The Brighton Waste house: From zero waste on site to waste as a valuable resource.

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Premise: From zero waste on site to waste as a valuable resource.

This paper discusses the process of developing a design thesis testing the idea that construction waste could be a valuable resource, of assembling a team that designed, constructed, delivered, and continues to monitor the performance, of Europe's first public building constructed from approximately 90% material that others discarded.

Research questions.

1. Can one construct a permanent building (achieving Full Planning & Building Regulations Approvals) "on time and one budget" using predominately waste & surplus material from construction sites and other sources?
2. Can the building be designed and constructed to a very high level of post occupancy performance i.e. could it be 'carbon negative' in use, producing more energy than it requires to function properly?
3. Can the design & construction processes, as well as the on-going occupation of the building, be an open inclusive pedagogic tool involving young learners in all aspects of the project development, providing increased understanding of the challenges, objectives and some positive solutions involved in delivering such an innovative project.

Themes influencing the research.

1. The UK generated 200 million tonnes of waste in 2012. 50% of this was generated by construction. Commercial & Industrial activities generated 24%, with households responsible for a further 14%[1].
2. Approximately 20% of all material arriving on building sites ends up incinerated or going to landfill and 30% of this is new material never used[2]. Finding ways to reduce or eliminate waste from the construction process could help reduce environmental destruction from mining etc., as well as add value to material resource currently defined as waste.
3. Many large corporations such as Apple Inc., Caterpillar Inc. Kingfisher plc and others are very concerned about resource security and high levels of taxation associated with corporate responsibility (including dealing with waste/ end of life products)[3]. They are taking issues of re-use and by association principles laid out in 'Cradle to Cradle'[4] by McDonough & Braungart very seriously. The Circular Economy has the potential to galvanise industries that are looking to make money providing services and goods while working in harmony with Planet Earth.
4. Proving that material currently discarded as waste can make a contemporary public building that performs to very high standards will draw attention to its potential as a

[1] Source: Department for Environment Food & Rural Affairs, Government Statistical Service 'UK Statistics on Waste 2010-2012' published March 2015

[2] Source: Waste and Resource Action Plan (WRAP) publsihed2011

[3] Conversation with ReMade SouthEast in April 2011

[4] Book outlining huge potentials of 'Circular Economy' first published in 2002 by Farrar, Straus and Giroux

valuable resource, potentially reducing the amount of waste created in the future, changing construction techniques to promote low waste alternatives such as off-site fabrication, designing for demolition/ remanufacture, while creating new jobs within this sector.

5. Learning about designing and constructing buildings is often undertaken in academic and vocational 'silos'. The need to share research data whether academic or 'at the goal face' from a 'live' construction site is particularly important in the UK as many so-called 'low energy' projects do not perform as well as expected when occupied[5]. The need to understand and then to meet the challenges offered by designing and constructing in an authentic 'circular' or sustainable manner is hugely challenging and currently very difficult to achieve. Getting the whole design team (designers, makers, suppliers and constructors) to work together in a completely inclusive manner in order that they might learn together and from each other, and to document the outcomes from this project is perhaps the main objective of this ongoing project.

What is new?
This is the first public building in Europe made predominantly (90%+) from material discarded by others, while achieving Full Planning and Building Regulations Approval. Also achieving 'carbon negative' status during first year of occupancy.
It is also the first 'live' construction project for permanent university building performing as mentioned above, built by over 360 young people including apprentices, students from design and construction sectors, and volunteers: all under the jurisdiction of one very experienced site agent.

The approach: An inclusive pedagogic tool.
To involve design & construction students, academic colleagues from the University of Brighton, City College Brighton & Hove and other academic institutions, professional design consultants, local authority officers, SME's and national contractors, national social media networks, local schools and community groups, in the design, construction and in-use monitoring of Europe's first permanent public building made of (approximately) 90% material others had discarded. To create a 'live' on-going research initiative raising awareness of issues pertaining to 'The Circular Economy', Resource Efficiency, Resource Security[6], Re-use & Remanufacturing, Consumption & Production, and to capture the process via various social media platforms.

