. (See section 4.2.3 for end destinations)

Crushing the demolition material on site and utilising the recycled product saved on disposal costs, transportation and prevention of importing additional virgin material.

4.1.4 Ceramics

The pre-demolition survey identified a number of ceramic products in the old fire station including seven sinks, five toilets, five urinals and four shower trays. It is good practice to consider whether washroom fittings may be recovered for reuse elsewhere with some residual salvage value. The products in this instance were unfortunately unable to be reused due to the age and style of the fittings. The ceramic products were crushed into recycled aggregate.

4.2 Waste by Hierarchy (Demolition)

To achieve zero waste, efforts need to be focused at the highest level of the waste hierarchy with waste prevention and minimisation.

4.2.1 Prevention

Due to the nature of a demolition project, difficulties can arise in identifying opportunities to prevent waste, as waste material is already incorporated into the building which requires demolition. Consideration should be given as to whether a building needs to be demolished or could be refurbished. In this case, refurbishment was not possible due to the building no longer meeting the needs of the Fire and Rescue Service, as such, demolition was the only viable option.

4.2.2 Reuse

Quantities of materials reused from the pre-demolition survey equate to 1.7 tonnes. An approximate volume of the items reused is estimated at 9m^3.

4.2.3 Recycling

Due to large quantities of inert material produced from the demolition process, it was suggested that a crusher was brought to site for material recycling. A total of 838.25m^3 (1064.58 tonnes) of crushed brick and concrete with a 100% recycling rate was produced during the demolition phase. 455 tonnes of the crushed material was used as sub base and fill throughout the project. Unfortunately, the quality of the crushed material did not reach the specification allowance for the permeable paving. As such, the remaining crushed recycled material was used off site at two different locations:

1. James Developments at Bryn Eglur Developments, Llanfarian, Aberystwyth. The material was used to create hardstanding and roads as part of their housing development and;

2. Cofadail Farm, Trefenter, Aberystwyth. The material was used for hardstanding.

The recycling rates for all waste materials recorded an average of 97.7% (1108.13 tonnes in total). The individual waste streams are as follows:

- 95% for reinforced concrete with totals of 1064.58 tonnes including 5% metal rebar. (Please note: 38.33 tonnes of reinforced concrete removed by CB Environmental Ltd for further processing is included in this total)
- 100% for metal.
- 95% for plastic.
- 99% for cardboard.
- 100% for plasterboard.

4.2.4 Recovery

In total, 41.94 m^3 (14.26 tonnes) (1.25% of total demolition waste) which was predominately timber was sent for recovery. The timber was shredded at CB Environmental Ltd prior to being dispatched to the Tilhill Biomass Plant at the UPM run paper mill in Shotton. The energy efficiency of the incineration plant is not known.

4.2.5 Landfill

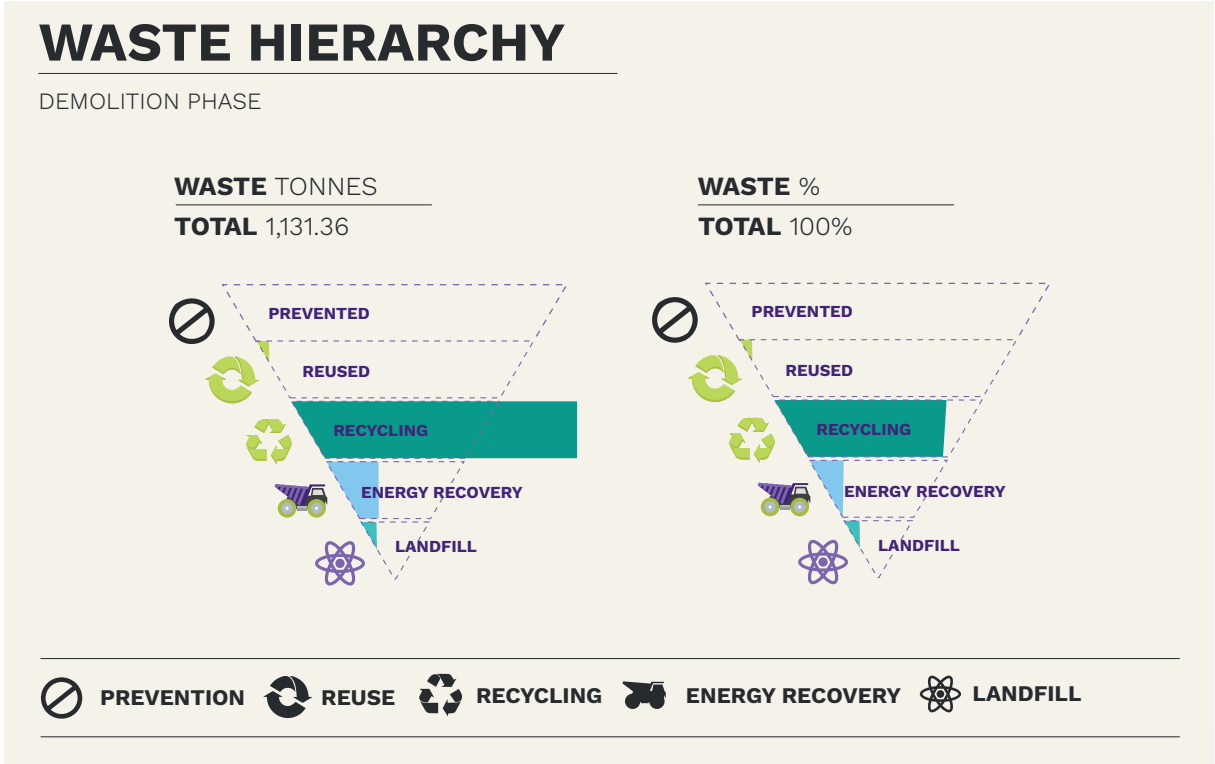
CB Environmental Ltd reported that 7.78% of demolition waste, 8.05 tonnes, produced from the project was sent to landfill at Brynposteg.

Asbestos was found during the demolition of the former Fire Station. 0.92 tonnes of this waste was sent to a hazardous landfill facility, taking the total to 8.97 tonnes of waste sent to landfill for the demolition stage of the project. Sending asbestos to landfill is considered to be the only viable option currently available.

Description	Composition of total demolition waste to landfill (%)	EWC Code	Waste to landfill by material type (in tonnes)
Inert (rubble)	20.99	17 01 07	1.69
Wood	24.60	17 02 01	1.98
Plastic	1.86	17 02 03	0.15
Metals	12.17	17 04 07	0.98
Insulation	3.11	17 06 04	0.25
Plasterboard	10.19	17 08 02	0.82
Mixed C + D Waste	25.22	17 09 04	2.03
Cardboard	1.24	20 01 01	0.10
WEEE	0.50	20 01 36	0.04
Total residual C&D =			8.05

Residual waste sent to landfill, data provided by CB Environmental Ltd

The diagram below illustrates a proportional representation of the waste arising by waste management type during the demolition phase.



