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David Lea and Patrick Borer: two examples of high-performance buildings

Tesi di Laurea di
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Thanks to my family, my love and friends for the support and the affection. Thanks also to all the people helped me to write this thesis

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Introduction

This work is the result of research on architects David Lea and Pat Borer. Both decided to move from London to little towns in Wales. They chose to lead the sort of integrated, balanced life they believed in - living as members of a decentralized, rural, relatively self-sustaining society in harmony with nature. This is the first aspect that connects them. The second one is the CAT (Centre of Alternative Technology near Machynlleth) where they have been working together in many projects.

I've begun doing many research at the Politecnico of Torino Library about these two architects and their work. I've found some documents but not enough. Most of the publications are on UK magazines and journals so I had to look for others in the architects' country.

My journey started in mid December 2017 in London where I've found many documents at the RIBA and the British Libraries - more about David Lea and the CAT that about Patrick Borer.
I wanted to visit and explore at least one building for each architect to make a comparison between their construction methods and identify their outstanding peculiarity.
So I've chosen two similar case studies about houses extension, Pat Borer's in Peniarth Urchaf and David Lea's in Aeron Valley. They enjoy in the same climate conditions and also in the same landscape, similar materials are used.

First, I've met Pat Borer who hosted me in his wonderful house where we had an interview that gave me informations about his life and work and about his sustainabity ideas of architecture and way of life.

Then I've visited Peniarth Uchaf house where I've met Peter and Cynthia Jones who told me about their house, its history, design, construction and its life till now. They gave me also many details about materials, consumption, costs, bill of quantities and some picture about the building during the construction works.
It has been interesting to know their opinion about the house and the work done: what they expected from the design and how the new extension has changed their way of living.
Pat Borer showed me the drawings, told me about some alternative materials that might have been possibly used and why it was built in that way.

After that, we focused on the WISE building and his relationship with David Lea. He told me about his projects with the CAT since its foundation, the Centre's history and evolution, his work as a teacher and planner, how it changed its vision of architecture and how it helped him to understand how building materials work.

Then I visited the CAT to meet Paola Sassi[1] who introduced me the Centre and showed me the WISE building. The contributions of David Lea and Pat Borer were clearly recognisable, it was possible to identify the architectural aspect of the designers from the material to the composition and to lighting inside. Paola Sassi told me about the problems noticed

1 She is an architect specialised in sustainable design. In addition to jointly leading the Part II Architecture course at CAT, she teaches and undertakes research at Oxford Brookes University and the Oxford Institute of Sustainable Development. Previously she taught sustainable architecture at Nottingham University and Cardiff University. Paola has over 30 years of architectural practice experience mainly in Germany and the UK.

during the use phase and, more interestingly, how people use common spaces in a different way than predicted in despite the design phase.
All the interviews were recorded to give me the possibility to write an accurate analysis and to report the right information collected.
My last stop was a little further South near Aberystwyth - Dyfed -. The Segger house, in the countryside. I've seen the entire property in a very rainy day so I couldn't take pictures from the outside. I was welcomed by Peter Segger and Anne Evans, the owners, who showed me the original cottage and the extension and told me about their requests, desires and their 'green' idea of life and work matching that of the building.
The Farm is really important in the field of organic agriculture the claim of the house's design needed to be in tune with their way of growing food.
They gave me all the information useful for my research: documents, really accurate bill of quantities, drawings by Lea - from plans to details - electricity and oil consumptions, and more.

Unfortunately I could not meet David Lea as he was sick at that moment but he was very helpful and shared some documents about his work.
The purpose of this work is to show Pat Borer's and David Lea's methods of green architecture by the use and material selection and the spaces composition. It is important to show at least one example for each one and also the most interesting project done together. In this way it's possible to understand better their qualities and aims.

There are few publications about Borer's work so I thought it was helpful get to know his architecture and his huge amount of research dedicated to natural materials.

My intention is not to write a biography but to show their design profiles through what they build and figure how Borer and Lea can be acknowledge for their expertness.

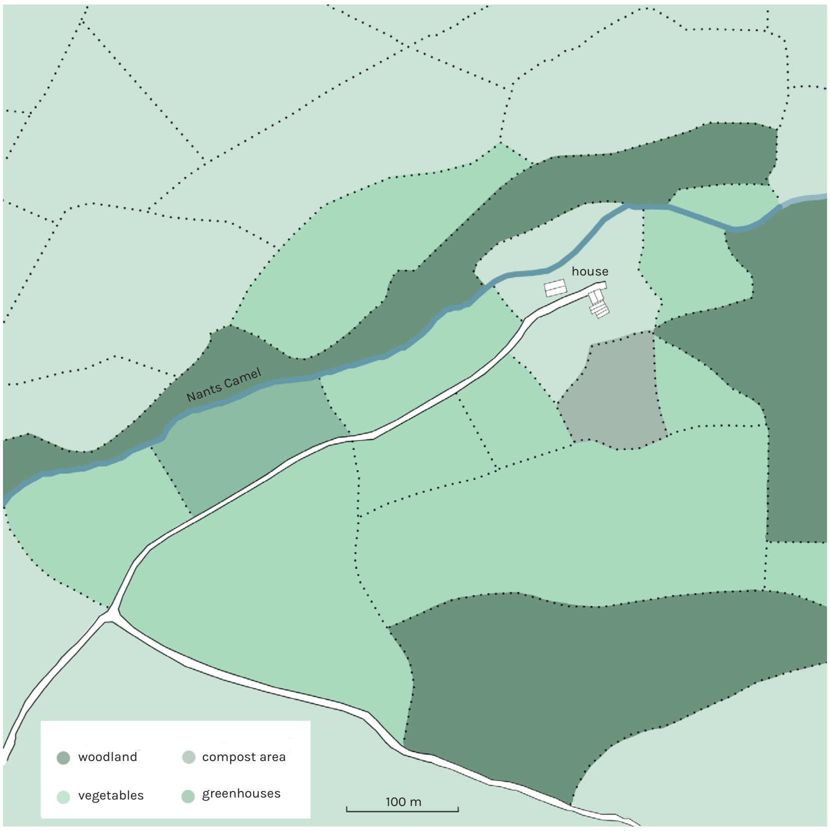
Chapter one

Blaencamel Farm

Blaencamel - *'blaen'* means a quick, clever mind capable of grasping and assimilating new ideas, and this name aptly suits the spirit of place and *'camel'* is from the river Nant Camel that flow across the land - is a small family farm nestling in the beautiful Aeron Valley 5 km from the seaside town of Aberaeron. The owners started to be organic in 1974 setting up to develop and expand their farm as organic and sell their produce in large volumes to markets, supermarkets and organic shops all over Wales. For over 30 years the Segger family has been producing a wide range of vegetables and salads to Soil association standards as they are doing today. They tried to distribute their produce in a shorter chain.

Pic 1.1
Map of Wales
(V.B. photo)

The farm's 20 ha – 6 ha vegetable garden, 3 ha woodland, 0,6 ha of greenhouses plus roads, yards, some environmental areas, permanent grass areas and a compost area - support a wealth of wildlife fields and hedgerows. Approx 8 ha are farmed and the land is in constant rotation so in any given year about 5-7 ha are in veg production. The other fields will be in green manure or being grazed by a small flock of sheep.



Pic 1.2 Blaencamel property (V.B. photo)

In addiction to cultivated land, Blaencamel includes several hectares of wonderful semi-ancient woodland, the River Nant Camel which joins the River Aeron close by, and an area of unimproved wet pasture where the ruined remains of a former holding can be seen.

The Seggers are trying to achieve a balance between crop production and the preservation and enhancement of the local environment. Their crop production starts with clover and grass which support the sheep flock, that in turn enrich the soil so it can be used to grow vegetables. They also make compost using a specially designed process famous throughout the organic world. almost 22 years Peter Segger spent almost 22 years travelling around the world and learning vital lessons about how the soil's health has impacts on biodiversity and climate. His farm's most important step taken so far is compost. It is composed by 1/3 green waste material -as woodchips from hedges, grass cuttings, grass from fields, grow green manure -, 1/3 carbonaceous materials – minerals from stables and dry brown material like straw, hay, cardboard boxes from a local organic shop -, 1/3 of manure – plus, if necessary a little bit of clay. This mix is converted into humus that helps the ground taking carbon from the atmosphere, and promotes the proliferation of into the soil – a large collection of bacteria and fungi - that are a great source for food plant and make the soil active.

Pic 1.3, 1.4 Blaencamel compost (www.blaen-camel.com)

This serves at least four functions: good nutrition is supplied to the soil, removing any need for fertilisers; the comprehensive mix of micro-organisms in the compost counteracts soil disease; waste products are transformed into something useful; finally, well made compost acts as a carbon sink – part of the Segger's response to the challenge of global warming.

The Seggers new aim is to become as low carbon as possible. Because of their awareness of climate change issues, the Segger's decided to avoid all imports and to re-localize all their marketing – no sells outside South Wales – and opened a little farm shop. This shop provides some markets and restaurants in West Wales with great tasting salads and vegetables. Buying locally helps the rural economy, reducing the food miles and ensuring that the food bought is fresh. Today they have no inputs - except seeds and agricultural vehicles and their fuel, although Peter Segger is now making an electric tractor, which will be powered by renewable energy. They are one of just seven farms in Wales to produce with a shorter chain market. All of them are part of the Sustainable Food Trust.

Pic. 1.5 Making compost in Blaencamel farm. (www.blaencamel.com)

The key to being able to produce a range of vegetables including salad - year range -, tomatoes - including heirloom types -, aubergines, peppers, strawberries, peas and other delights and extending the growing season is 0,6 ha of greenhouses and polytunnels. It is precisely the dependence on imported fruit and vegetables, the production and transportation of which uses vast amounts of water, fuel and other resources, that inspired Peter Segger and Anne Evans to grow local.

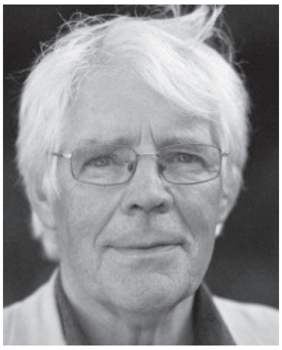
Pic. 1.6, 1.7 Blaencamel farm's vegetables (www.blaencamel.com)

The farm has won awards both for organic production and ecological building. The Seggers are trying to bring culture back into agriculture. The farm is firmly rooted in its community with strong links to the local schools which visit regularly. They also host visits from universities, organic groups and international growers groups.

Data	
m^2	120
rooms	9
£	110.000
£/m^2	916
start work	1997
end work	1999

Blaencamel house

Peter Segger and Anne Evans needed to extend their typical 19th century Welsh cottage because their family had outgrown. They moved in Blaencamel cottage in 1974 and started the extension works felling the first tree in August 1997. The masonry cottage stands in the middle of the farm. It is approached via a slightly sunken lane flanking the West side, and there is a parking to the North.



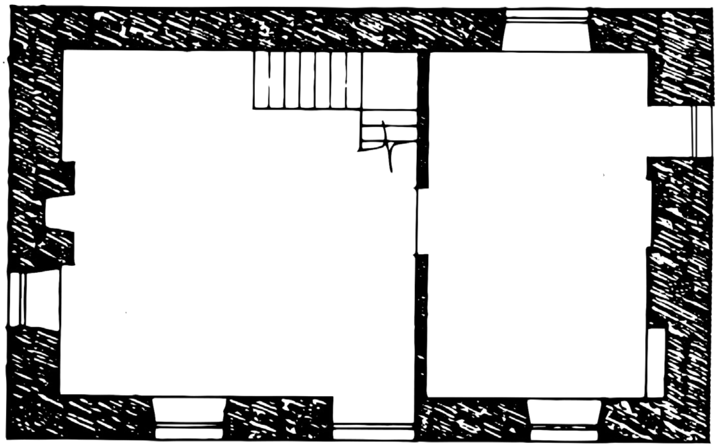
Pic. 1.8
Peter Segger
(sustainable-foodtrust.org)

Pic. 1.9
Anne Evans
(naturalhero-es.org)

The owners wanted the extension to express in architecture the organic vision which guides their farming. To build from materials produced on their land was the starting point. Where this was impracticable the materials were to be local - and if not local, at least environmentally benign. They also wanted a large space and walk through it and observe the outside. The Seggers met David Lea, the architect, because of the shared interest in green philosophy (growing food) and natural farming methods. Many years later they decided to assign him the project.

"They were ideal clients. We shared the same values about the environment and many other things too."[1]

1 Adam Voelcker, *David Lea. An Architect of Principle*, Artifice, 2015, p. 47



Pic. 1.10
Old Cottage - Ground floor - Scale 1:100 (drawing by David Lea)

Pic. 1.11
Old cottage -West Elevation
Scale 1:100 (drawing by David Lea)

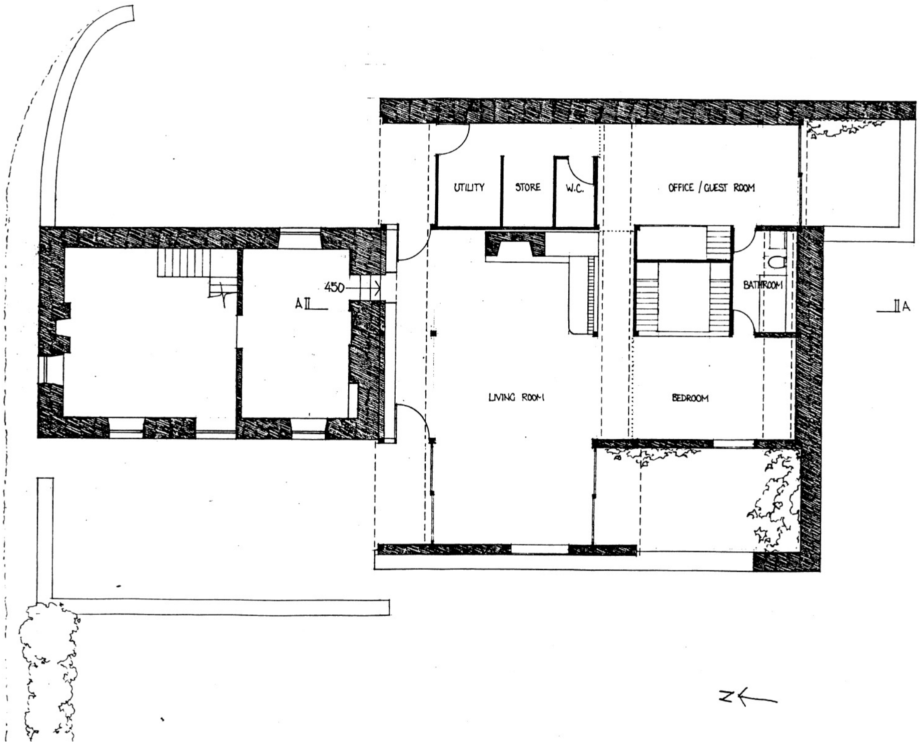
The old house was to remain Peter Segger said: *"Everyone builds on, renders and paints, and the old house disappears, but we didn't. We wanted to maintain the architectural history of the house and its characteristics"*.[1]

The old cottage was too tiny for five people; the Seggers wanted to change completely the comfort and the way of living the spaces. The family wanted a big opened living space where they could chat, eat and have a cup of tea together. Unfortunately the old building didn't provide enough space to allow these activities.
While they were working with the extension they were living in the cottage. They started to live in the entire house in 1999 as they thought the works were finished. Unfortunately, there were many problems with rain infiltration so the works finished, through the years, until 2006.