Developing the design thesis.
During the Spring of 2012 Baker-Brown met a number of experts in the subject area of waste as a valuable resource. Designers such as Nick Gant who runs the Sustainable Design MA at The University of Brighton and crucially Diana Lock from ReMade South East, a government funded organization charged with getting larger companies and corporations to reduce the amount of waste their product created in manufacture and crucially in-use. Lock told Baker-Brown that many large multi-national corporations were very concerned about 'resource security' as well as the cost of the ultimate disposal of their products. They were looking at ways to avoid relying upon buying large amounts of raw material, as well as avoiding sending their products to landfill or incineration, in order to make or sustain their profit margins, or in some enlightened cases, to reduce their burden upon Planet Earth's natural resources. The sensible money was investing in the world of the 'Circular Economy'.

In August 2012 Baker-Brown called a mini "waste summit" where he met Cat Fletcher who helped form FREEGLE UK "an exchange for unwanted stuff" with over 2.2 million subscribers. Baker-Brown and Fletcher, together with Dr.Ryan Woodard, a Research Fellow at The University of Brighton who has been working in waste management research for over 15 years, together with Gant and Lock, contrived a plan for redesigning the build so that it was constructed of waste and surplus material from the construction industry. Following

[5] A recent Innovate UK initiative published findings in April 2014 ('Retrofit the future: a guide to making retrofit work' clearly demonstrated that many completed buildings did not perform as expected).
[6] There are increasing difficulties with sourcing raw materials due to conflict, global warming or in some cases resources are running out.

Fletcher's suggestion, they also considered collecting items of waste material currently flooding domestic waste sites; material such as VHS videotapes and CD's. The idea developed from that of focusing only on waste from the construction industry, to a project that would raise awareness of how wasteful we all are going about our everyday domestic lives. This would open up the project to a bigger audience as well as change it from an exemplar construction project that could directly inform the construction of many other buildings, to a project more akin to a polemic, a thought provoker, or as RIBA Awards Judges noted:-

"*the Brighton Waste House has sufficient scientific integrity to be taken seriously by the construction industry and just enough political clout to influence recycling policy. It is clear this interesting project will continue to question important issues of recycling that affect everyone*". Source: RIBA Jury citation 'The Stephen Lawrence Prize 2015'[7]

Assembling the Design Team.
The Design Team comprised architects (BBM Sustainable Design) including project Architect Dan Harding who is an alumni of the University of Brighton and City College Brighton and Hove, Structural Engineers (BBP Consulting Engineers) and Environmental Engineers (Robinson Associates). Baker-Brown's role was brief definer, coordinator and academic. This team had previously worked very successfully on THTKB four years earlier.

Developing the design.
It was agreed that this building, which is actually university teaching accommodation, not a house at all, should be designed to be as energy efficient as possible. Due to the unusual constraint of being built with waste the design team didn't try and deliver a design that met Code for Sustainable Homes or BREEAM requirements. It was decided upon to run an IES (Integrated Environmental Solutions) digital mode[8]l to set energy efficient 'benchmarks' relating to the site, the programme, the form & orientation, levels of 'U' Values required through the external fabric, as well as ideas for the cost effective primary energy source (conventional and renewable). It was decided that the building would be all-electric as far as heat and power were concerned due to services constraints on site. The team decided that the mechanical, electrical and power installations would be designed to be as efficient as possible: the building would not show an array of 'green technologies' as many 'demonstration eco houses' do as these buildings are often over complicated and too expensive. We wanted to prove that this low energy building made of waste would be cost effective, fuel efficient, and that it could be built on time and on budget.

The first challenge was to decide on the design of the load-bearing walls or frame for the building. The team had previously been successful at sourcing second-hand timber from skips and ply sheeting from large top tier construction contractors for temporary pavilions exhibiting student architects work. So it was decided to take advantage of this by designing a timber and ply frame comprising 400x400mm section beams and 400x400mm section columns at approximately 2.5m centres. In between the columns we designed 400mm deep, 900mm wide and 2400mm high ply boxes (like cupboards). We called these boxes 'cassettes', which would later prove a bit confusing. However, it was these cassettes that provided the opportunity for collecting and in effect storing waste material from sources other than the construction industry.