4.3 Demolition Waste Analysis by Waste Type

Just over 988.37m^3 (1131.36 tonnes) of waste was produced as a result of the demolition work. The majority consisted of inert waste, predominately reinforced concrete at a total of 1064.58 tonnes (838.25 m^3).

CB Environmental Ltd provided weighbridge data, visual inspection reports and photographs of the skip contents. During the early stages of the scheme, the project reported lower recycling rates which improved following discussions and recommendations with L.G. Murphy the chosen demolition company. One skip achieved as low as 40% recycling due to its mixed contaminative nature. Other mixed skips achieved 70%, 65% and 95% recycling rates.

4.3.1 Bricks

With the outer skin of the fire station and drill tower built from brick, data from SMARTWaste reports a total of 218.40m^3, 262.08 tonnes in weight, 24.67 % of all crushed inert waste was produced during the demolition phase.

4.3.2 Concrete

617.96m^3 (802.5 tonnes) of the crushed inert material was of a concrete nature, which was later used on site. The remaining material was reused at two other locations discussed in section 4.2.3

4.3.3 Mixed Waste

The only mixed waste skips produced throughout the demolition were reported in August, 21.96 tonnes in total. This was a result of small amounts of plastic, cardboard, insulation and metals entering the segregated skips causing contamination. Cross contamination can be avoided by visually inspecting skips at the end of the working day, plus stricter controls throughout the day. Skip costs can sometimes double if any contamination occurs. Contamination also reduces the quality of recyclate produced and therefore decreases recycling rates.

4.3.4 Metal

In total 72.14m^3 of scrap metal (29.64 tonnes in weight), resulted from the demolition and items disposal. Scrap metal waste was also produced from crushing reinforced concrete. Metal trusses from roofs and other structural steel members were found throughout the former fire station.

4.3.5 Timber

Timber waste equated to 41.94m^3, (14.26 tonnes), 1.26% of the total demolition waste produced. Timber waste predominantly arose from the roof works, ceiling joists, timber stud walls, skirting, architrave and door linings.

4.3.6 Asbestos

3.67m^3 (0.92 tonnes) of asbestos was sent to landfill, the only viable option available at present.

4.4 Peaks in Demolition Waste

During the demolition programme, there were several distinct peaks in waste generation. The reasons for the peaks are suggested below:

4.4.1 August 2015

In August 2015, the starting month of the project, the largest monthly total of waste was produced. Crushed aggregate, along with mixed waste, metals, wood and items identified as part of the pre-demolition survey totalled 521.28m^3 (612.62 tonnes).

The second largest waste stream produced in August and September 2015 was scrap metal 27.94 tonnes in total, recording a 100% recycling rate. The scrap metal was sent to CB Environmental Ltd.

4.4.2 September 2015

In September, a site peak with totals of 467.9m^3 (518.74 tonnes) of waste was recorded. 422.9m^3 (504.38 tonnes) of crushed aggregate being the majority of waste, with other waste streams including;

- Metal and wood due to a previous soft strip phase.
- Large quantities of inert waste arising from the demolition of the superstructure, consisting of brick walls, concrete floors and a five-storey drill tower.

5 Construction Data Analysis

In summary 105.78m^3 (42.16 tonnes) of waste was generated during the construction phase of the project.

5.1 Construction Waste by Hierarchy

The following data analysis section is based on figures and end destinations provided by LAS recycling, Lampeter.

5.1.1 Prevention

A design review exercise was undertaken by Lawray Architects, to look at minimising waste through off site fabrication and reduce offcuts through standardising design. The following measures were undertaken with the aim of designing out waste:

- All brickwork was set out to standard material dimensions reducing the need for cuts and waste. Angled bricks were specified and were manufactured offsite.
- Offsite manufacture of roofing insulation to ensure close to zero waste on installation.
- REVIT model ensured that material estimates could be made accurately in order to avoid waste of material due to over ordering.

Polyflor and Altro flooring were purposefully chosen for vinyl flooring in designated areas due to the product's high recyclable content. Recofloor provided a take back scheme for the offcuts which can be recycled into new product.

In total 30.3m^2 (203kg) of cladding waste offcuts was saved through Lawray Architects setting out the design and avoiding a 400mm offcut from each length of cladding throughout the footprint of the building.

Brickwork waste savings of 1.02 tonnes have been calculated, due to offsite manufacturing for two angled corners of the building design.

The offsite manufacturing also saved time and avoided health and safety issues if brick angles had been cut onsite.

5.1.2 Reuse

The existing coat hangers from the former fire station were reused in the new building.

Damaged concrete blocks were also reused as formwork around concrete beam encasements. Shuttering material was reused once formwork was removed.

All pallets were reused on site to receive bricks and blocks on delivery, later to be moved to allocated work areas.

5.1.3 Recycling

The recycling rates reported by LAS, Recofloor and Reconomy for construction waste included:

- 100% recycling reported for metal waste, 18.57m^3 (7.82 tonnes) sent to E J Metals.
- 100% of cardboard waste 4.2m^3 (0.92 tonnes) sent to Parry & Evans Recycling services, Welshpool.
- 100% Plasterboard 3.75m^3 (1.58 tonnes).
- 100% Siniat Plasterboard 8.48m^3 (2.8 tonnes) recycled at New West Gypsum Recycling in Bristol, through Reconomy.
- 100% Vinyl Flooring 1m^3 (0.5 tonnes) recycled at Whitefield through Recofloor.
- 100% Canteen waste 7m^3 (1.4 tonnes) removed by Ceredigion County Council.
- 100% Plastic 10.51m^3 (2.42 tonnes) sent to J & A Young, Leicester.
- 100% Wood recycling 5.35m^3 (1.82 tonnes) at Penold.

In total 19.26 tonnes of waste arisings were recycled over the construction phase of the project.

Kingspan (take back service)

5.1.4 Energy Recovery

Although diversion rates from landfill were high, 45.7% of waste was recycled with 53.9% of the waste produced sent for energy recovery. In total 51.41m^3, (22.7 tonnes) of waste produced from the fire station was sent for energy recovery, the majority of which was mixed waste. The energy efficiency status of the plant has not been able to be verified and so it's efficiency is not known. The ambition of Welsh Government is that by 2020 less than 10% of all waste produced will be sent for energy recovery/landfill. For the construction phase of the project this was not achieved.