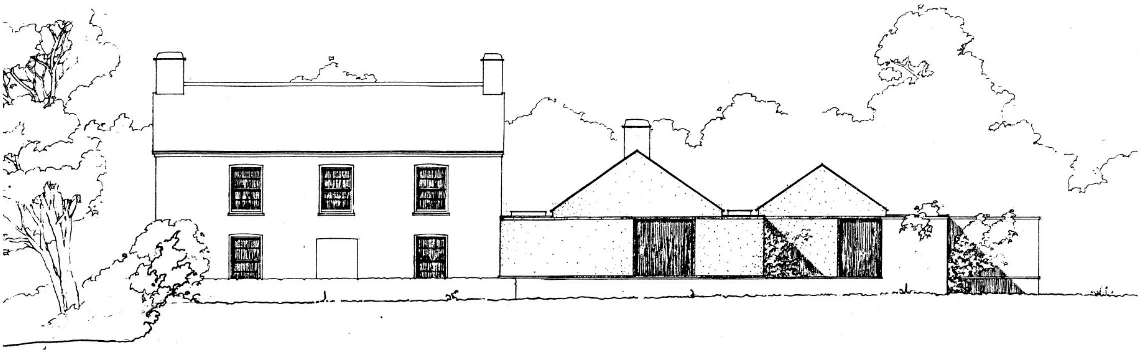
When the children grew up they moved to other cities to study or to create their own families so nowadays the only occupants are Peter Segger and Anne Evans. This is a huge house just for two people but it has been a resource in the past, when the family was bigger, because it behaves as they want.

From the outside to the inside the first look goes to the great and thick stone walls that encloses the house. Their function is to protect the extension but also are space garden dividers as little courts. They are thought as little rooms. It is also interesting looking at the slate roof: the extension one, that is composed by two roofs, is crossed to the cottage because of the structural forces and to have a spatial incessancy with the old house. Lea's idea was also to not have the same outlook from the house, so he decided to rotate the plan. Thanks to the beautiful landscape that change in every season (as Peter Segger explained me) the house has many facing to the external space.

1 Interview with Peter Segger (17th December 2017)



Pic. 1.12
Plan
Scale 1:200
(drawing by
David Lea)

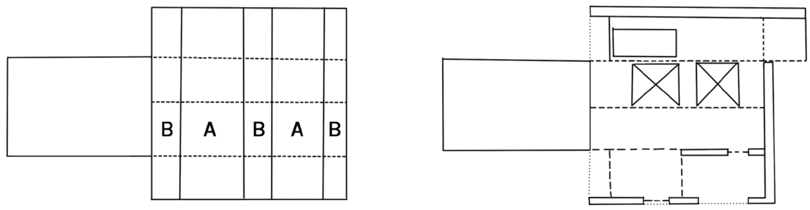


Pic. 1.13
West eleva-
tion
Scale 1:200
(drawing by
David Lea)

Pic. 1.14
the extension
seen from the
South
(Photos by
Fabio Vitale
for VilleGiar-
dini)

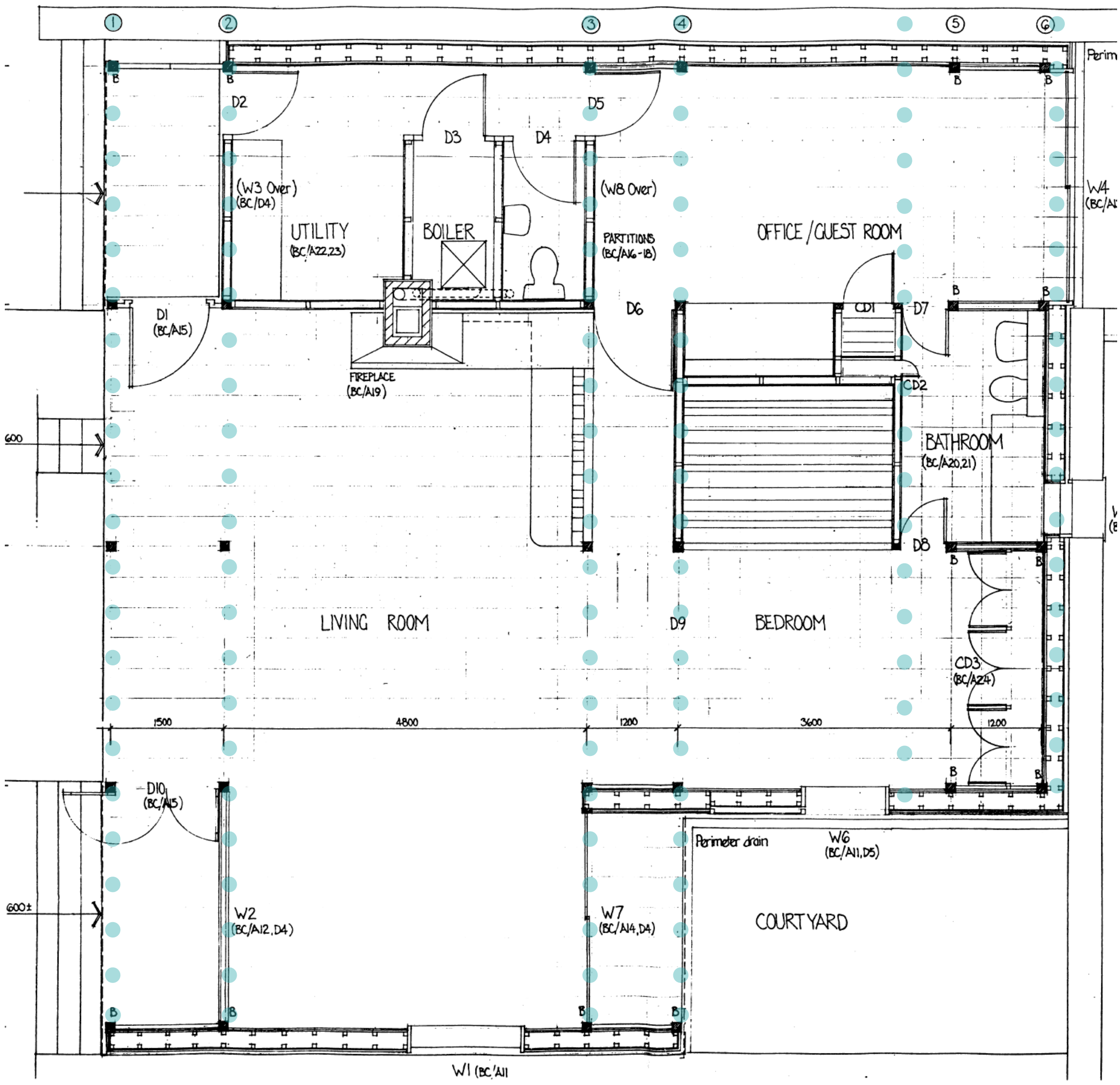
Peter Blundell Jones[1] related the internal space of the extension on his *New meanings from old buildings* Arq 5:
"*The structure is a green oak frame standing on an insulated concrete raft [...] Structural crosses, doubled oak columns, glazed areas of roof, and B-A-B-A-B rhythm (Pic 1.15) in the plan are all parts of the same Kahnian plan organization which produces two major volumes (under the pitches) and three minor ones. The larger of the two main volumes (A) contains the main living room, culminating in its fireplace and chimney. The other contains the new master bedroom and office. The narrow strips in between (B) – serving spaces in Kahn's definition – are low and daylit and also transitional. The one next to the old cottage produces the transitional space between the two buildings, but also two roofed porches to the sides. The middle one produces a passage and a further porch facing South. The end one captures light for the bathroom.*"

Pic. 1.15 Schemes of the composition of the house (drawing by V.B.)



The liberation of the frame from walls allows fully glazed bays, unthinkable in the technology of the old cottage, but the three pairs of glazed double doors bringing full modernist transparency do not open to the fields.
The only 'picture windows', in contrast treated as holes in the wall, occur in the West walls of the most important spaces - the living room and the bedroom. These are relatively thin rendered walls, deliberately contrasting with the thick solid stone walls growing out of the ground which interpret the setting. The rendered walls belong to the frame.

1 Was a British architect and architectural historian. He trained as an architect at the Architectural Association School, and held academic positions at the University of Cambridge and London South Bank University. He was a professor of architecture at the University of Sheffield as well as being a regular contributor to the Architectural Review.



Pic. 1.16
House extension plan
Scale 1:100
(drawing by David Lea)

Looking at the plan on pg. 28 we can describe it as a four bays space composed by a living room - that occupies the bigger part of the extension and face the garden on the South with a 'picture window'[1] (pic. below)- and a bedroom that has the same width of the cottage and takes two bays.
It has a double bed and a bathroom, the place of maximum privacy, with a tiny window. This room is composed by thin rendered walls - as the entire extension has - and it is separated from the living room by an oak sliding door.
The other big part of the house is the office/guest room it has also a double bedroom and is connected to the principal bathroom. The last part of the space is occupied by utility rooms - as the firewood boiler and a small little bathroom.
The kitchen is still in the cottage and it is on a different layer than the extension (look at the plan on pg. 23). The traditional building it is not used as much even if there host someone.

Pic. 1.17
West bay. A look from the living room (Photos by V.B.)

1 Word by Peter Blundell Jones

Pic. 1.18
West bay. A look from the living room (Photos by V.B.)

Pic. 1.19
The other side of the living room and the bedroom (Photos by V.B.)

Pic. 1.20 and 1.21 importance of light inside the house (Photos by V.B.)

The paln of the house shows the David Lea's interest in Kahn architecture in the alternating bays and the idea of served and serving spaces. He also has been influenced, during his career, with Mies and Wright and it is clear, in this house how they inspired him across the interpretation of the spaces through the walls - linear and minimal.

Pic. 1.22 and 1.23 lighting effect and chipboards frame (Photos by V.B.)

The Segger House is a great reminder of nature thanks to the wonders of the clients of making it with green timber. Lea discussed much with the Seggers about how the oak behaves and how much it might move. The idea to use their own timber was stronger that the possibility that timber might not work the way he wanted.

Pic. 1.24 Building under construction (Photo by Seggers)

The David Lea's building it a great example of reinterpreting its relationship with the surroundings. The cottage retains its identity and the extension give it a new vision merging the two part perfectly. The use of many windows and bays is different from their typical function, they are visually absorbed by the surround. In terms of light, structure and space concept it is clear how this new building is completely different to the old one and how they are in contrast. In wet Wales, it is most surprising that even on a dull day the strips of roof lights make the indoor space seem cheerfully bright. This is also true at night.
Lea reports: *"I remember Peter Segger saying he got up one night and wandered around the house, enjoying the moon and the stars, which he could see through the roof glazing"*.[1]

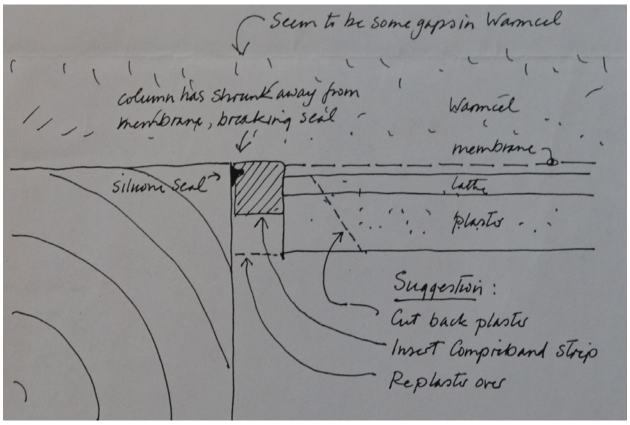
Pic. 1.25 and 1.26 Exterior of the house (Photos by David Lea)

1 Adam Voelcker, op. cit.

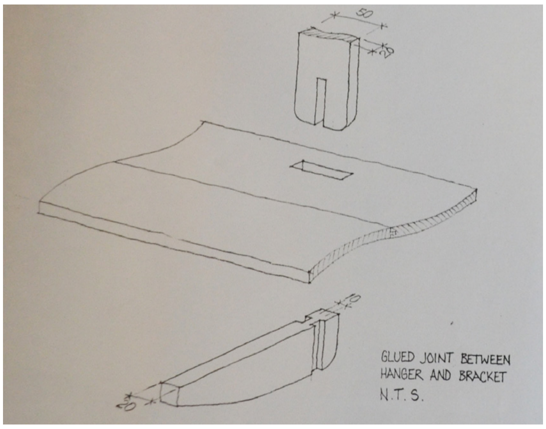
Materials and construction

Mature oak trees were felled from the property, and transported to a local sawmill. This timber was used as green for columns, beams, rafters, ties, transoms, sills and roof glazing bars. The structure is a ‘modern’ timber frame, calculated to use the smallest possible sections. A traditional frame would have used far more oak.

Almost every piece of timber in the building was described in schedules, however the constructor and the sawyer failed to translate the schedules into numbers of unstraight trees, until they had gone through the saw. This led to some supply problems. Below, some of these designs: window handles, shelf parts, windows details, seat details.