The vaulted roof structure over the top floor studio was initially designed as a glue-laminated timber truss. It was my inquiries into sourcing a glue lamination press that lead to one of the best partners for the project. This is discussed later on in this paper.

A 4kW array of photovoltaic solar panels sits on the largest South-facing facet of the roof. It provides approximately 25% more electricity than the building requires over a year.

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7 https://www.architecture.com/RIBA/Contactus/NewsAndPress/PressReleases/2015/2015RIBAStephenLawrencePrizeshortlistannounced.aspx

8 IES modeling is a sophisticated digital design tool allowing designers to create low carbon buildings

Current Building Regulations 'U' Value levels for the roof, external walls and ground floor were achieved by applying 'returned' and/ or damaged polyurethane insulation (normally used in the construction of buildings) secured to the outer face of the 400x400mm timber box frame and 'cassettes'. This 400mm external 'wall zone' was used for 'storing' waste material, either heavyweight material providing internal air temperature stablising 'thermal mass' or lightweight material providing, to various degrees of success, additional insulation. All walls were to be monitored for condensation, temperature and off gassing.

It was decided that external windows and doors would be supplied as new high performance units. Second-hand units are not easy to source and their thermal effectiveness could not to be relied upon. We felt that waiting for second-hand high performance units would delay the project for a year or so, as the whole design revolved around the size of external openings.

The design of the foundations and 'over-site' was agreed as low carbon concrete, i.e. concrete with a 40% reduced cement content (replace with pulverized fuel ash) plus aggregates from demolished concrete buildings. It was not possible on this project to avoid the specification of cement. The (rather ironically) ground conditions were quite unstable as they were made-up ground with a high degree of spoil (including composting rubbish) from a former car park.

In addition to the specification of below ground drainage and generic 'performance specifications' for other key elements, this was the extent of the design that initially went to Building Control for a Conditional Building Regulations Approval. Building Control was hugely supportive of this project allowing us to develop the rest of the design during the construction of the building. The Building Control Officer even attended design development meetings on site.

The Construction Team.
The Mears Group a national contractor charged with servicing and maintaining a large percentage of UK's social housing stock, including Brighton & Hove's, contacted Baker-Brown in early 2011 stating that they were keen to help build the project as they had a healthy apprenticeship scheme in Brighton and wanted their apprentices to work on the project. In the Spring of 2011 the Mears Team stablised the ground on site, constructed the foundations, installed the drainage and cast the ground floor slab for the Waste House. Whilst completing these works their apprentices help architecture students on an adjacent site on the same campus build the first temporary pavilion to show final year projects in the graduation show. This process was such a success that Mears decided to help build the rest of the Waste House. Mears also agreed to provide an experienced site agent to run the construction site, together with their apprentices. We planned to start works on site in the autumn of 2012.

It was during this period that Baker-Brown had a fortuitous meeting. He went to meet tutors delivering construction courses at City College Brighton and Hove, as he wanted to see if they could construct a glue-laminated timber beam for the roof of the building. City College couldn't make a glue-lam beam, but they wanted to build the Waste House as every year they build the equivalent of a new in their three story workshops. In addition to this the team employed Cat Fletcher of FREEGLE UK to source waste material for the project. We had our team.

The construction & learning process.
Mears took control of the construction site and were responsible for security, coordination and all aspects of health and safety. In addition Mears supplied up to four apprentices every day. However they were on standby to do 'normal' Mears work on nearby housing estates, so they would often have to leave site. Mears were our 'Main Contractors'. In addition to this we had City College student carpenters, electricians, plumbers, bricklayers, decorators etc. supervised by their qualified tutors. They were our 'Sub-contractors'. City College students would be on site two or three times a week. However the site agent wouldn't know if he had two students to work with or thirty. Managing a construction site with an unknown number of relatively untrained sub-contractors was one of the biggest challenges for this project. Despite this the building frame was constructed within 3 months by students in City College workshops and then assembled and completed by 360 students, apprentices and volunteers

on site in only 12 months. In addition we had specialist suppliers who would often install their products or systems in partnership with our young constructors and their tutors.