A breakdown of waste sent to energy recovery is shown below:

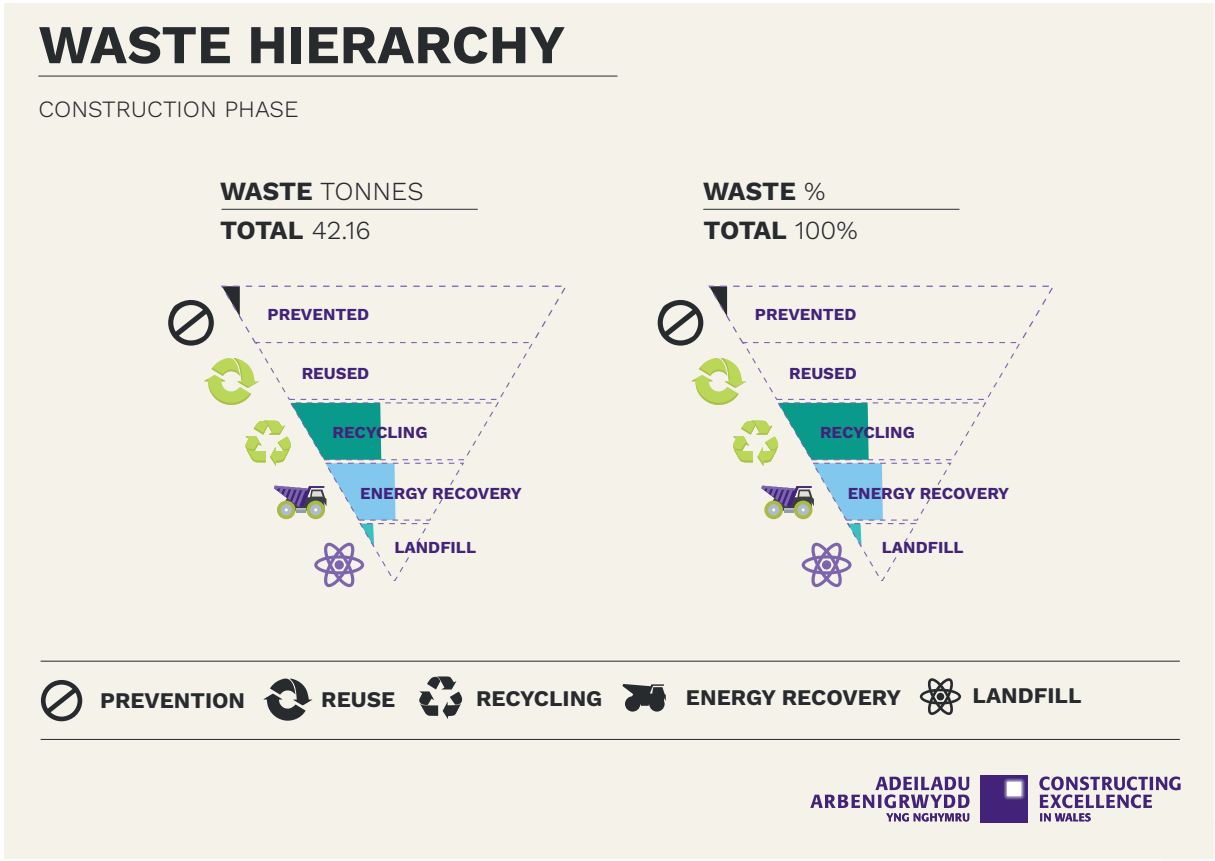
- Mixed waste 20.67m^3, (17.54 tonnes) 100% of all general waste produced was sent for energy recovery.
- Timber 10.05m^3, (2.74 tonnes) 100% of waste sent for energy recovery.
- Canteen food waste sent for anaerobic digestion 4.73m^3 (1.8 tonnes).
- Kingspan Insulation 16m^3, (0.48 tonnes) 100% of waste sent for energy recovery.
- 0.14 tonnes of plastic waste sent for energy recovery.

Unfortunately, all insulation waste removed from site through the Kingspan take back scheme service was sent for energy recovery.

5.1.5 Landfill

The only item that was disposed of to landfill was a 198kg piece of alkathene water pipe. Although the pipe was placed in a segregated plastic skip, due to its unrecyclable content, the pipe could not follow the remaining plastic to J & A Young for recycling and thus ended up being sent to landfill.

A proportional representation of the waste arising by waste management type is shown in the diagram below.



An example of the reused coat hangers in the fire station cloakroom

5.2 Construction Waste by Phase

5.2.1 Design

Initiatives to prevent waste arisings through design measures were incorporated by Lawray Architects from the beginning of the project, these included:

- External walls – Mixture of brick and metal cladding. All brickwork was set out to standard, reducing the needs for cuts and waste. Where complex corner angles occurred, angled bricks were specified to be manufactured offsite. Metal cladding was specified to standard sheet widths to ensure reduction in waste.
- External windows and doors – Were all manufactured off site.
- Insulation cut to falls scheme was prepared taking into account the complex shape of the roof itself. Offsite manufacture of the roofing insulation proposed to ensure zero (or very little) waste on installation. The material itself used a PVC membrane that has a high recyclable content.
- Floors – Ground bearing slab. REVIT model ensured that accurate volumes can be estimated to the nearest m3 in order to avoid waste of material, with the same benefits found for the First-floor slab.
- Partitioning – Varying steel heights meant certain irregularities in terms of cutting. Ceiling heights corresponded with a sheet of plasterboard laid vertically (2400mm high) and therefore allowed for investigation into the potential to use alternative treatment subject to fire and acoustics above this level to underside of structure.
- Flooring – Majority of flooring specified in Polyfloor Vinyl. This enabled a flooring return scheme to manufacturer whereby all offcuts (if any) are taken back and wastes are 100% recycled back into product.
- Internal Doors – All door sets manufactured off site and pre-hung in the factory (zero waste on site).
- IPS and cubicles – Also specified in Polyfloor Vinyl, to enable 100% recycling of waste arisings through takeback scheme.

5.2.2 Groundworks

Just over 8.57m^3 (7.68 tonnes) of waste was produced during the groundworks including 5.2m^3 (6.54 tonnes) of metal waste and 1.9 m^3 (0.8 tonnes) of wood waste. The remaining 1.47m^3 (0.34 tonnes) was of a plastic nature.

During these activities, a length of alkathene water pipe ended up in the segregated plastic skip. The site team were later informed by LAS Recycling that the product was disposed of incorrectly and required an alternative disposal. This was detrimental to the final waste figures as the pipe was the only item to be disposed of at landfill during the construction phase due to the product's unrecyclable content. The total weight of the plastic pipework was 198 kg.

5.2.3 Structural Works

In total, just over 30.8m^3 (7.76 tonnes) of waste, 18.4% of the total construction waste arisings was produced through structural work activities. The majority of which comprised 16m^3 (0.48 tonnes) of Kingspan insulation, followed by 2.7m^3 (1.94 tonnes) of wood waste and 1.77m^3 (1.54 tonnes) of mixed waste. This was the first mixed waste skip produced in eight months. The remaining 1.82m^3 (0.42 tonnes) of waste was of a plastic nature.