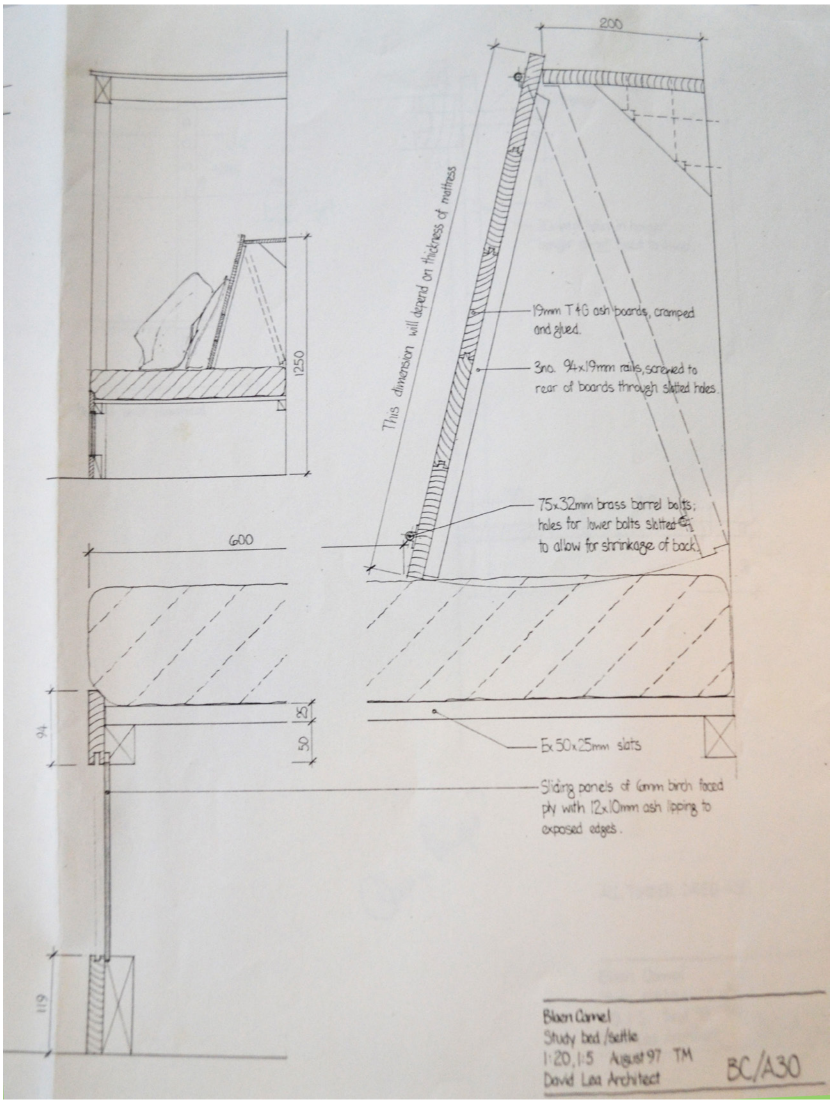


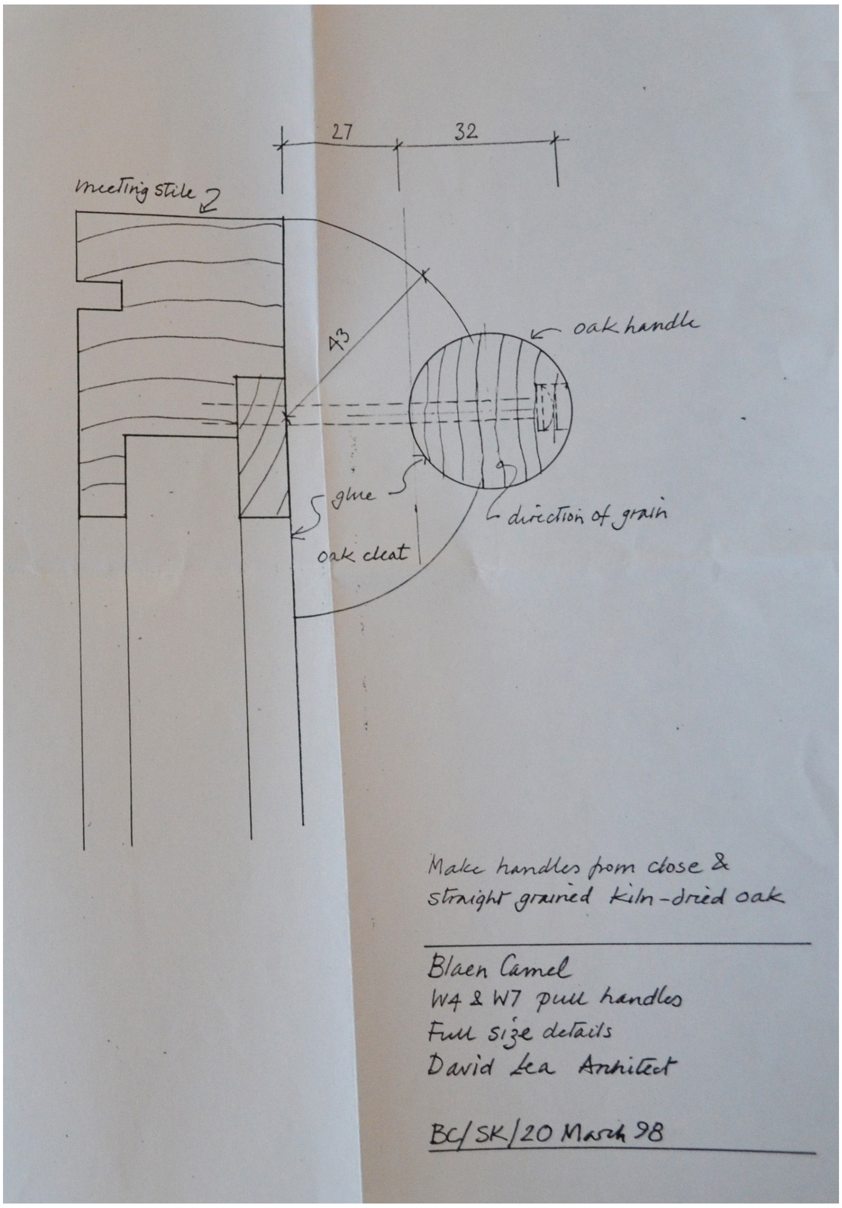
Pic. 1.27 Details of timber construction of a typical column/panel joint (drawing by David Lea)



Pic. 1.28 Details of timber construction: study shelves of dried ash (drawing by David Lea)

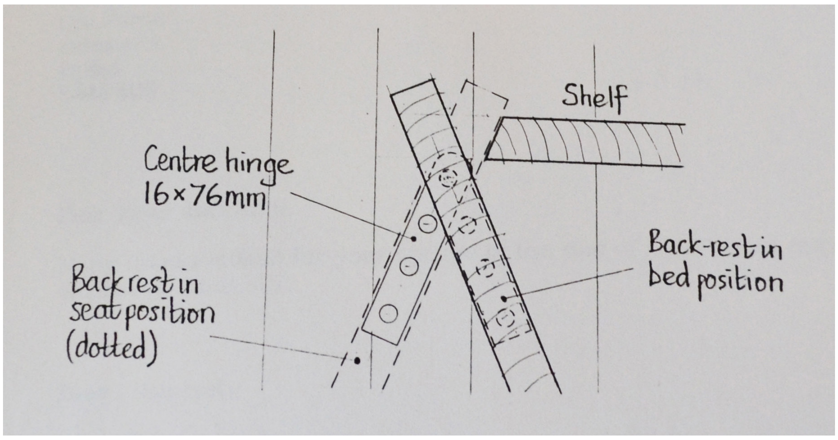
Pic. 1.29
Details of timber construction: study bed backrest (drawing by David Lea)





Pic. 1.30
Details of timber construction: pull handles (drawing by David Lea)

Pic. 1.31 Details of timber construction: a shelf in the study (drawing by David Lea)



The thickness of 200 mm insulation in the walls, and 300 mm in the roof was provided by paired softwood studs, fixed to the outside of the oak frame. The external walls, built of stone from the re-opened quarry across the stream, wrap and protect the insulation. Originally conceived as a dry assembled rain screen, the stones were actually bedded in mortar because modern wallers found this method easier.

The perennial problem of frame buildings - the relationship between column and wall - has challenged architects since building began. The thickness of the insulation layer required to obtain an energy efficient building has complicated the problem in recent times. The obvious position for the timber frame is at the centreline of the insulated wall. However at Blaencamel the owners wanted the oak frame to be visible internally and so it was placed at the inner face of the cladding. Thus the vapour check membrane had to be sealed to the oak posts at the edge of every panel to prevent warm air leaking from the building, and possibly condensing in the cavity. The builders had to attend to this very carefully.

Pic. 1.32
deformed ash
wood
(Photos by
V.B.)

Local materials have been used. The green oak frame was cut from the clients forest nearby, the garden walls are of local stone, the roof covering of Welsh slate. Polished slate is also used for sinks, sills and some flooring finishes. Both the timber battened walls and the roof are heavily insulated, mostly with local wool, though some warmcel[1] (recycled paper) was added when wool supply ran out. Peter Blundell Jones told in *The fragrance of timber* that those materials help to restate the house to the locality, and lime wash on lime render produces a natural wall surface without the artifices of modern paints. Lea is adamant about leaving untreated timber to age, as preservatives arrest the natural ageing process and are toxic.

Pic. 1.33 Trees felled from the owners forest (Photo by Peter Segger)

And he also said that if the most visible materials are local and traditional, this is not the case with all of them. Large double glazed windows are chosen, as well as low-E double glazed units for the rooflights and laminated glass panels. The gutters are lined with welded stainless steel and the flashings done with lead sheets. Heating is supplied by electric pumps through an under floor system of plastic pipes. Numerous details could only belong to the late 20th century.

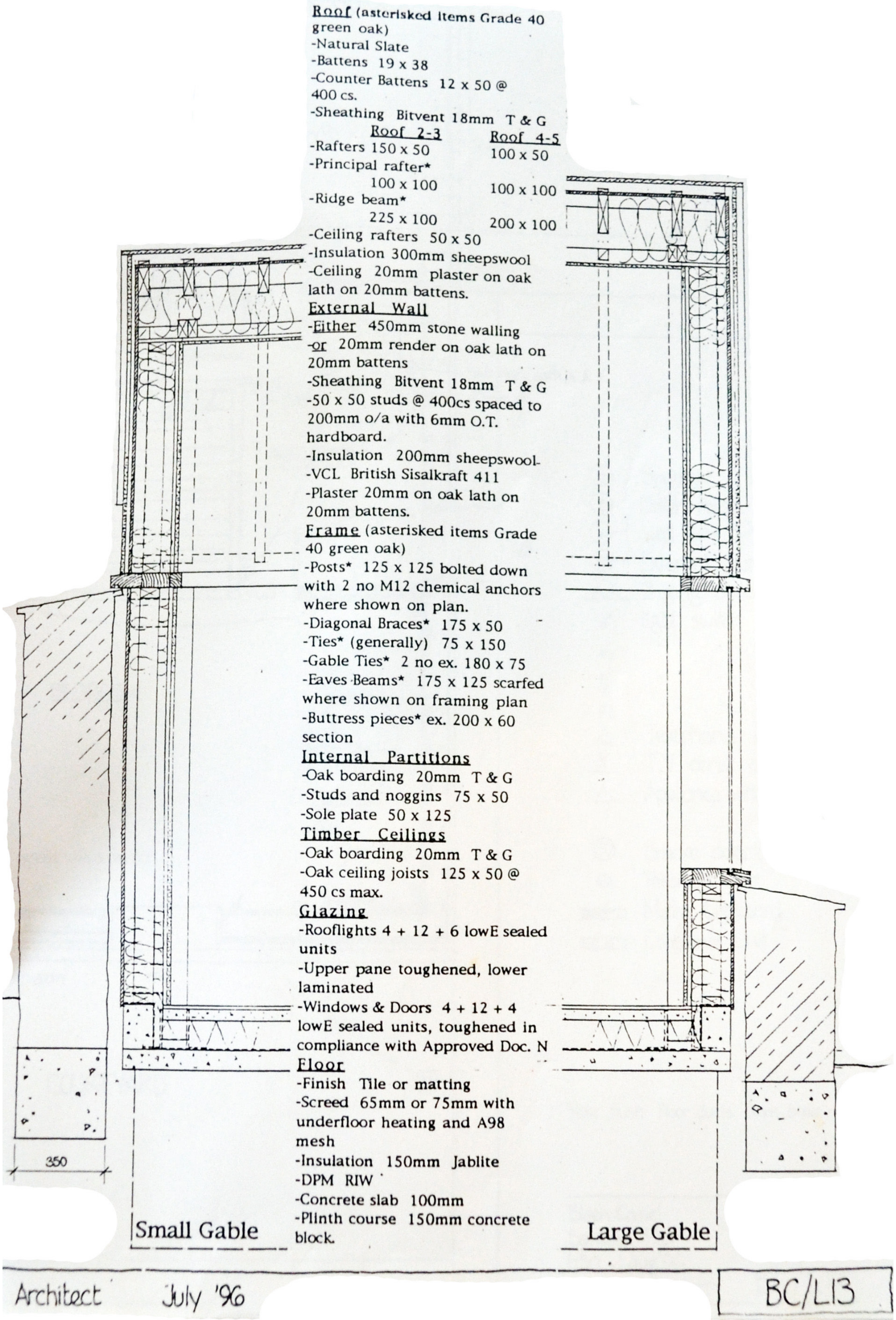
1 See attachment B for specifications about the material

The 75% (by weight) of materials are local - less than 20km from the property -, all of the wood, the wool and the stones used in this project are from the property; 15% came from Wales; and the remaining are from 100 km away or more.

Joining David Lea's working architectural composition, light and spaces and Pat Borer's green way of building it is interesting to see what a complete building came out.

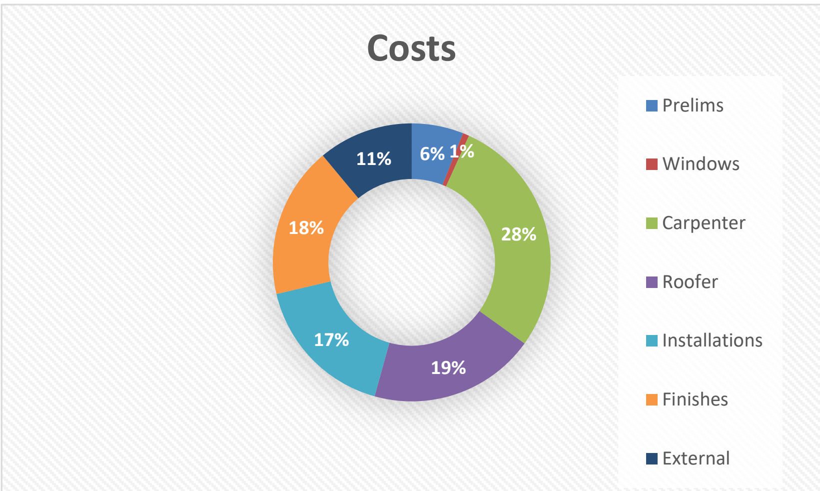
Patrick Borer was called in as consultant for details.
Borer's idea, as he explained during my interview, is that architects want to build in concrete because it simpler, vesatile, strong and durable. But no architect with green credentials can build in a material with such a high embodied energy and environmental impact. Environment friendly materials are attractive and a great alternative. This house is a great example of his knowledge in local materials and green architecture: his interest for green wood and living materials show us his huge knowledge in environment and his idea of a building that 'breaths' and 'lives' with the occupants demonstrates he really care about environment. To use green oak with no treatment and lime match perfectly both the owners and architect design.

Pic. 1.34
North and
East sections
walls
(Drawing by
David Lea)



PV panels placed on the land around the house produce electricity for the house itself and to other buildings - used for farming - in the estate. The consumption is about 15,000 kWh/y. [1] It is interesting to know that electricity is not used for heating. The Seggers have an underfloor heating system in the extension but in the old building radiators were preserved yet they are not in use now because the only room lived of the cottage is the kitchen.
The Seggers use a oil and firewood fulled boiler to produce hot water for heating and domestic use. The decision to switch from an oil-fuelled Yorkstar condensing boiler to a Hertz state-of-the-art fire-wood and oil boiler was taken in order to take advantage of the huge amount of wood produced by their woodland.
Unfortunately, they don't use it completely. They discovered that their firewood was too moist and didn't work as they thought. So they, now, have to burn oil - 1500 l/y[2] - to obtain the amount of hot water they need. This worsens the impact of the building.

I was able to obtain information about the cost of the house extension through the bills of quantities kindly provided by the owners.



Pic. 1.35
Cost (%) divided by work (Graph by V.B.)

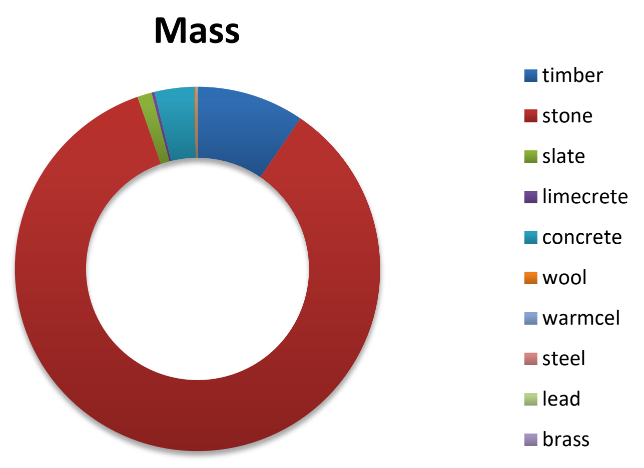
1, 2 Data provided by the owners

As it is shown in the graph above the costs seem well distributed except for the windows part: The windows just include glass costs because all the wood parts were provided by the owners, labour is under the 'carpenter' heading.
It's important to remark that the carpenter's costs don't include the wood cost - except for its form cuts - .

Pic. 1.36
Cost (£) divided by work done
(Graph by V.B.)

Costs	£
Prelims	6,147.21
Windows	754.70
Carpenter	28,723.61
Roofer	19,788.04
Installations	17,382.79
Finishes	17,962.72
External	11,276.95
Total	102,036.02
£/m²	850.30

Thanks to the information given by the owners it has been possible to calculate the amount of materials used in the construction and from these, the Embodied Energy and the Embodied Carbon of the house (extension).
It is clear, that timber is one of the most used materials (about the 10%of weight) in this building.