During the on-site construction period there was a Volunteer Summer School Camp that ran from June 2013 until September 2013. Over 50 students completed the most challenging part of the construction process during this period, i.e. the vaulted roof structure. 25 of the volunteers were City College students, and another 25 were architecture students, with many of those from the Interior Architecture School. This was perhaps the most profitable time as far a skills and learning exchange amongst students, apprentices and the one or two professional trades people we had on site. It was the one period of time where design students could spend three, four, maybe six weeks in a row working on site. Some of these committed design students became so adept at their new trade that they ran small teams of volunteer carpenters on site; teams that included City College carpentry students. It was during this time that Mears promoted five City College students to Apprentices because of their work on our project. A number of our students received Achievement Awards from Mears.

We also worked with deaf students, as well as a number of students with learning and behavioral difficulties. Construction sites have always been a social and intellectual leveler, and so it proved with our Waste House. We recorded of 25 short films during the construction period that included interviews with students from all institutions taking part. We also welcomed over 750 pupils from local primary and secondary schools, as well as other technical colleges from around the South East. This unusual learning environment was completely facilitated by our immensely patient site agent David Pendegrass who had to do a Health & Safety Induction for every person who arrived on site, whether they wanted to work or simply visit, and remember he also had to get the Waste Hose built on budget and on time. This he did.

Locating appropriate waste material.
Baker-Brown would meet the construction team on site every week to check progress and identify materials and products that needed to be sourced. Often the conversation would involve the site agent and Cat Fletcher.

There were basically two strategies put into place to find material. The first strategy was the conventional one. Mears, BBM and City College Brighton & Hove employed their contacts and networks within the construction industry to source second-hand, surplus and waste construction material.

The second strategy was less conventional. Cat Fletcher used her FREEGLE UK social media networks (FREEGLE UK has over 2.2 million subscribers with 18,000 in Brighton & hove) to locate waste material. Individuals, local authorities, building contractors & suppliers, schools and businesses from all over UK supplied the project with materials such as 25,000 toothbrushes from Gatwick Airport, 2 tonnes of waste denim, 4,000 VHS video cassettes, 4,000 DVD's.

In addition Baker-Brown sourced waste material from demolition sites his practice BBM were working on. UK VAT rules dictate that retrofit and extension works to residential properties attract VAT at 20%. However new-build residential projects are 'zero rated' and attract no VAT. BBM were working on a project where the VAT was in excess of £360,000. The client instructed that his home be completely demolished for less than £10,000 to avoid this VAT. BBM collected timber from the demolition and re-used it to form the vaulted roof structure of the Waste House. The client had his home rebuilt from scratch attracting no VAT and saving him about £350,000. Baker-Brown is currently campaigning with the Green Party to alter VAT to favour retrofit projects over new-build projects.

Utilising waste from the Waste House.
It is estimated that over 40 tonnes of waste was diverted from landfill or incineration by constructing the Waste House. However the process of constructing the Waste House created waste material. Whenever possible we set up projects using this material. Architecture students created designs and built them after locating and using waste from the

Waste House. In addition a local 'zero waste' restaurant called 'Silo'[9]constructed tables and shelving from surplus material from the Waste House. A local community group used waste material to create chairs, and an allotment shed in Hollingdean used surplus carpet tiles, vinyl banners and timber from the Waste House.

Specifying new material and products.
There are a number of products and systems that contemporary buildings require where it is not possible to install as second-hand. Electrical circuits comprising wire stripped out of buildings will require too many joints or junction boxes to be reliable. Second-hand above and belowground drainage and waste pipes are technically a health hazard and not appropriate to re-install without a professional cleaning operation. We sourced second-hand light fittings: five of them from a scrapped 60 years old container ship. However light bulbs have to be new.