A Kingspan take back scheme was arranged for removal from site with insulation segregated into tonne bags. Unfortunately, the site team were later informed that all of the Kingspan off cuts were sent to energy recovery and not recycled.

A Siniat plasterboard take back scheme was also introduced at the site, recycling 8.48 m^3 (2.8 tonnes) of Siniat board back into the manufacturing process, helping to work towards a closed loop economy.

5.2.4 Finishing Trades

In total, the finishing trades produced 41.98m^3 (26.72 tonnes) of waste, 63.37% of the total construction waste arisings by tonnage, 18.39m^3 (16 tonnes) of which was of a mixed waste nature. 8.69m^3 (2 tonnes) of plastic waste was produced, predominantly from packaging. During this phase of the project waste segregation slipped due to a change in site management, time constraints on site and limited space for individual segregated skips.

Details by trade or activity are as follows:

5.2.5 Plasterboard Partitioning and Cladding

During the finishing phase of the project 3.75m^3 (1.58 tonnes) of plasterboard waste was produced (Siniat board quantities not included). During May, the project produced 3.04m^3 (1.28 tonnes) of scrap metal resulting from the installation of metal stud partitions and ceiling grids. The scrap metal left the site in three skips, however, there is no clear evidence shown for the exact quantities produced from each individual trade.

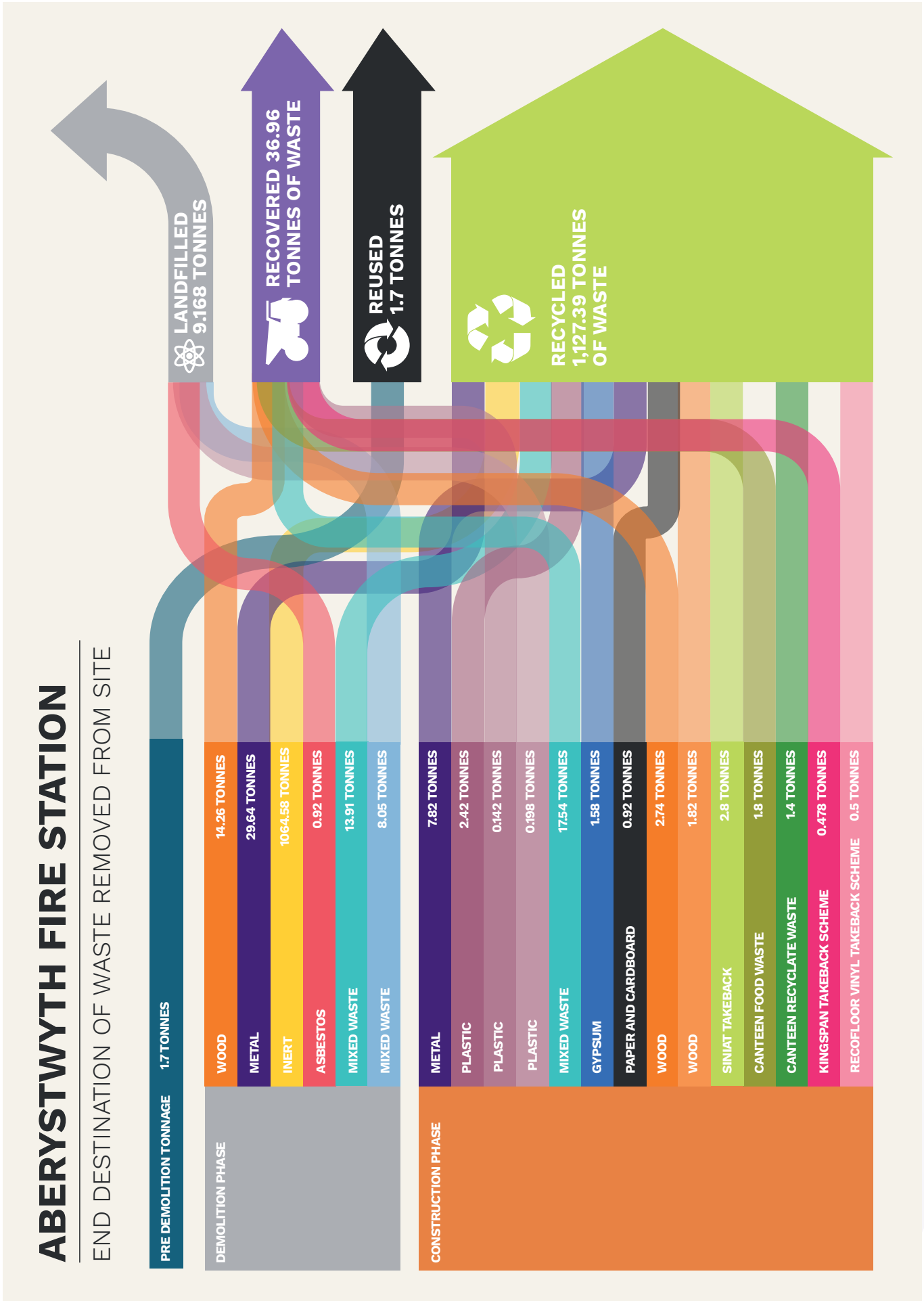
5.2.6 Joinery, Decoration and Vinyl Flooring

During the finishing stages of the project 5.41m^3 (1.8 tonnes) of timber waste accumulated from carpentry works on site.

5.2.7 Vinyl Flooring

Due to a take back scheme, 1m^3 (500kg) of vinyl floor offcuts were removed from site and recycled back into vinyl floor product. Throughout the finishing phase of the project a total of 4.2m^3 (0.92 tonnes) of cardboard was produced, mainly due to packaging and material protection.

Due to the diligence of the site manager, some mixed waste skips contained individual tonne bags in order for segregation to still take place when space was an issue on site and there was only space for one skip.