Pic. 1.37 Materials employed in the building by mass (Graph by V.B.)

The embodied energy of human made objects is used as a indicator to assess environmental impact. Connected with the pressing issue of climate change, embodied CO_2 analysis allows some understanding of environmental impacts, and is linked with embodied energy analysis by the component of emitted carbon dioxide (CO_2) from most energy sources.

The principal source of CO_2 in building materials is the combustion of fossil fuel in their production, or the use of ingredients or energy sources that in turn require a significant use of fossil fuel. In our case study, all the energy required has been studied in the way of reduce waste as much as possible. An important example is given by the wool data. EE has been calculated from two sources: the ICE (Inventory of Carbon and Energy, 2011) of the University of Bath and the ÖKOBAUDAT platform by the German Federal Ministry of the Interior, Building and Community. Wool came from the Seggers sheep and has been just shorn and washed.

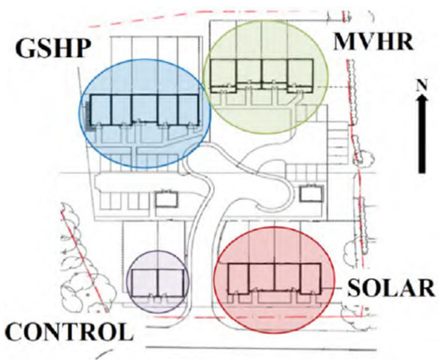
Every conversion has been made local and no fossil energy has been used except some water or electric energy. Another significant data is the timber one because its value is lower than what the database suggests (7.4MJ/kg). The EE is provided by an average between the two databases and considering the very least usage of energy. The green oak, has been just cut and added to the construction. The Seggers wanted to see how those pieces of wood could live after his transformation and through the seasons and the years.

Pic. 1.38
EE and EC list
(Graph by V.B.)

Materials	Mass (kg)	EE (MJ/kg)	EC ($kgCO_2/kg$)	EE (MJ)	EC ($kgCO_2$)
timber	11,426.71	0.01	0.60	91.41	6,856.03
stones	102,000.00	1.26	0.07	128,520.00	7,446.00
slates	1,536.92	0.50	0.02	768.46	30.74
limecrete	316.17	5.30	0.76	1,675.70	240.29
concrete	4,240.80	0.75	0.10	3,180.60	31.62
wool	198.00	0.26	0.00	1,102.61	0.00
warmcel	60.00	1.60	0.40	96.00	79.20
steel	33.53	21.10	1.37	707.48	45.94
lead	7.60	25.21	1.57	191.60	11.93
brass	3.40	44.00	2.46	149.60	8.36
Total (kg)	**119,812.13**	**99.99**	**7.35**	**136,483.46**	**14,750.10**
Total (kg/ m^2)	**998.43**	**0.83**	**0.01**	**1.67 GJ/ m^2**	**122.17 $kgCO_2/m^2$**

The tabular values come from the ICE (Inventory of Carbon and Energy, 2011) and are multiplied to the mass column for each factor. The result of this calculation has been compared to Harpa Birgisdóttir, 2016[1] with the Lingwood case study. It consist of 15 houses (as in the infobox in the next page) in Lingwood, UK, built in 2008. The entire cost of the project was 1,7m pounds and provide each flat with 71 to 83 m^2
It can explain if our case study can due to a 2008 example (10 year later that Segger house).

1 see Attachment B p.



BUILDING KEY FACTS

Intended use: Housing (affordable rent/shared ownership)
Two house sizes: 71/83 m² internal floor area
Location: Lingwood, Norfolk, UK
Building year: 2008 Cost: £ 1,7m
Design and construction by Flagship Housing Group Ltd
Project phase studied: Design and Construction
Structural material: offsite engineered structural panel timber frame

Pic. 1.39 and 1.40 Lingwood masperlan and its EE and EC (Harpa Birgisdóttir)

Pic. 1.41 Lingwood buildings details (Harpa Birgisdóttir)

It is possible to compare the two buildings - lingwood and Blaencamel -, although they have different uses, because they are both new constructions and are built with similar materials.
As it is shown in Attachment B our case study can be a good example of low-E building: the EE results are less distant from and EE value of the example building (it has been made an average of square meters and EE archivement). If we consider that Lingwood, - composed by 15 houses - cost £1,7m - each house £113.000 and is smaller than Blencamel - we can observe that David Lea's extension is less expensive. We must also consider that Blaencamel is, at least, 10 year older than Lingwood so it is interesting how the difference between both are so little.

Total Primary Energy consumption:

Scenario 1: 5.7 $GJ/m^2_{usable\ floor\ area}$

Scenario 2: 7.7 $GJ/m^2_{usable\ floor\ area}$

Scenario 3: 8.2 $GJ/m^2_{usable\ floor\ area}$

Embodied greenhouse gas :

Scenario 1: 405 kg $CO_2/m^2_{usable\ floor\ area}$

Scenario 2: 535kg $CO_2/m^2_{usable\ floor\ area}$

Scenario 3: 612 kg $CO_2/m^2_{usable\ floor\ area}$

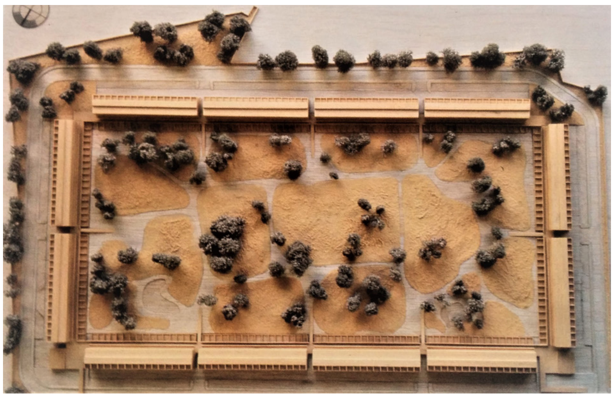
About the Total Primary Energy consumption it is important to notice that our values are based on the ICE that has an average values for each element so it can be difficult to be precise with all treatments and transformation processes. However, it is calculated that in Lingwood, we have EE of 5.7 GJ/m^2 that is more than in Seggers have. Also the EC in our case is drastically lower, most likely for the constructing methods adopted and the locally benign materials used.

The attachment shows that Lingwood is 26% lower embodied energy than a masonry house so the Segger's is even better. Otherwise the CO_2 amount is difficult to compare because the two buildings have different functions but it is possible to say that natural material are healthy and help people to live and breath cleaner but also that David Lea methods anticipated in 1997 a way to build that had and has brilliant results and can be applied nowadays.

David Lea
Life and ideas about architecture

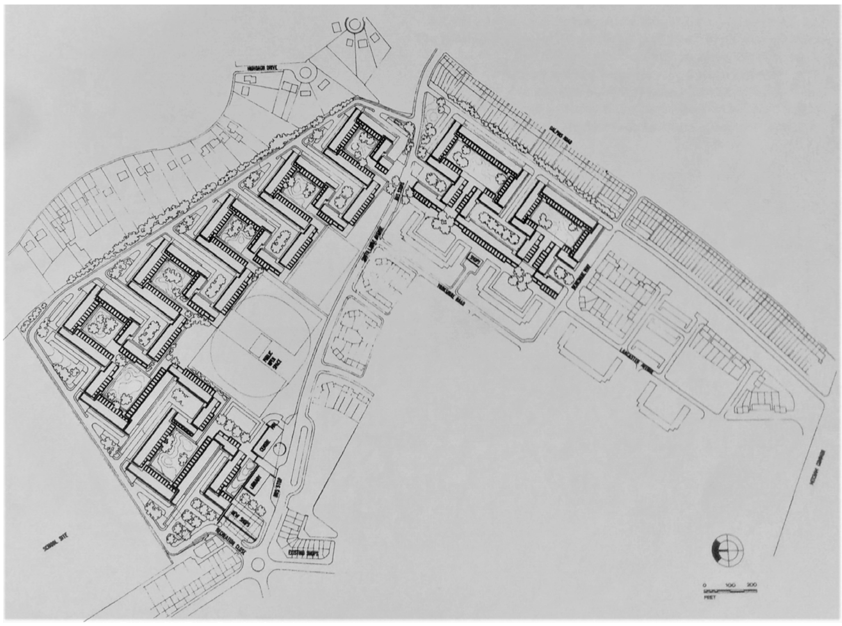
The architectural life of David Lea started when he was 13 and entered Clifton College in Bristol where his interest in art gradually grew up thanks to a very good teacher who thought that architecture was an important part of the historical aspect. When he was 16 he decided to became an architect. In 1959 he went to Cambridge to study architecture where Sandy Wilson and Colin Rowe had a very direct influence on him about the deep sense of history, of architectural history and historical context. The other important thing for Lea was the courtyards: it is a part of historical sense – partly with collegiate courtyards and, in bigger scales, part of planning urban space – of buildings as containers of urban space rather than objects in the landscape. After his Cambridge studies he moved to London – where he lived 1967 and 1975 - where most young architects felt to contribute to local authority housing.

Pic. 1.42 David Lea (www.bdonline.co.uk/life-class-david-lea/5012301.article)



Pic. 1.43 Maquette housing, London Borough of Merton (from Adam Voelker- David Lea. An Architect of principle photo pg. 67)

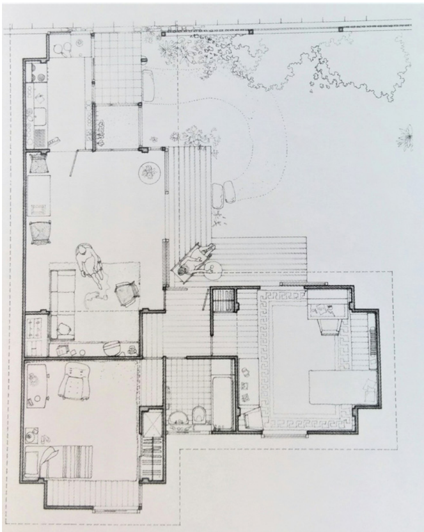
He started working with Richard MacCormac on a social and architectural vision on people's needs in new housing and how relationships were built up. So they tested the perimeter development theories about density designing at an urban scale. This was the first time when Walter Segal's ideas appeared in David Lea's mind. Then, he started to escape from brick architecture and develop the timber-frame.

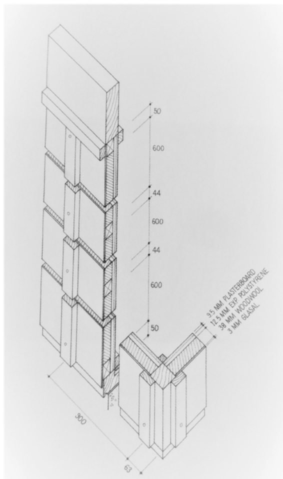


Pic. 1.44
Plan housing, London Borough of Merton (Adam Voelker- David Lea. An Architect of principle photo pg. 67)

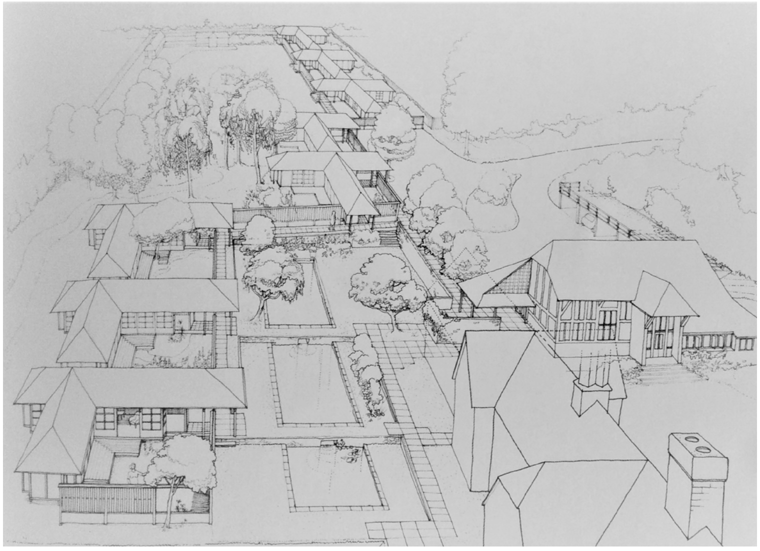
At this point he started to develop his knowledge on natural materials he introduced himself to the Japanese architecture where he focused similarities with Walter Segal: lightweight timber-framed constructions that were rational, very well worked out, simple and minimal. The natural ageing and weathering of timber, especially oak, is a beautiful process which results in most harmonious colour.

His own conviction, based on experience and observation of ancient building in Britain and Japan is that sealing timber against the weather is unnecessary, not only for oak, but also for most softwoods, provided that the construction in designed not to hold water in any joint. An example of this aspect is the Sheltered Housing in Churt, Surrey, that had a free grid plan so each building can be different from any other, but used standardised components. David liked the idea of flexibility of the spaces.





Pic. 1.45, 1.46, 1.47, 1.48 Sheltered housing, Churt: plan, two details of the house and a wall detail (from Adam Voelker- David Lea. An Architect of principle photo pg. 70)



Pic. 1.49 Sheltered housing, Churt, bird's eye view (from Adam Voelker- David Lea. An Architect of principle photo pg. 69)

After this first project, many others came. These showed similarities to the Japanese architecture as Bledisloe Court at the Royal Agricultural College and the WISE building at CAT, Machynlleth.

Pic. 1.51 Bledisloe Court, Royal Agricutural College, Cirencester (from Adam Voelker- David Lea. An Architect of principle photo pg. 82)

He is also passionate with F.L. Wright using very simple construction to achieve important flowing lines and spaces in an extremely inventive way, the brilliant planning with many spatial connections, the sites and their surround gardens and generic in environment.

Pic. 1.50
David Lea's house, Ogoronwy (drawing by David Lea)

In the '70s some idealistic people were moving to the country and buying smallholdings and starting their 'agricultural' careers. So did David Lea. He chose Ogoronwy in North Wales where he settled in 1976. There, he could focus on the harmonious connections between working with hands and head, people and nature.

Pic. 1.52
David Lea's house, Ogoronwy (photo from Adam Voelker- David Lea. An Architect of principle, pg. 78)

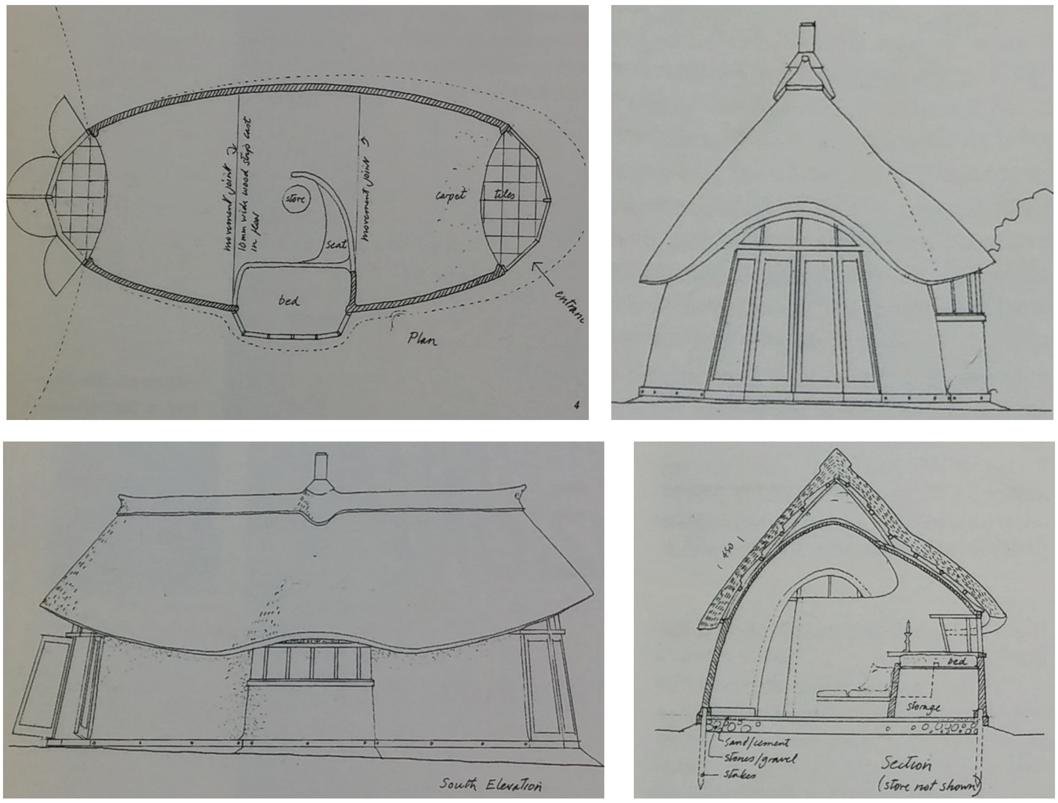
Moving to Wales he was immediately involved in the CAT where he met Pat Borer and started their cooperation. At the beginning they worked together inside the site: designing and planning the funicular railway stations – the lower by David Lea and the higher by Pat Borer -, the AtEIC building. Pat Borer became his technology mentor in many of his projects.
Lea's architecture is the art of organising the space, defining space by structure and showing forth structure in light.