In short it is difficult to install what the construction industry calls 'first fix' services: piping work and wiring. However the 'fittings' such as sinks, wc pans, IT equipment, Mechanical Ventilation and Heat Recovery system, and even flat screens for presentations were second-hand and straight forward to sourced.

Achieving Building Regulations Approval.
As mentioned earlier, Brighton & Hove City Building Control were very supportive and an integral part of the design team, attending design and progress meetings. Installing dvd's, videos, and denim into external wall cavities does not test Building Regulations as they are separated from the internal environment by the internal wall linings. The Waste House is constructed primarily of timber and ply sheets with various second-hand plastics acting to a greater or lesser extent as low-grade insulation. Most homes built in the UK in 21st Century are timber framed with plastic insulation infilling wall cavities and plastic vapour control membranes[10] sitting behind internal plaster or timber wall linings: pretty similar to the Waste House in fact.
The most challenging aspects for the Building Control Officer were proving the fire and flame resistance of the 2,000 second-hand carpet tiles used for external wall cladding, and the ply wall linings used in the main first floor studio. To satisfy these queries we set up a test rig of 15 carpet tiles fixed on a brick wall, as they would be installed on the Waste House. In the presence of the Building Control Officer our site agent directed a hand-held blowtorch onto the tiles for 5 seconds and then for 10 seconds. On both occasions the tiles started to smoke quite heavily. However as soon as the blowtorch was taken away the tiles immediately extinguished.
The first floor wall linings were more straightforward. They were constructed of third-hand ply sheet that had previously been used by the team to created a 9m high 'waste totem' at EcoBuild 2013[11]. Material for the totem had to be flameproofed before it was decorated with second-hand paint and installed in the exhibition hall. This flame retardant ensured that we could re-use this material as the internal wall finish of the first floor studio space without any fear of Building Control not approving it fit for purpose.

The academic legacy.
Since the spring of 2011 the themes and challenges embraced by the Waste House have been influencing the core delivered curriculum of the undergraduate architecture and interior architecture courses at the University, as well as at in partner institution City College Brighton and Hove. Baker-Brown coordinates architecture 'technology' and 'practices'. Both modules used the process of designing and then constructing the Waste House as an inspiration, awareness raiser, and vehicle to deliver RIBA approved learning outcomes.

Architecture students considered design projects tackling issues associated with valuing waste as a resource, as well as broader issues relating to the Circular Economy. One undergraduate architecture student designed a timber construction system that inspired the

[9] Brighton based restaurant creating little or no waste on site www.silobrighton.com

[10] Membrane used in timber frame buildings to stop off-gassing from insulation, create air-tightness and reduce likelihood of condensation within wall.

[11] Owners UBM claim this is the largest construction trade show in the World.

'cassettes' used in the Waste House. Construction students from City College completed learning modules of their carpentry, electrics, plumbing, brick laying, plastering, decorating and maintenance by working initially in the workshop, but then crucially on the 'live' construction site. Both Baker-Brown and Fletcher delivered lectures to both City College construction students as well as architecture students as part of their core curriculum. They also gave presentations about waste and designing for a circular economy aimed specifically at children and young learners as young as 6 years old. As part of the university's ongoing Widening Participation Programme[12] over 750 young people were shown around the construction site during the construction period they presented to.

Students from regional tertiary colleges visited the site, as well as other students from the School of Science and Engineering. Since its completion the Waste house hosts regular school visits on Wednesdays where open design workshops are held.

While on site a Jordanian PhD student approached the University asking if he could be involved in the digital monitoring of the external wall fabric. He moved to UK to do just this.

Since the inception of the project in 2010 the University of Brighton has hosted a website focusing on the development of the Waste House as an idea through to completion. It is regularly updated and serves as an archive and learning resource.

In March 2013 Baker-Brown and Gant curated a 3-day seminar entitled 'The WasteZone' where 12 guest speakers discussed the idea of waste as a valuable resource from many different perspectives[13]. The Waste House team also designed and erected the 9m tall 'Waste Totem'[14] drawing the attention of the 65,000 visitors towards issues of Re-Use.