ABERYSTWYTH FIRE STATION
END DESTINATION OF WASTE REMOVED FROM SITE
LANDFILLED 9.168 TONNES
RECOVERED 36.96 TONNES OF WASTE
REUSED 1.7 TONNES
RECYCLED 1,127.39 TONNES OF WASTE
PRE DEMOLITION TONNAGE 1.7 TONNES
DEMOLITION PHASE
WOOD 14.26 TONNES
METAL 29.64 TONNES
INERT 1064.58 TONNES
ASBESTOS 0.92 TONNES
MIXED WASTE 13.91 TONNES
MIXED WASTE 8.05 TONNES
CONSTRUCTION PHASE
METAL 7.82 TONNES
PLASTIC 2.42 TONNES
PLASTIC 0.142 TONNES
PLASTIC 0.198 TONNES
MIXED WASTE 17.54 TONNES
GYPSUM 1.58 TONNES
PAPER AND CARDBOARD 0.92 TONNES
WOOD 2.74 TONNES
WOOD 1.82 TONNES
SINIAT TAKEBACK 2.8 TONNES
CANTEEN FOOD WASTE 1.8 TONNES
CANTEEN RECYCLATE WASTE 1.4 TONNES
KINGSPAN TAKEBACK SCHEME 0.478 TONNES
RECOFLOOR VINYL TAKEBACK SCHEME 0.5 TONNES

5.3 Peak in Construction Waste

During the construction programme, there were several distinct peaks in waste generation. The reasons for the peaks are suggested below:

5.3.1 April 2016 Peak

A peak was identified in April with 28.95m^3 (6.26 tonnes) of waste produced. The majority of waste consisted of insulation, 16m^3 (0.39 tonnes) in total, followed by Siniat plasterboard with 8.48m^3 (2.8 tonnes) produced. Take back schemes for the two waste streams were arranged by the EZW team (please see Section 10 for information on the take back schemes implemented).

Throughout April, 2.70m^3 of wood and 1.77m^3 of mixed waste was also produced.

5.3.2 May 2016 Peak

In May, 21.70m^3 (7.01 tonnes) of waste was produced. All waste produced during this period was segregated on site. Work packages including internal finishing, mechanical & electrical installation and external groundworks.

Waste arisings during this period included, metal 3.04m^3 (1.28 tonnes), wood 5.41m^3 (1.82 tonnes), plasterboard 3.75m^3 (1.58 tonnes), plastic 5.30m^3 (1.22 tonnes) and cardboard 4.20m^3 (0.92 tonnes).

5.3.3 June 2016 Peak

At the start of the project the waste segregation exercise progressed well, with only one mixed waste skip leaving the site in eight months. However, site activities and the number of subcontractors increased on site in June, resulting in an increase in the number of mixed waste skips leaving the site. This totalled seven skips in one month.

Due to external works on site during this period, the segregation of waste was limited due to space constraints.

In total 8.91m^3 (7.76 tonnes) of waste was produced in this month, all waste was disposed of in a mixed skip.

5.3.4 July and August 2016 Peaks

Heading towards the completion of the project, only mixed and plastic waste skips were present on site, with waste figures reaching 26.11m^3 (10.6 tonnes) for the combined months. However, waste segregation was carried forward by segregating the site waste into the mixed waste skip using individual tonne bags.

A vinyl floor take back scheme was introduced in July. In total 500kgs of vinyl floor was recycled from Aberystwyth Fire Station helping to work towards a closed loop economy.

Recofloor: vinyl takeback scheme

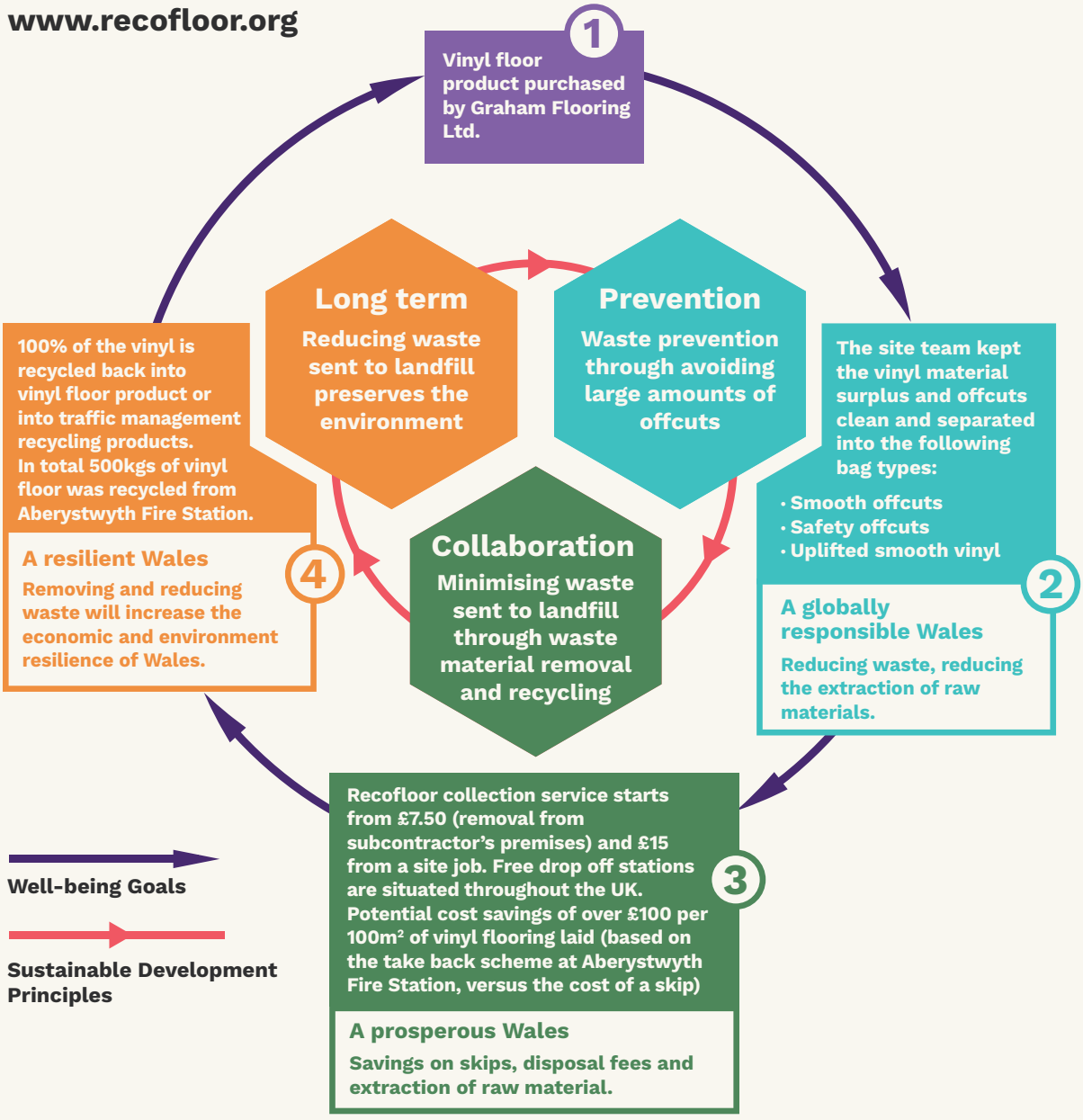
Segregated plastic skip - July

CIRCULAR ECONOMY: ABERYSTWYTH FIRE STATION

RECOFLOOR CASE STUDY

Enabling ZERO WASTE

www.recofloor.org



What can be recycled?