Pic. 1.53
WISE building
(photo by Pat Borer)

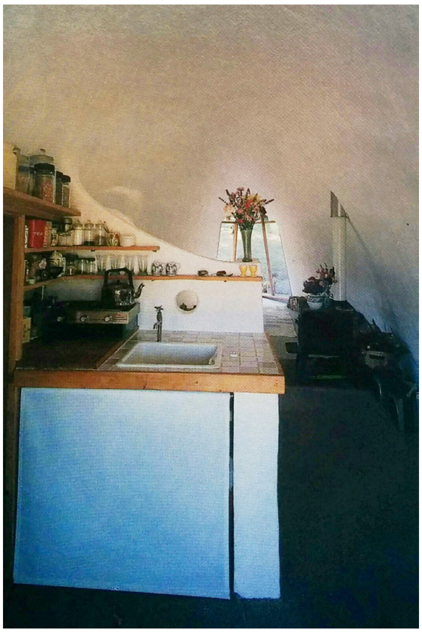
Pic. 1.54
AtEIC building
(photo by Pat Borer)

Another characteristic building by David Lea is the Artist's Studio in Somerset, 1988. It has been built by the owner itself, as Lea said me, with just 3.300 £. Its boat-like shape is the result of a construction system based on the use of small timbers and they have used untrimmed to preserve their structural integrity. The walls are filled with straw and covered in chicken wire than rendered in a sand/cement/lime mix. The roof is thatched with wheat-straw on thatched battens. Lea wanted the thatch to have a really strong, swooping eaves line like Kiomizu-dera in Kyoto.

This is one example of David Lea's design, though by it seems no typical Lea's one, that show his interests and attitudes. The minimal design and the way it has been built demonstrate the deliberate elimination of superfluity. About materials, concern for the plant leads, Lea toward renewable and preferably local resources, away from products which are toxic or require a large energy input in manufacture.



Pic. 1.55
Plan, section and elevation of the Artist Studio in Somerset (drawing by David Lea)



Pic. 1.56 and 1.57
Plan, section and elevation of the Artist Studio in Somerset
(drawing by David Lea)

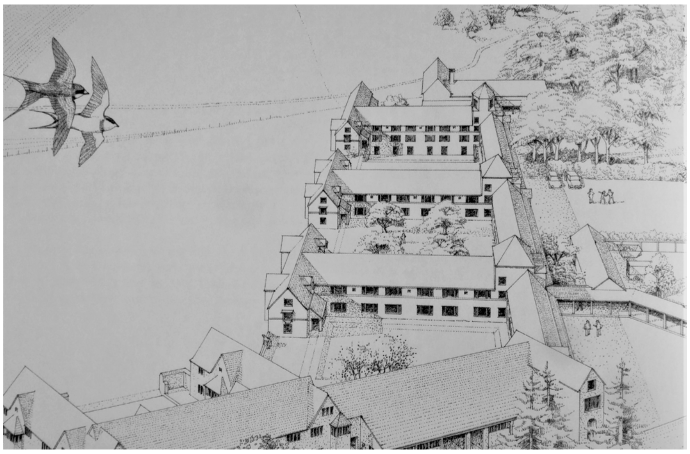
The building is now used as an occasional holiday hut by the family. It has a small kitchen and woodburning stove. Water is brought into the house in bottles, there is no water system.
David Lea idea was a building very economic lightweight rural housing - using this method - but relatively short-life: the studio has been up for more than 30 years now and has just been re-thatched.

Pic. 1.58
Artist Studio in Somerset
(Photo by David Lea)

David Lea describes in Adam Voelcker's book that people, space, light, materials, structure, services, cost, must all be brought into harmonious relationship; each aspect contains further sets of potential relationships, for example between inner space and the space of nature, public and private space, sheltered and open space. The architect is constantly evaluating sets containing different classes of things. In designing, for example, a rooflight one might consider quantity and quality of light, psychological effect, heat loss, water tightness, construction, durability, cost etc. The value given to each of these things will depend on the viewpoint of the various observers and their own relationship to the total project: client, guest, critic, architect, builder, or building inspector.

What is truly remarkable, and a great cause of celebration, is that, in general, there is a great deal of agreement that he has a great architect.
This is shown by his long career with all his projects, althought most unbuilt.

Pic. 1.59, 1.60, 1.61 Coad Court (from Adam Voelker- David Lea. An Architect of principle pg. 102)



Chapter two

Data	
m²	280
rooms	14
£	348,000
£/m²	1,357
start work	2007
end work	2015

Peniarth Uchaf building

The project consists of the regeneration of a typical Welsh barn. The Joneses, the clients, wanted to convert this barn into an house because the cottage, where they lived, was too small for them so they decided to use the barn next to the house to expand their house.

Pic. 2.1
Map of Wales

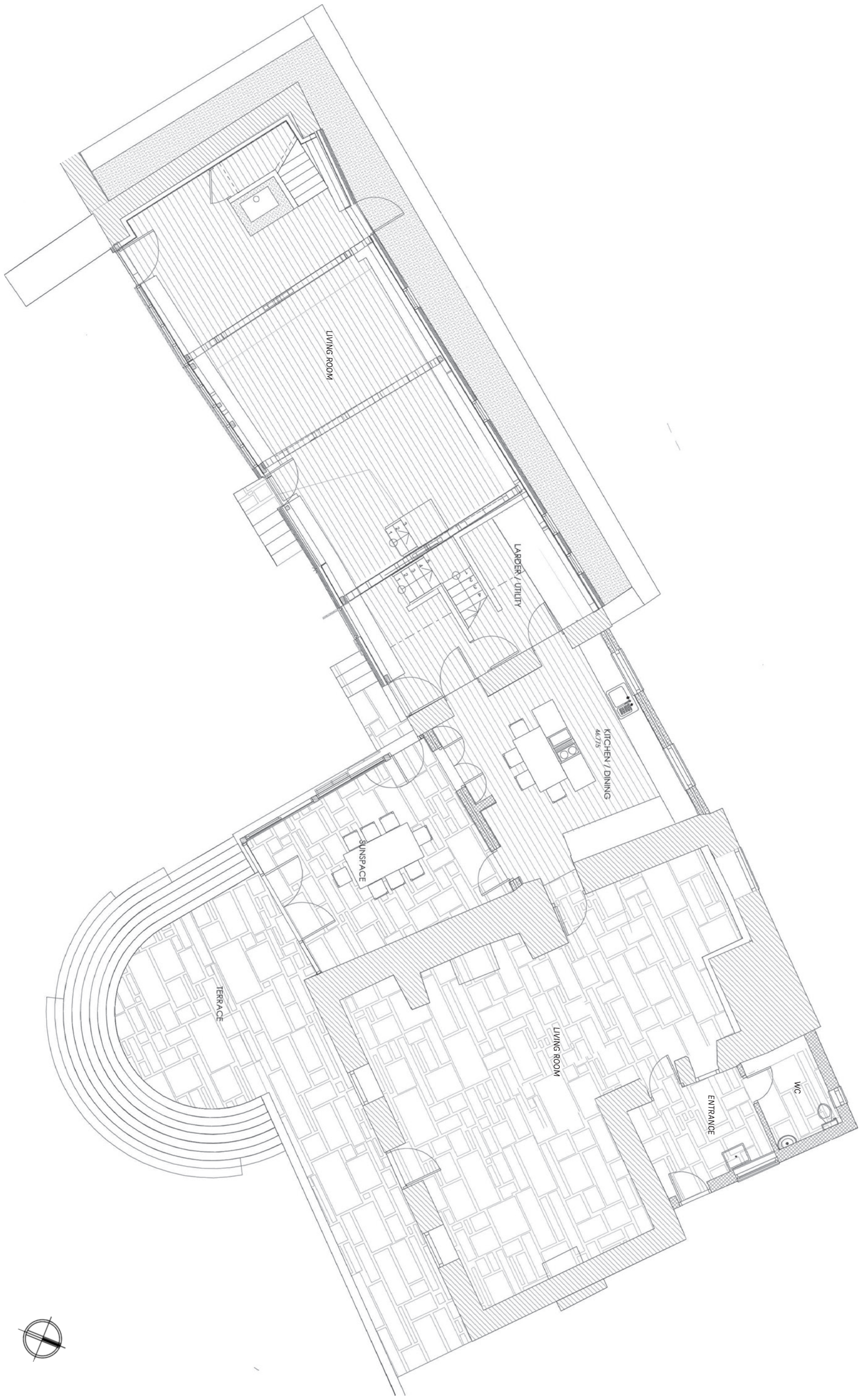
The house is in Powys, at the top of a hill called Peniarth Uchaf. It is surrounded by hills, mountains, woods and fields. Studying the wood trusses of the barn it appeared that it was built in 1594. With some studies, just one alteration is known: in 1750 the stone facade wall must have been transformed, because the new front home wood is newer than the others. The family bought the entire estate – cottage, barn and land – in 1986 and moved in 1987. From that date on they have always been living in the building, even during renovation work.

Pic. 2.2
Old cottage
(Photo by V.B.)

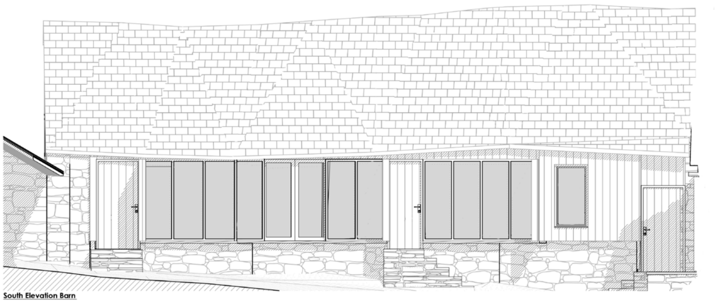
Environment and history had a strong influence on the owners. They wanted to keep the barn as much in the original condition as possible and also use local materials. They decided to involve Patrick Borer because of his 'green' architecture:

"Pat suggests only that all architects always want to build in concrete because it is simple, versatile, strong and durable. But no architect with any green credentials can build in a material with so high an embodied energy and hence environmental impact (not to mention the aesthetic limitations). More environmentally friendly materials such as hemp-lime are an attractive alternative. Projects with a timber frame and Hemcrete, a blend of hemp shiv and lime based binder creates breathable, highly insulating low-cost walls."[1]

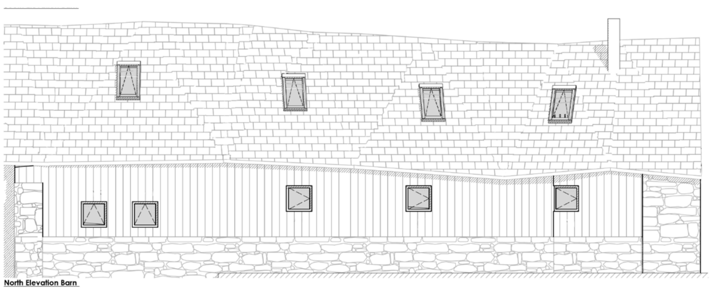
1 of Kelvin Mason, Icon of green building: interview with Pat Borer, Green building, vol. 21, no. 1, 2011 Summer, p. 24-28



Pic. 2.3
Plan
Scale 1:200
(Drawing by
Pat Borer)



Pic. 2.4
South-East barn facade
Scale 1:200
(Drawing by Pat Borer)



Pic. 2.5
North-West barn facade-
Scale 1:200
(Drawing by Pat Borer)

The extension was to be used as a wide, open-space living room capturing as much natural light as possible, and would have been a warm place to be, in spite of the glazed walls.

The first problem to solve was the connection between the old barn and the cottage. Borer decided to build a volume in between, with a kitchen at the ground floor and a small bathroom and a storage room upstairs. After he presented the design to the owners, the Joneses demanded him to enlarge the kitchen as there was no space enough for the whole family.

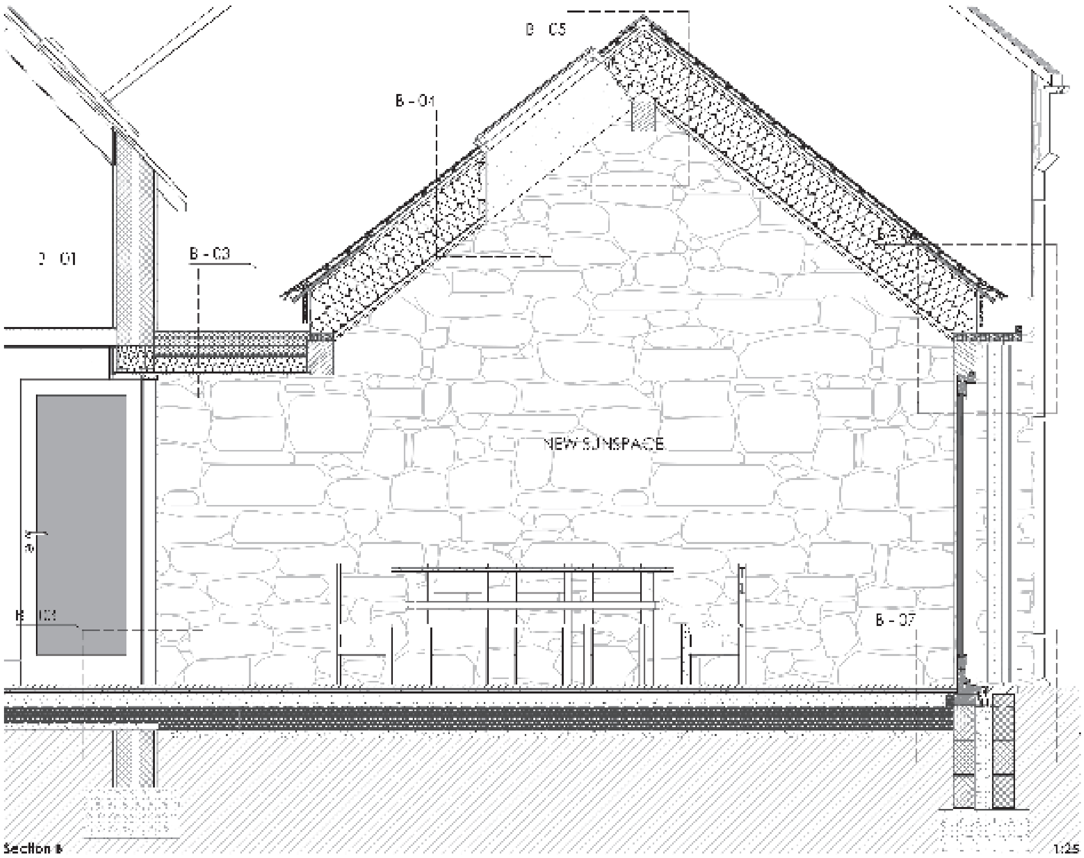
Borer's idea was to create a new space inside the house not only useful as a dining room but also as a place to stay and spend leisure time. So he conceived a sunspace in order to be delighted by the nature around the house both in summer and winter and avoided tiny windows that inhibit the outlook. The extension has just one side attached to the old cottage, the other three are glass walls (the one that separate the sunspace from the kitchen it is in glass too as shown in the photos of attachment C).