The Waste House also hosts the University of Brighton's Sustainable Design MA with students working in the first floor studio 2 days a week. Prof. Jonathan Chapman and Nick Gant have their office on the ground floor. Community groups, local schools & other educational establishments, as well as local and international businesses, and local authority groups use the Waste House. The building hosts meetings, lectures and symposia with large construction contractors as well as commercial enterprises such as Body Shop and Marks & Spencer's.

This is an ongoing research project, involving new generations of students being set projects testing, improving and updating the Waste House whose performance is being constantly monitored by the School of Science and Engineering.

However perhaps the biggest legacy the Waste House project leaves is that of raising awareness of the negative issues associated with society's linear, throwaway, consumer-led lifestyle. The building has many stories associated with the materials collected and residing within it. For example an airline cabin service company at Gatwick Airport collected 25,000 plastic toothbrushes for the project in only 4 days. These statistics stop you in your tracks are it were, and we believe get you thinking about where stuff comes from and where it currently ends up. Perhaps it will also get more people realising the potentials for re-use and more particularly the potential for designers to play a huge part in our future Circular Economy, and of course to understand "that there is no such thing as waste, just stuff in the wrong place". Source: treehugger.com 2011

Since it opened in June 2014 over 400 articles have been published around the world, in newspapers, on tv & radio as well as on many websites. The project has attracted an enormous amount of interest.

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[12] The Higher Education Funding Council for England (HEFCE) funds widening Participation at the University of Brighton on the basis of low levels of young participation in higher education in urban, rural and coastal areas.

[13] WasteZone explained http://arts.brighton.ac.uk/staff/nick-gant/waste-zone-at-ecobuild

[14] Waste Totem published in Architects Journal http://www.architectsjournal.co.uk/footprint/-waste-is-just-stuff-in-the-wrong-place/8643971.article

Capturing the design and construction process
We commissioned a graduate from City College Brighton & Hove's film school to record the whole process and edit approximately 25 short films. An additional 20 short films were shot of the completed building explaining the reasoning behind the design decisions as well as the many stories behind the sources of the materials used. All films were put on line on the Waste House website which went live at the beginning of the build and is still 'live' and updated.

Lessons Learnt
1. That designing structural beams and columns using second-hand, waste and surplus material raises unusual challenges for a structural engineer. If you don't know where the timber materials originate from you won't know the stress grade and therefore the actual strength of the product. Our structural engineer therefore had to assume it was the weakest material on the market. This initially manifested itself in a draft design from the engineer that suggested larger structural beams and columns than normal. This design proposed using far more material than would be normal. It was only when the design was refined over a number of weeks, so that it became more specific to the actual loads on each structural member, that if became more material efficient.

2. In addition, during the manufacture of these elements the structural engineer had to oversee and approve every structural element in the workshop: they were constructed by young people with as little as two months time spent on a carpentry course.

3. The team designed a timber-framed building assuming we could source over 400 sheets of waste ply and approximately 2km of timber studwork: we had after all done this before when constructing temporary graduation pavilions. However in 2012 we were not able to do this as it rained during every month. Initially we were receiving water saturated and delaminated ply that was not appropriate to use. It took the team two months to find damaged ply suitable to use and delayed the project. We learned to find material first and then think about how it might be useful or not, instead of designing while assuming materials would be available: a completely different process to normal.

4. Materials would often be offered weeks or even months before they were needed. It was crucial to the success of this project that we could store material keeping in safe and dry. Brighton & Hove City Council let us borrow a building nearby to use as a temporary resource store.

5. If properly briefed and supported, young people with limited skills and experience within the construction industry, can construct a building using unusual materials that performs at very high levels of energy efficiency.

6. A 'live' construction site can run effectively while shutting down for an hour a week to allow visiting tours from over 750 school children interested in the project.

7. Young people from different backgrounds, and with different skill sets learn can from each other and crucially work together to deliver a complex constructed project.

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