- Clean, smooth and safety vinyl offcuts
- Old stock vinyl roll-ends (either smooth or safety – Cut up or stack neatly on pallets)
- Smooth uplifted flooring – depending on condition and quality can be recycled into traffic management products

Benefits

- Cost savings
- Reduces waste sent to landfill
- Improves Corporate Social Responsibility
- Improves waste performance
- Appropriately permitted take back scheme (Permit details: Polyflor Ltd CB/UM3080FK--POLYFLOR LTD, Altro: EPR/MF0439NC/A001, Aztec Environment Waste Carrier Licence: CB/TM3685TR).

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Noddir gan Lywodraeth Cymru
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5.4 Construction Waste Analysis by Waste Type

5.4.1 Timber

The construction phase produced just over 10m^3 (4.56 tonnes) of timber waste. This material was taken to LAS recycling Lampeter, 24 miles away from the fire station and later sent to Stobat Biomass for energy recovery.

All pallets on site were either reused throughout the course of the project or dismantled by a site operative later to be upcycled into garden furniture.

Bearers from the steel delivery were taken back by a steel company. The lower quality bearers were used by the contractor for fencing blocks in the local allotments.

5.4.2 Plasterboard

12.23m^3 (4.38 tonnes) of plasterboard waste was produced during the construction phase of the project. 2.8 tonnes (63%) of the total plasterboard waste produced was removed from site by Reconomy and manufactured back into Siniat board.

5.4.3 Packaging

Packaging waste increased towards the end of the project reaching a total of 11.37m^3 (2.62 tonnes). This equates to 48% of total waste produced from the finishing works of the project.

5.4.4 Metal

18.57m^3 (7.82 tonnes) of metal waste was produced during the construction phase of the project.

5.4.5 Cardboard

One cardboard skip was removed in May 2016 consisting of 4.2m^3 (0.92 tonnes) of cardboard waste.

5.4.6 Mixed Construction Waste

Throughout the construction phase 20.67m^3 (17.54 tonnes), 41.6% of the total construction waste produced on site was disposed of in a mixed nature. The waste was removed by LAS Recycling who reported that 100% of all mixed waste was sent for energy recovery at two separate facilities. MES Environmental in the West Midlands and Neath and Port Talbot Recycling Ltd.

WRW set themselves a maximum target of 55.3m^3 for mixed waste through SMARTWaste forecasting. Overall the site produced less than half of this maximum target. This can be attributed to best practices observed on the project, including a decision by the site manager to segregate waste in the mixed waste skip with segregated tonne bags when space was limited.

Mixed waste skips were removed from site at a total cost of £4,087.

5.4.7 Canteen Waste

Previous EZW projects have found that the disposal of canteen food waste and recyclates can often cause an issue for construction sites. Volumes of canteen waste can be high and can often contaminate site skips resulting in reduced recycling rates. The EZW team liaised with Ceredigion Council to set up the collection of the site's canteen waste as part of the Council's collections. This ensured that 100% of the food waste produced at the site was recovered, as it was sent to an anaerobic digester in Oxfordshire.

Based on the number of food bags used, 4.73m^3 (1.8 tonnes) of canteen food waste was sent for anaerobic digestion. Canteen recyclates 7m^3 (1.4 tonnes) were sent to CWM Environmental for recycling.

Benefits from this initiative include:

- Increased diversion from landfill for recyclates and food waste.
- Fewer collections of mixed waste skips from construction sites, reducing the number of skip lorries on the roads.
- Lower mixed waste skip weights reducing waste disposal costs.
- Increased recycling rates.
- Increased throughput for digestion facilities.

As a result of the initiative, none of the segregated skips were contaminated with food waste helping to drive high recycling rates and recyclate quality.

5.5 Manufacturer Take Back Schemes

Through engaging with the supply chain CEW set up accounts with three separate take back schemes, two of which were recycled back into product. Creating a closed loop economy is the best economic, social and environmental outcome achievable. A total of 14% of the overall waste produced was saved using these schemes. The supply chain take back schemes introduced to the project are as follows:

- Vinyl flooring by Recofloor (Closed Loop) 1m^3 (0.5 tonnes).
- Siniat weather board (Closed Loop) 8.48m^3 (2.8 tonnes).
- Kingspan Insulation 16m^3 (0.48 tonnes).

Recofloor
Vinyl Take-Back Scheme

6 Analysis by cost

6.1 Actual Waste Management costs

6.1.1 Demolition waste cost

The total cost of removing 103.41 tonnes of demolition waste was reported at £4841.67, including haulage costs.

CB Environmental Ltd removed eleven 35 cu yd. skips during the demolition phase of the project. The waste in these skips included;

- 26.04 tonnes of mixed waste.
- 36.30 tonnes of scrap metal waste.
- 2.74 tonnes of timber waste.

In addition, CB Environmental Ltd also provided five removals of concrete waste, equating to 38.33 tonnes.

Whilst the segregation initiative enabled higher levels of recycling, the project team have indicated that as a result the programme was extended by three weeks to allow time to segregate waste on site.

6.1.2 Construction Waste Cost

LAS Recycling removed a total of 35 skips (mixed and segregated) during the construction phase of the project. In addition, there was also approximately 1 skip of canteen waste removed from the site, as well as 2 skips from the Kingspan takeback scheme, estimated based on volumes of the waste produced. In total, the construction waste management cost was £6,000.17. Costs are based on figures provided by WRW, at a price per tonne, plus transportation, and are inclusive of costs from the take back schemes and canteen waste removals.

A cost breakdown summary of waste is shown in Table 1:

Mixed waste skips were the most common skip type used during the construction phase at 31.58% of the total number of skips used. This naturally incurred the highest cost equating to 56.83% of the total expenditure on waste for the construction phase of the project.

6.2 Potential Waste Management costs

6.2.1 Demolition

In total £4,277 was spent on disposing of 26 tonnes of mixed waste at an average of £164.50 per tonne. If the mixed waste had been segregated then £1,937 could have been saved (based on an approximate average segregated waste cost of £90 per tonne).

A three week delay resulting from the material segregation exercise cost WRW approximately £9000 in prelims and overheads.