Pic. 2.6
Sunspace
(Photo by V.B.)

This space is also important because it provides heat to in all the surroundings rooms - works exactly as a greenhouse -. It has its own roof that is connected by a flat roof with the barn because of the rainy weather and to connect the two spaces with the easily way. It is filled by old slates from the building's and new ones from a nearby quarry. Also the North-East wall of the cottage, on the upper part, is covered by slates to protect from the heavy rain that comes from the East in every season. The lining has been made some years later the end of the external works.
The timber wasn't treated and now it is possible to see, on the South facade, how the sun damaged the timber frame. This process proves that it has been lived through the years in a very natural way. Use untreated timber in buildings poses no health risks to the user and can help to regulate the humidity of the indoor environment. Wood is warm to feel and touch and has a very interesting aesthetic appeal.

FLOOR:
-20mm tiles on thin bed
-100mm mass concrete slab with underfloor heating pipes and light mesh reinforcement
-VCL/Radon barrier
-150mm polyurethane foam insulation (100mm in kitchen)
-DPM
-Blinding and hardcore
U-Value: 0.15W/m^2K

FLAT (LINK) ROOF:
-Butyl rubber or EPDM single layer membrane on fleece
-150mm polyurethane foam insulation to falls
-300mu ploythene VCL with taped joints
-12mm plywood sheathing
-100 x 50 joists at 400mmc/c filled with Warmcel insulation
12.5mm plasterboard & skim
U-Value: 0.13W/m^2K



EXTERNAL WINDOWS AND DOORS:
-Laminated Oak frames and doors
-Multipoint locking
-Low-E glazing 4-16-4 or 6-12-6 with soft coating, inert gas fill and thermal edge spacers.
U-Value: 1.5 - 1.2W/m^2K

FOUNDATIONS:
-150mm thick concrete strip footing at minimum depth of 900mm
-Plinth walls of 140mm concrete block inner leaf and 300mm nominal stone outer leaf

Pic. 2.7
Sunspace Section and material details
Scale 1:100
(Drawing by Pat Borer)

Just beside the final wall of the barn there is a mezzanine with a balcony (this wasn't in the original project; it was built years later and was also designed by Pat Borer). The Joneses wanted to overlook the West side of the valley too.

Pic. 2.8
The balcony mezzanine (Photos by V.B.)

During the construction there were many problems with water. As said before, the house is placed at the top of a hill, and all the rain water flows to the base. To avoid water infiltration and moisture they digged 50 cm down on the North side and built a wall in order to protect the house (Attachment C). To prevent problems after they found water under the floors they decided not to dig in the kitchen but to place the new slab up on the older one.

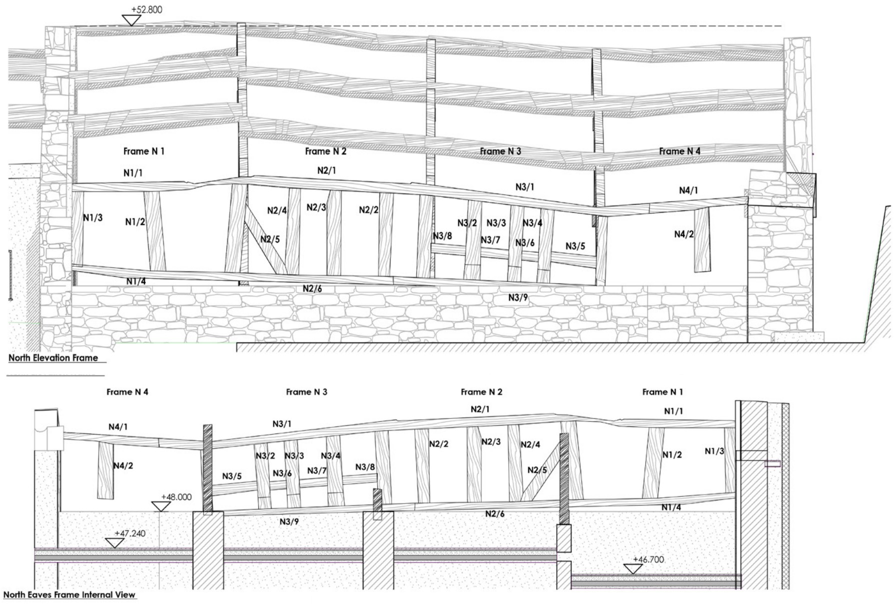
Pic. 2.9
Water infiltration during the extension works (photo by Peter Jones)

The house is composed by three parts in chronological order of built: the old cottage (in red in the plan below), the 'link' (in green) - kitchen and dining room - and the barn (in yellow) with the sunspace. These parts lay on different levels, so there are some steps to connect them. When the construction started, in 2007, the owners didn't mind, but now they point it out - clients are getting older and as time passes, it will become difficult for them to climb stairs.

Pic. 2.10
Plan description
no scale
(drawing by Pat Borer)

An other issue was the roof. The owners' intention was to maintain all the old trusses and also the final wall of the barn. The National Heritage required the ash wood frames to be reinforced and not demolished. The damaged beams had to be substituted with others from a old barn nearby. A new roof had to cover the middle, new part of the house and the barn but this was not possible because the walls are not parallel to each other. So, Borer decided to split the sunspace from the rest of the building and give it a separate roof with a flat part connecting to the barn. The visual merging is obtained by using the same material throughout: slate.

Pic. 2.11
Barn trusses
(drawings by
Pat Borer)



Pic. 2.12
Barn during
renovation
(Photos Peter
Jones)

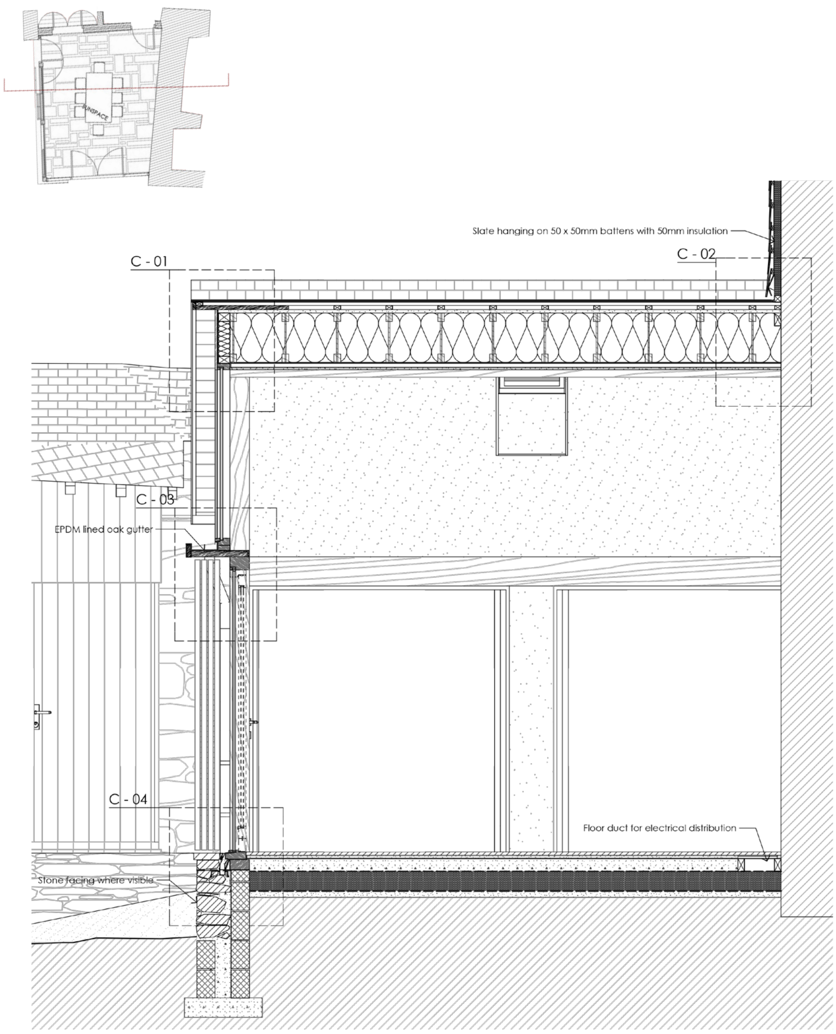
Another problem were the trusses. They were badly damaged by the moist weather and hadn't enough structural strength so they had to be reinforced. This was obtained inserting steel bars, hidden in the beams. The builders took the three frames from the barn, they adjusted and cut all their ends and built concrete blocks as base (disegni?!). They saved as much timber as possible, the plinth height varied in accordance with the length of the surviving frame.

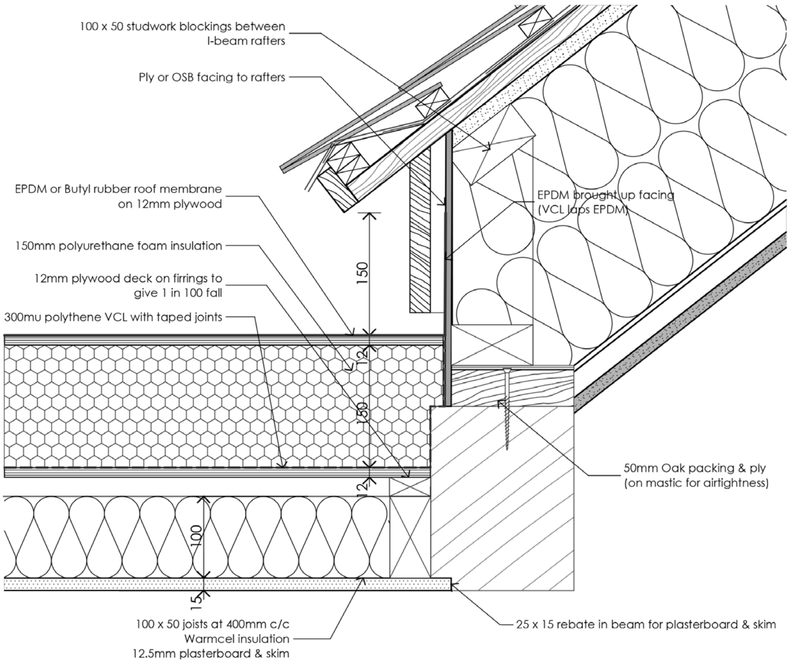
Pic. 2.13, 2.14, 2.15, 2.16 Trusses adjusted and concrete blocks (Photos by V.B. and Peter Jones)

Materials

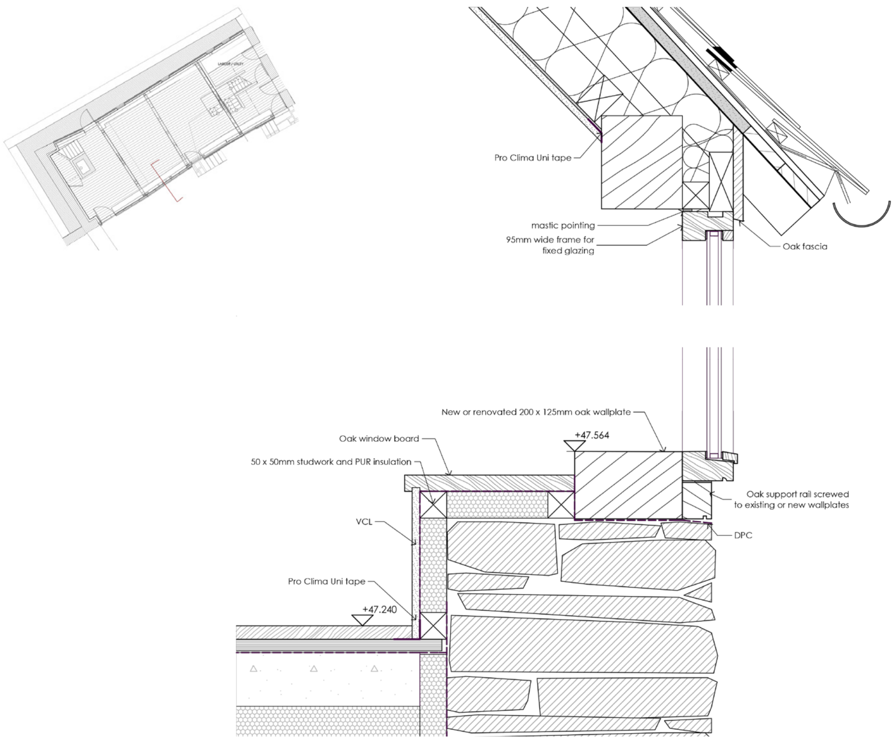
The extension is composed by insulated timber framed walls outside existing oak frame and lime plaster. This happen mostly on the North-West facade, because the South-East one is glazed with oak shutters. The insulation is Warmcel; the South-West stone wall has an insulated dry lining to prevent moisture. The greater thickness of insulation that can be contained within a given wall depth compared to a masonry construction.

Pic. 2.17 Sunspace detail (Drawing by Pat Borer)





Pic. 2.18
Flat roof detail between barn and sunspace (Drawing by Pat Borer)



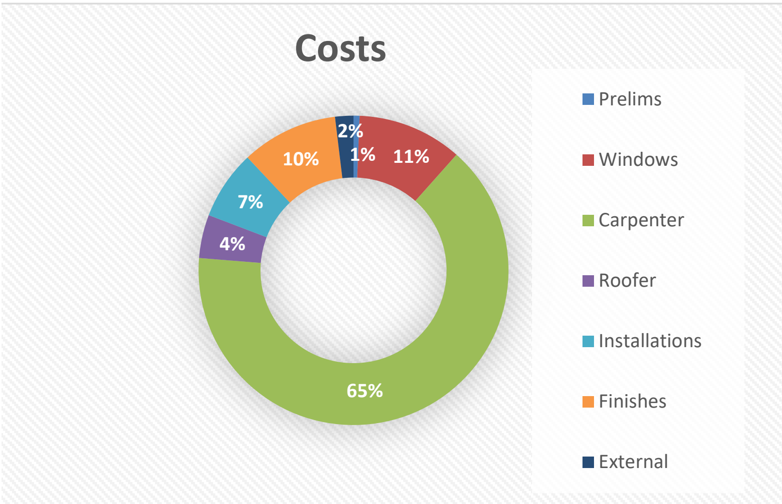
Pic. 2.19
Barn detail (Drawing by Pat Borer)

Pic. 2.20
North facade
(Photo by Peter Jones)

Floors are massive concrete slabs with light mesh reinforcement, underfloor heating and polyurethane foam insulation. PV panels are placed on the hill behind the house; its electrical consumption is about 10856 kWh/year. Sometimes especially in winter the owners travel abroad. In that case the heating is not in function. It is provided by electric power: the heating system is a heat pump.

Pic. 2.21
Underfloor heating
(Photo by Peter Jones)

Looking at materials and technologies it is conspicuous to compare Peniarth Uchaf with Segger house, as Pat Borer designed the technological part of both. Also in this case most of the materials are local - about 75% (by weight) are less than 20 km away. As shown in the graph below, differently from Blaencamel farm, much of the cost is due the carpenter's work, also because it includes the wood price.