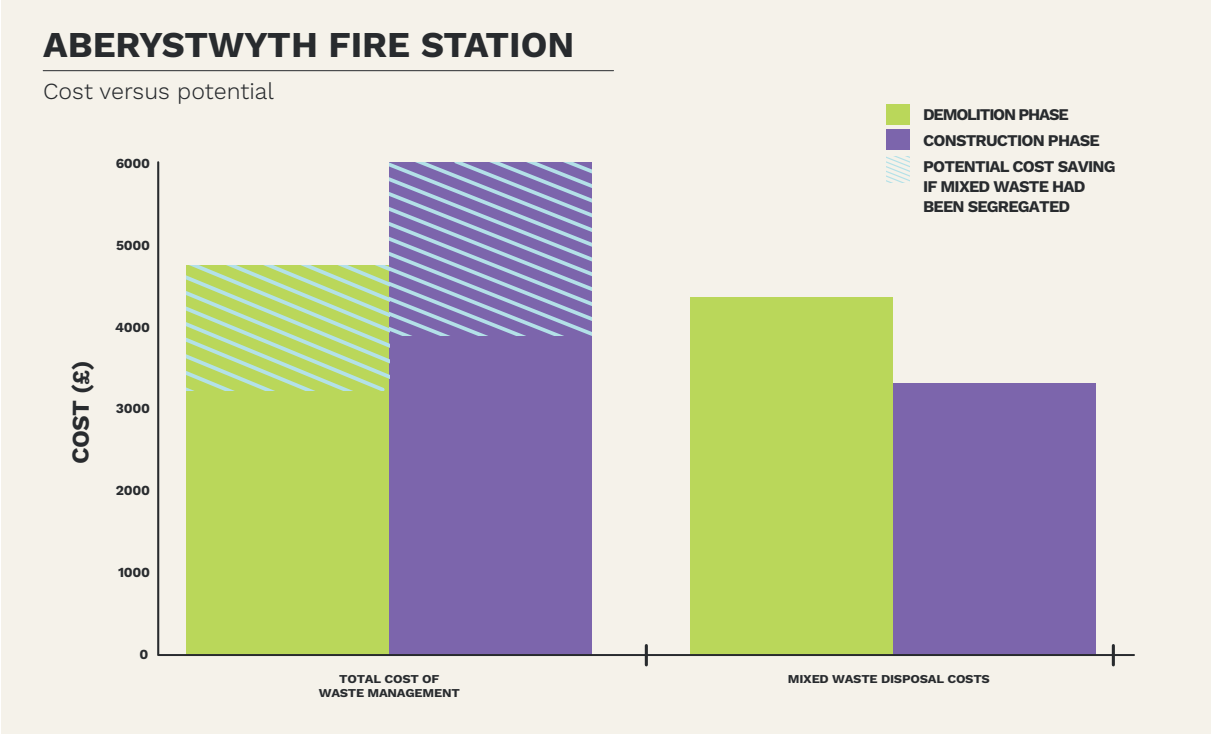
6.2.2 Construction

WRW spent a total of £6,000.17 on construction waste removal. If all waste had been segregated at source at an average removal cost of £90 per tonne, waste disposal would have cost £3,780, a potential saving of £2220.17, (37%).

Table 1

Skip Type	% of Total No of skips	% of Total Cost	no. of skips	Cost of skips (£)
Mixed Waste	31.58	56.83	12	3409.82
Timber	13.16	9.00	5	539.80
Plastics	15.79	8.50	6	510.00
Plasterboard	5.26	6.26	2	375.40
Paper/Cardboard	5.26	4.14	2	248.20
Metal	13.16	0	5	0.00
Siniat (Plasterboard)	5.26	11.34	2	680.40
Canteen Waste	2.63	1.30	1*	78
Kingspan Takeback Scheme	5.26	2.14	2*	128.55
Vinyl (Recofloor)	2.63	0.50	1*	30.00

Note: In the above table, the * refers to an approximate skip quantity, due to the nature of how these wastes were removed from the site.



6.2.3 Kingspan

The Kingspan removal service cost £128.55. With Kingspan insulation waste equating to 16m^3, the insulation would have filled two 14-yard skips. At the price of a mixed waste skip this could have cost £568. As a result, the Kingspan takeback service saved approximately £439.75.

6.2.4 Vinyl Floor (Recofloor)

In total £30 was spent on the vinyl flooring take back scheme. Due to the small amount of vinyl floor waste produced (500kg) no waste cost savings can be estimated.

6.2.5 Siniat Plasterboard (Reconomy)

A total of £680 was spent for two skips of Siniat off cuts to be removed as part of the take back scheme. This is twice the cost of a general plasterboard skip removed by LAS recycling. However, Reconomy offered a service whereby the offcuts were taken back to the manufacturer and recycled back into product, helping to promote circular economy principles.

6.2.6 Canteen Waste Removal

As a result of the canteen waste initiative, 11.73m^3 of waste was prevented from entering the site skips. A 14-yard skip can hold approximately 10.70m^3 and therefore this service has saved approximately £284 on the cost of mixed waste skips. The canteen waste initiative cost £78 and therefore a saving of £206 was achieved along with 100% recycling/recovery.

7 Analysis against benchmarks

7.1 Demolition Phase

Waste data is available from BREs SMARTWaste system for twenty-nine demolition projects in Wales. The data has been analysed to produce performance indicators for waste arisings per 100m^2 for volume and/or tonnage of waste produced.

The twenty-nine demolition projects on SMARTWaste average 26.6m^3/100m^2. The demolition phase of this project achieved figures of 79.3m^3/100m^2, suggesting that the demolition phase generated more waste than the demolition of an average building.

Table 2

Aberystwyth Fire Station Demolition Phase	Volume of waste per 100 m^2
SMARTWaste average	26.6m^3
Aberystwyth Fire Station Demolition	79.3m^3
Difference	52.7m^3

7.2 Construction Phase

New build public building projects on SMARTWaste reported an average of 14.2m³/100m² and 5.1m³/£100k for an average of six projects. The construction phase of the project achieved figures between 8.5m³-11.74m³/100m². A range in this benchmark is necessary, as conversion factors have been used to ensure all data is in the same unit of measurement leading to minor inaccuracies. Therefore the Fire Station was between 40%-17% less wasteful than established benchmarks.

Table 3

Aberystwyth Fire Station Construction Phase	Volume of waste per 100 m²
SMARTWaste Average	14.2m³
Aberystwyth Fire Station Construction	8.5m³-11.74m³
Difference	5.7m³-2.46m³

8 Future Proofing - Application of Environment (Wales) Act

The project has highlighted future potential issues for the industry. Specifically, with regard to the upcoming incineration and landfill bans for wood, paper, cardboard, glass, plastic, metal and food waste as part of the Environment (Wales) Act. If the Act had been in place for this project approximately 36 tonnes of material would require an alternative disposal solution. As such, research will need to be carried out to understand what alternative disposal options, along with the appropriate infrastructure, are necessary to enable the necessary changes now required by legislation.

9 Key challenges

The main challenges around site waste include:

- Waste management end destinations
  All mixed waste produced during the construction phase was sent to an energy recovery facility. The end destination of waste materials needs to be known, to enable identification of difficult to manage wastes and to ensure more emphasis is placed on recycling rather than energy recovery. The ambition of Welsh Government is that by 2020 less than 10% of all waste produced will be sent for energy recovery/landfill. For the construction phase of the project this was not achieved.