Pic. 2.22
Cost by work
(V.B.)

The double glazed windows were imported from mainland Europe (timber included).

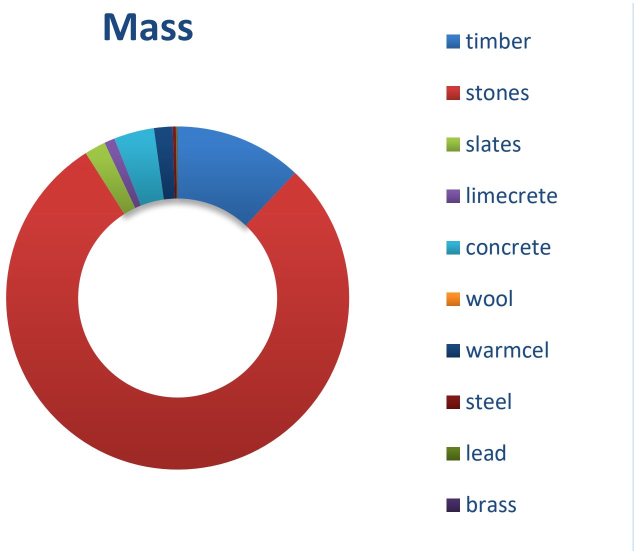
Costs	£
Prelims	1938.90
Windows	33630.83
Carpenter	198,784.21
Roofer	13,921.17
Installations	22,131.59
Finishes	30,975.27
External	5,878.86
Total	307,260.83
£/m²	1,097.36

Pic. 2.23
Tble of Costs
(V.B.)

This extension has been expensive than Blaencamel. This is due to the ancient trusses: the costs arise from disassembly, displacement, treatments and reinforcement.

It has been difficult to calculate the EE and EC of this house because data were uncompleted and imprecise. So I've estimated the quantities of materials through technical drawings and invoices provided the owners and many of those data are probably imprecise because recreate the bill of quantities has been difficult too.

Pic. 2.24
Mass of the building
(V.B.)



Calculation are based on ICE (Inventory of Carbon and Energy, 2011). The result of this calculation has been compared to the Harpa Birgisdóttir et al., 2016 as the Blaencamel example.

Comparing this building to the data of attachment D our case it is a good example of low-E building although the results are worse than Blaencamel. On the table in the next page it is important to notice that the kg/m^2 are not so distant to Segger house although the EE is nearly doubled.

It is possible to compare the two buildings because they are both new constructions and are extensions built with similar materials (also with the Lingwood building)-

Materials	Mass (kg)	EE (MJ/kg)	EC (kgCO2/kg)	EE (MJ)	EC (kgCO2)
timber	38,931.60	0.02	0.30	778.63	11,679.48
stone	256,299.70	0.90	0.05	230,669.73	13,583.88
slate	6,487.60	0.50	0.02	3,243.80	129.75
limecrete	3,204.30	5.30	0.76	16,982.79	2,435.27
concrete	12,328.34	0.75	0.10	9,246.26	320.43
wool	0	0.00	0.00	0.00	0.00
warmcel	5,677.52	1.60	0.00	9,084.03	0.00
steel	974.29	21.10	1.37	20,557.52	1,334.78
lead	364.43	25.21	1.57	9,187.28	572.16
brass	162.22	44.00	2.46	7,137.46	399.05
Total (kg)	**324,430.00**	**99.38**	**6.63**	**306,887.50**	**30,454.80**
Total (kg/m^2)	**1,158.67**	**0.35**	**0.02**	**2.75 GJ/m^2**	**108.76 kgCO2/m^2**

Pic. 2.25
EE and EC
table(V.B.)

In this case timber has a different value than Blaencamel because the wood treatments were different and the ICE Inventory doesn't have enough tools to use.

Comparing this building to the Segger house it is remarkable the lower level of EC, although Segger's is smaller it has a higher value. It is probably because the warmcel has no EC value in ICE Inventory and a great quantity of insulation - that in Blaencamel is in wool - drop the result.

Other substantial differences are probably due to the surface areas of the houses and their distance from the materials sources.
All the material calculated are just the new ones, the reused materials - like the stones of the West wall weren't calculated because of they weren't treated in any way and weren't transported.

Also in this example the Lingwood study shows that Pat Borer, as David Lea, can built with high knowledge in materials and in how they fit perfectly with his green architecture ideas.

This demonstrates that knowing as much as it is possible every material and their reaction to the environment and to the occupants can create a great and healthy building with similar costs to an high-tech one (like the Linwood one).

Patrick Borer

Patrick Borer was born in London on March 18, 1947. He graduated at Kingston School of Architecture in 1972 and in the same year qualified as Architect at RIBA. He lives in middle Wales since 1990, on a small-holding as member of a decentralized, rural, relatively self-sustaining society in harmony with nature.

Pic. 2.26 Pat Borer (blueandgreentomorrow.com)

In 1976 he started to work at the Centre of Alternative Technology (CAT) in Machynlleth, Powys, where he developed his knowledge in green architecture (most in self-build architecture).
Borer has been involved in the design and development of ultra-low energy buildings making use of solar heating systems, benign building materials and technologies, healthy indoor environments, and co-operative ways of building as it is demonstrated in the Peniarth Uchaf building. Recently, along with David Lea, he designed the Wales Institute for Sustainable Education (WISE) at CAT.

'*We believe that modernism in architecture is how green building is going to be accepted, if it is accepted at all, in the world of students – the real architectural world – who won't look at something if it's hairy wood with grass growing on top*'.[1]

1 of Kelvin Mason, Icon of green building: interview with Pat Borer, Green building, vol. 21, no. 1, 2011 Summer, p. 24-28

"It is impossible to design a building without knowing how to build it[1] ".

Focussing on materials selection, Patrick Borer affirms that design cannot be divorced from construction, energy and other aspects of building.
Design is a holistic and cyclical process – iterative, no single thing comes first. Materials inform architecture. Apart from structural considerations, many other things differentiate the materials' choice: the client's wishes, the interests of the architect, local climate conditions, and more. Now it is a fabulous time because there are so many new materials around and new ways of using old materials too. Borer's choice of building materials is operational. Materials must obviously fill their function. Borer opts for natural and locally available materials; he consciously focuses on embodied energy rather than embodied carbon. Borer views using less energy as the imperative rather than diversifying to renewable sources and perhaps seeing that as a license to profligacy. Therefore, not only he chooses to use timber, but also strives to use as little as possible.

Pic. 2.27, 2.28
House in Furnace, West Wales
(Photos by Pat Borer)

1 of Kelvin Mason op. cit.

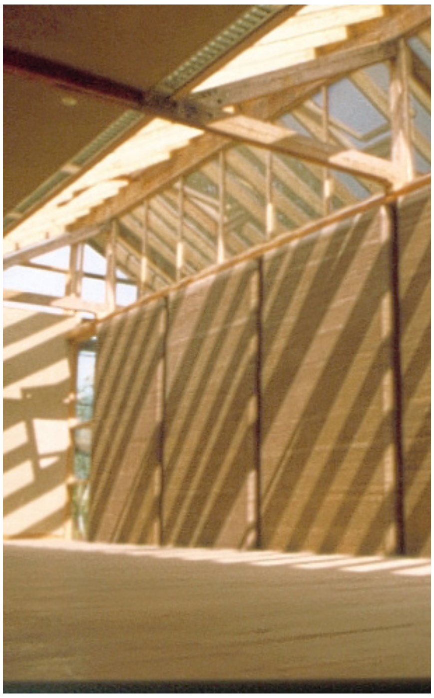
Borer's idea about environment and local materials is shown in the Furnace building. The house - photos at p. 80 - has a cross-shaped plan, centred around a two-storey, cruck framed 'sunspace' that is the main social and circulation space. The major rooms get the sun from east and west and the North side that faces a road is built in a protecting stone wall (stones from the cottage itself and others from a local demolition). The client's desire was to use the best environmental practice. This is similar to Peniarth Uchaf design.

Pic. 2.29 House in Furnace, West Wales (Photo by Pat Borer)

Pat Borer thinks that evaluating the sustainability of a material is difficult. Taking rammed earth, one of the materials used in the WISE building, as an example, typically the earth is going to be locally sourced, preferably from the building site. For WISE that was not possible because the CAT lays on an abandoned slate quarry with no suitable soil. So it was taken it from a site 80 km away.
'We know that earth is just earth, so we know the only embodied energy is from digging it out, putting through a sieve, bringing it to the site and ramming it . There's nothing else in it, no additives. So, it must be one of the cleanest materials around.[1]

1 of Kelvin Mason op. cit.

"About timber, Pat Borer makes an ethical claim of localism: the preference of local materials means you can see where is coming from. This claim is irrefutable and highlights an everyday, verifiable link between justice and the local. On the other hand, however, localism may render more distant injustice invisible and makes us less likely to be concerned and take action. As with food, to foster social justice construction materials sector should probably cost more"[1].

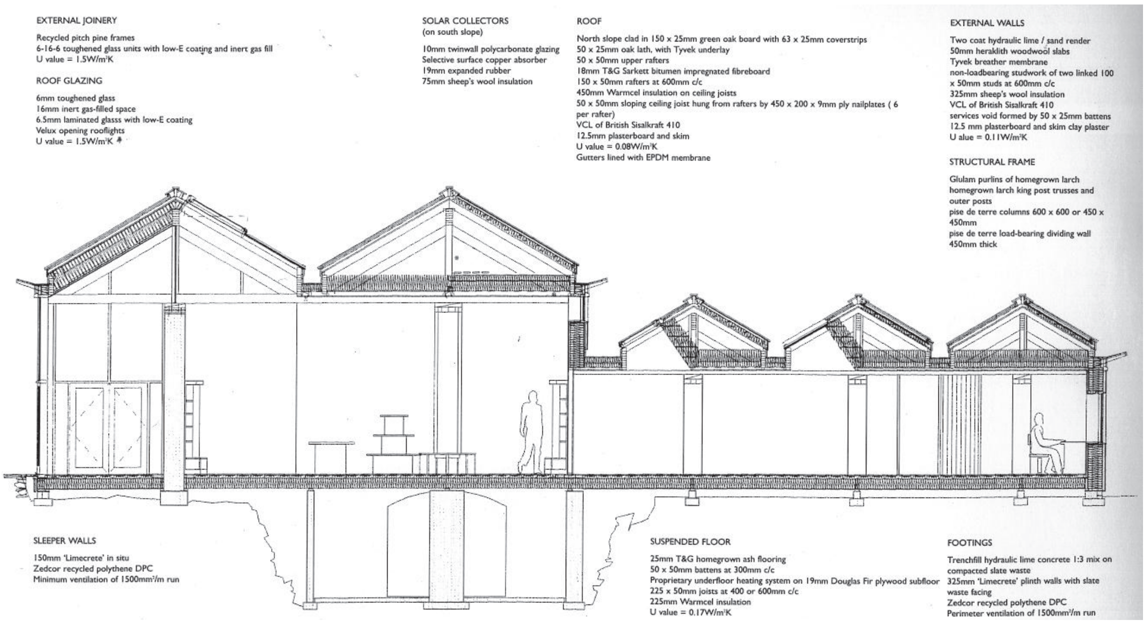


Pic. 2.30, 2.31 AtEIC building, CAT (Photos by Pat Borer)

The example of rammed earth Borer rates as the most relevant in his architectural life is the Autonomous Environmental Information Centre (AtEIC) at CAT.
There is the most forgiving hydraulic limecrete on this project and there are no chemical surface finishes. Instead of cement concrete blocks, it has been made thermal and acoustic mass earth-blocks on site and bedded them on hydraulic lime mortar. In addiction to this: locally sourced timber, non-reinforced rammed earth structural walls and columns and still look good after 20 years, and wood wool sheathing bound with magnesite - rather than cement -.

1 of Kelvin Mason op. cit.

Pic. 2.32
Section of the Autonomous Environmental Information Centre (AtEIC), at CAT
no scale
(drawing by Pat Borer)



The play of light and surprise reflections and vistas are enchanting, the spatial arrangement is charming. To all the building and ecological functional justifications of the section has been added the careful generous proportioning of this nave and its two side aisles.

In the last few years Pat Borer has moved away from the timber stud wall and now he is keen on materials such as hemp-lime and straw bales - walling materials that are complete in themselves in terms of structure and insulation. Not all building materials contribute anything aesthetically or in terms of having a transformative effect. Perhaps the one essential difference between green materials and others, in term of insulation, is that walls built of green materials will always be thicker. Pat Borer points out that you might not even notice that a house has 'fat walls' and, even if you did, you would have no visual clue to what is inside the wall – it could be everything, insulation materials are usually hidden from view.
It seems that green building may not be so much about the outlook, the surface material and any particular visual aesthetic[1].

1 Source: www.cat.org.uk

Pat Borer thinks :
"*it may be about the feel of it. When you go into a green building it does feel completely different, and it smells different. For example materials like lime and clay are renowned for absorbing and retaining moisture, affecting air quality and thus giving buildings a certain feel.*
Evidently, then, the feel and smell of a place is related to the materials used. Bringing into play senses beyond the visual – smell and touch and bodily sensations – adds a dimension to the potential transformative effect of materials selection in sustainable architecture. There is, of course, also the role of lighting and acoustics to consider in attaining this sustainable atmosphere. There is a qualitative difference with green buildings, but it can't necessarily glow." [1]

Pic. 2.33 Bishop's Castle Court (photo by Pat Borer)

The Bishop's Castle Court, is a 2002 project that abstracts many of Borer's features.
The five ecological houses were designed to the highest 'green' standards of their time. They have post and beam frames of home grown timber and high levels of thermal insulation (Warmcel). The external joinery is triple glazed with low-E coatings and argon fill in softwood frames. High performance condensing gas boilers with solar water heating and advanced controls complete the low-energy package. Natural finishes, such as recycled brick work, lime renders and lime wash, home grown oak floors and organic paints are used throughout.

1 of Kelvin Mason op. cit.

Pic. 2.34, 2.35 Court of Bishop's Castle - during and after works - of two different towers (photos by Pat Borer)

When selecting building materials Pat Borer's definitive reference are not the BRE's Green Guide to Specification (GGS) and the Inventory of Carbon and Energy (ICE). Indeed, he retains a healthy scepticism. In the interview by Kelvin Mason, Borer notes that GGS is counter intuitive and often against reality for example materials – made from fossil fuels – such as expanded polystyrene are rated A+ while sheep's wool is only A. (Note that these are summary overall ratings; the GGS life-cycle analysis looks at thirteen environmental impacts, rating each). Borer allows that looking at buildings elementally, as the GGS does, is useful, but maintains that you must still consider individual materials in any construction.

About the sustainability aesthetic, Pat Borer is adamant that looks matter in sustainable architecture. There are, however, two distinct ways of mainstreaming the practice: fitting in or standing out. There isn't a green architectural movement equivalent to modernism – no 'sustainabilitism'; no single sustainability aesthetic. The choice between a house with quite small windows – the 'keep the heat in' strategy – or one with many more large windows – to benefit from passive solar gain – it is not a 'style' called sustainability.

Here below are a few pictures of a straw-bale construction by Pat Borer at the CAT.

Pic. 2.36, 2.37, 2.38
Straw-bale Theatre at the CAT
(Photos by Pat Borer)

If sustainable architecture is to be widely accepted and adopted, Borer believes it has to appeal to mainstream architecture, especially students. For the majority, a green modernist approach is likely to be more appealing than low impact developments. Natural light is an absolute key to Borer's conception of sustainability architecture.
Sustainable architecture might look either ordinary or spectacular. Although there is no one style or practice, however, green buildings do have something in common. This commonality goes beyond the visual and appeals to the wider senses. Such appeal reveals a healthy indoor environment. Significantly, another form of commonality may be intrinsic to sustainability architecture too. The relational commonality of participation, involving cooperative practices of design and construction: taking responsibility for, and pride in, the places we live in.