- Time
  Time challenges on-site were presented to the site team as a result of a tight programme. As such, this may have resulted in the site team not being able to give as much focus to waste management practices as initially intended during the construction phase of the project.

9.1 Segregation

Due to the waste segregation exercise during the demolition phase, there was a three-week extension to the intended programme. With both client and contractor being committed to the EZW project, waste segregation continued on site for the duration of the demolition phase which resulted in high recycling rates being achieved.

9.2 Planning

The set-up of the waste compound is a key part of a waste management strategy and should be a major concern of the site waste champion during planning for work on site. Waste compounds should contain segregated skips from day one on site and their purpose explained to everyone. Ideally a mixed waste skip should not be available, but if it is necessary it should be located furthest away from the site works to discourage its use.

In addition, it is crucial that the person responsible for producing waste forecasts makes regular contact with the site team to ensure that forecasts are achievable, reasonable and based on previous performance.

Waste should be a consideration in the selection of subcontractors. Main/lead contractors should give consideration to their duty of care and how it extends to the waste disposal options taken by subcontractors. Focus should be given to ensuring contractual obligations, specifying that all stages of the waste hierarchy are observed before disposal to landfill. This will reduce the potential impact of sub-contractor decisions on project reuse, recycling or other material recovery targets.

9.3 Behavioural/Cultural Challenges

A significant improvement was shown on this project from the previous EZW initiative at Millbank Primary school, predominantly due to permanent site staff and a proactive and committed site manager. Although site team engagement was excellent throughout the

project, a number of skips were contaminated lowering the recycling rates achieved. This was mainly due to waste attention falling on site. This was addressed by talking to the subcontractors and the site team.

9.4 Recommendations to Overcome Challenges

It is imperative to remain rigorous throughout the segregation process in order to achieve success. When segregation practices diminish and rogue items are placed in the incorrect skips, segregation standards can be difficult to restore. Recommendations to the site management team to drive segregation early on, through site inductions and toolbox talks should be implemented. Regular inspections of site skips and photographs taken can also prevent contamination. Photographs can be sent to sub contractor's management if needed, to address persistent issues.

Meetings should take place with waste management contractors to identify waste stream end destinations, along with material specific recycling and recovery rates. This is imperative with regard to demonstrating a project's environmental commitment and ensuring waste streams are pushed up the waste hierarchy.

It is crucial that the right questions are asked of waste management companies, to investigate end destinations for materials and associated recycling/ recovery rates.

The importance of documenting up to date waste data, licences and waste transfer notes through SMARTWaste not only protects the company legally but can help monitor waste streams and work towards avoiding and preventing waste. Through conversations with sub-contractors and by undertaking toolbox talks, commitment to zero waste can be achieved. Communicating zero waste aims to all site operatives is important to ensure full investment to the scheme. To this end, waste, and its segregation, should be discussed during site induction at all phases of construction and demolition.

9.5 Successes

There were a number of waste management successes on this project. Overall the project achieved 99.4% diversion of waste from landfill. Achieving Welsh Government targets for 2015/16 of 70% diversion from landfill and also targets of 90% by 2019-20.

Other successes include:

- 1.2 tonnes of waste prevented through designing out waste
- 1.7 tonnes of material reused as a result of the pre-demolition survey
- Cost savings due to site segregation and take back schemes
- An enthusiastic site manager, client, architect and waste management company all committed to the EZW scheme
- A site team dedicated to segregating waste on site
- Savings from designing out waste early on
- Successful take back schemes
- Very high recycling rates reported during the demolition phase as a result of the segregation exercise

10 How has EZW influenced waste management for the project team?

Martin Haigh (Site manager) Aberystwyth Fire Station

During the demolition of the former Aberystwyth Fire Station and the construction of the new build, advice and guidance was received from Constructing Excellence in Wales.

From the beginning of demolition, the importance of good waste segregation practices was highlighted to the site team, along with the fine-tuning ability to improving resource efficiency.

Regular tool box talks were presented to all operatives with an emphasis on waste minimisation and prevention. Best practice in waste management was high on the agenda. Regular site visits were carried out by Constructing Excellence in Wales Delivery Officers which helped give advice on segregation and assist the site to divert waste from landfill.

Our effort in working towards Zero Waste was further enhanced by funding being made available by Constructing Excellence in Wales. To have the canteen food waste collected on a weekly basis by the local council along with material take back schemes for materials such as Vinyl and Siniat plasterboard helped to promote circular economy principles and ensure these wastes were not disposed of to landfill.

All in all, partnering with Constructing Excellence in Wales through the EZW initiative was highly beneficial to WRW and the West Wales Fire and Rescue Service.

I feel that aiming for Enabling Zero Waste on the project turned out to be a great success and not only will it set the standard for all WRW sites in the future it will also demonstrate to prospective clients that WRW is focused and dedicated in working towards EZW on a long-term basis.

11 Conclusion and recommendations

This project has shown how a committed and enthusiastic site team can achieve real success with regard to waste segregation and landfill diversion rates.

The project has demonstrated that waste segregation practices can be implemented throughout a programme with high recycling rates being achieved. However, in this case it resulted in a three-week programme extension. It is therefore imperative for all parties involved in the project to agree on what focus and commitment they want to give to the segregation of waste. The benefits of a full commitment to waste segregation have been highlighted in this report.

There was a significant improvement shown on this project from the EZW scheme at Millbank Primary School. WRW has progressed waste strategies learnt from the EZW schemes, exceeded Welsh Government targets and demonstrated best practices throughout the project.

The site team are to be commended for their efforts and enthusiasm during the Enabling Zero Waste scheme. Having permanent site staff was found to be beneficial, as the process of the segregation of waste was managed much better than the previous WRW EZW project, Millbank Primary School.

Zero waste to landfill was not possible for this project, however, a very high landfill diversion percentage was achieved. Engagement with all members of the site team is important when attempting to maintain best practice and segregation during periods of pressure on site, especially the final stages before demolition and construction handover.

Overall the project achieved 99.4% diversion of waste from landfill which has achieved Welsh Government targets for 2015/16 of 70% diversion from landfill and also targets of 90% by 2019-20. Although diversion rates from landfill were high, during the construction phase 45.7% of waste was recycled with 53.9% of the waste produced (the majority of which was mixed waste) was sent for energy recovery (the efficiency of which is not known). The ambition of Welsh Government is that by 2020 less than 10% of all waste produced will be sent for energy recovery/landfill, for the construction phase of the project this was not achieved. That being said, during the demolition phase of the project 97.7% of waste produced was recycled.

Further focus is considered to be required on waste prevention and reuse rather than relying on the efficiencies of waste management infrastructure.