Chapter three

Data	
m²	2,280
rooms	40
£	4,200,000
£/m²	2,200
start work	2006
end work	2010

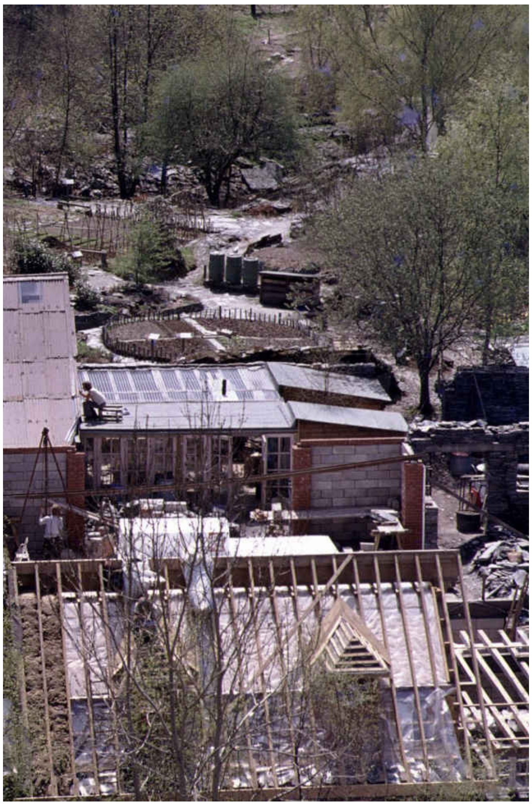
CAT
History and aim

The Centre of Alternative Technology was started in 1973 by a group of environmental enthusiasts in the disused Llwyngwern slate quarry near Machynlleth.

Pic. 3.1
Map of Wales
(Photo by V.B.)

The 16 ha site, containing an area of 2,8 ha dotted by interactive displays is the largest tourist attraction in the area. It grew by stages, demonstrating through a series of experiments how to change the way of life and make a better use of natural resources.

Originally the CAT, was a community committed to eco-friendly principles and a ‘test bed’ for new ideas and technologies - the Visitor Centre was a later addition. In the beginning, progress was slow, and the early attempts to raise money were frustrating. Volunteers worked long hours, often by candlelight (there was no electricity on the site). Slowly, increasing numbers of interested people came to the CAT, and many stayed. As more workers arrived, they brought a wide range of skills and experience. In 1974, the Duke of Edinburgh visited the CAT. After his visit, some staff suggested to turn part of the site into a Visitor Centre permanent exhibition to explain the CAT’s work and generate interest in alternative technology. It opened to the public in 1975. Since then, the CAT has grown to become Europe’s leading eco-centre, receiving many visitors every year.



Pic. 3.2
The CAT in the 80s
(gse.cat.org.uk)

The organization's first headquarters was a reconstruction of the original shed in which quarried slate used to be manufactured into mantelpieces and worktops at the end of the quarry's working life. Pat Borer, a practical, ecologically-minded architect, was by then involved in the project. He later invited David Lea, who lived in North Wales, to help with the design of the stations of the water-driven funicular railway (completed in the middle 1990s), which they designed using timber frames with steel connectors. When the fortunes of the CAT improved, raising some serious educational money, they were the architects on hand.

Pic. 3.3, 3.4Water-driven funicolar railway at CAT (Photos by V.B. and CAT photo)

The Centre is constantly changing and adapting. It continues to produce exciting new projects, schemes and ideas, building on over three decades of experience.

The CAT understands what we are facing an emergency situation both due to climate change and biodiversity loss; therefore it is vital that we comprise the earth's systems and act as good stewards. They aim at reducing their own impact on the environment as well as pro-actively finding solutions to urgent environmental issues.
A study by the CAT shows their intentions with their Micro grid system [1].
As an education and demonstration centre, they aim at continually improving their environmental management and performance. They communicate their environmental aims to staff, visitors, suppliers, contractors and sub-contractors and actively encourage others to adopt their own environmental policies.

Pic. 3.5, 3.6
CAT buildings
(Photos by
V.B.)

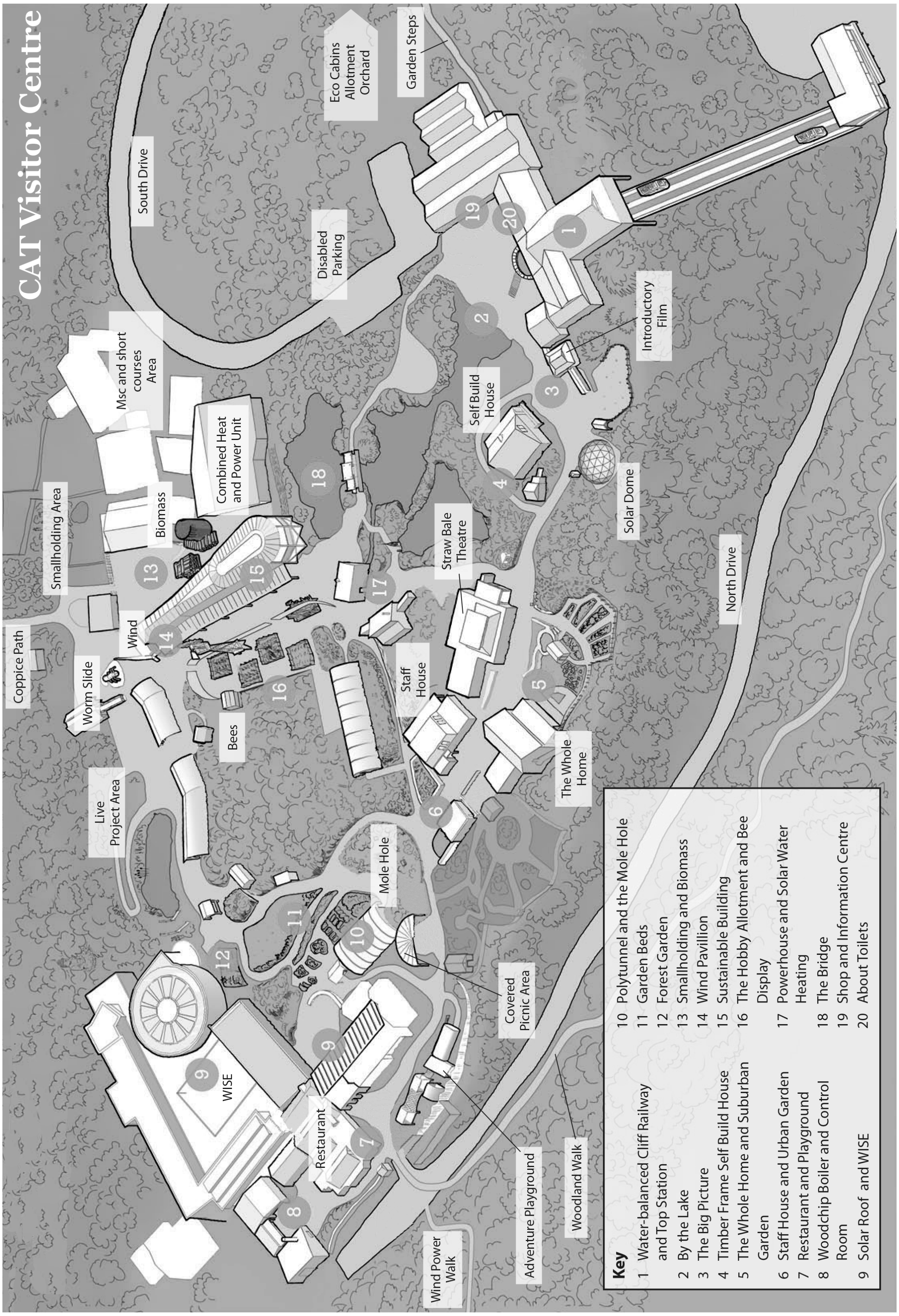
1 Attachment D, p.

These aspects are clearly shown though the construction methods, that I'll explain in the next paragraph, and also by real action that helps environment like:

"To reduce environmental impact and greenhouse gas emissions year on year by monitoring, reducing, optimizing and ensuring efficiency of all of their activities and specifically: monitor and reduce consumption of energy (heating, electricity), water and other natural and raw materials, ensuring that all uses are as efficient as possible, generate electricity from renewable sources where possible, and optimize their usage, monitor and reduce the amount of fossil fuels consumed including fossil fuels for transportation, reduce the impacts of purchasing through the adoption of a sustainable procurement policy. They also reduce the impacts of food, both from the sourcing of food, from the food they buy and sell, to the energy used from preparing their food and also maintain and increase biodiversity by surveying & appropriately managing their land. To garden organically. To manage their land simultaneously both for biodiversity and also for the development of the human community. To protect and enhance ecosystems that enables the capture and storage of atmospheric carbon dioxide. They are active to reduce waste, repair, re-use and recycle waste generated with a firm commitment to the prevention of pollution." [1]

Pic. 3.7
Energy experimental installations
(Photo by V.B.)

1 www.gse.cat.org.uk



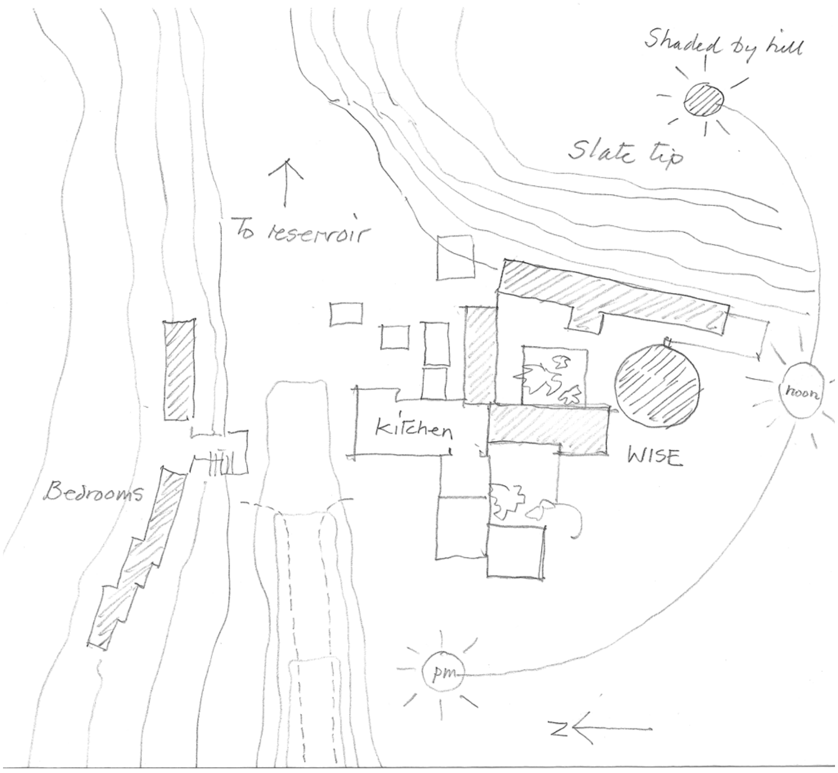
Pic. 3.8
CAT map
(gse.cat.org.
uk)

The WISE building
Introduction

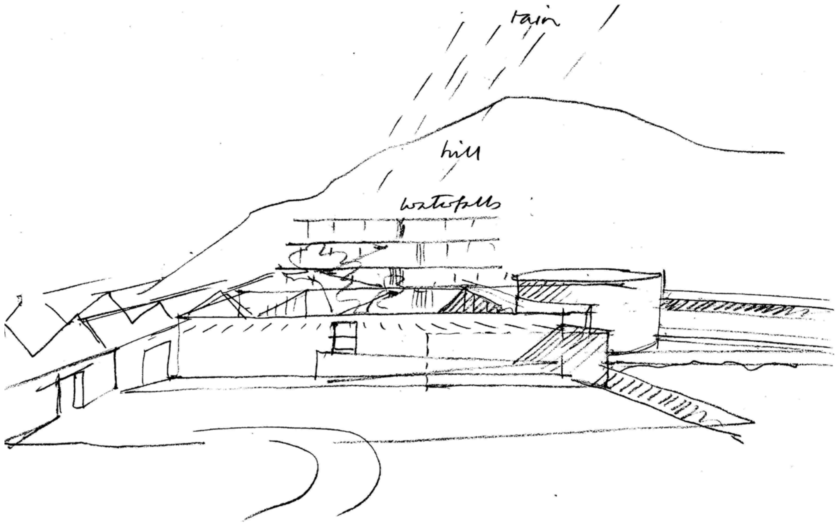
The Wales Institute for Sustainable Education (WISE) represents the central part of the Centre of Alternative Technology. On the 10th of June 2010, after almost 40 years after the birth of the centre and after so many experimentations in green tech, this building was opened to public.

The WISE building is an environmental training centre where professionals, installers and designers are offered many courses. The CAT also offers Master degree courses in Architecture and renewable energy for buildings (in partnership with the University of East London) and an ecological building PhD (offered by Wales and Cardiff Universities).

Pic. 3.9
Early sketch
of the WISE
(sketch by
David Lea)



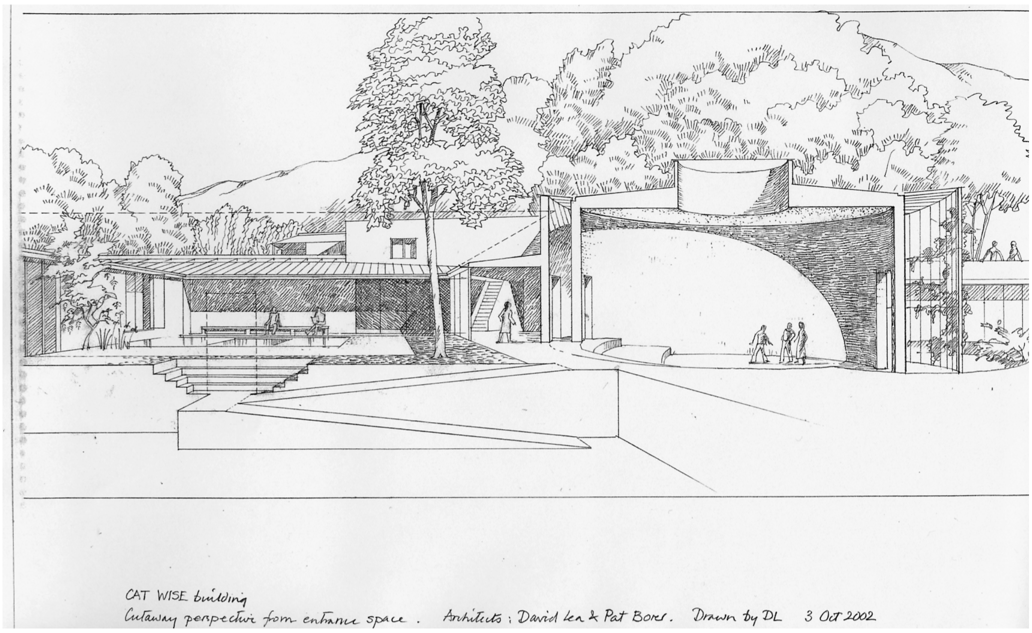
Patrick Borer and David Lea are the designers of an articulate of system volumes that accommodates the students and is a very good example of best practice in the way environmental techniques were implemented. It is composed by a conference room with 180 seats, classrooms, laboratories, a research laboratory, 24 double (ensuite) bedrooms, offices, PC rooms, a cafè and a restaurant.



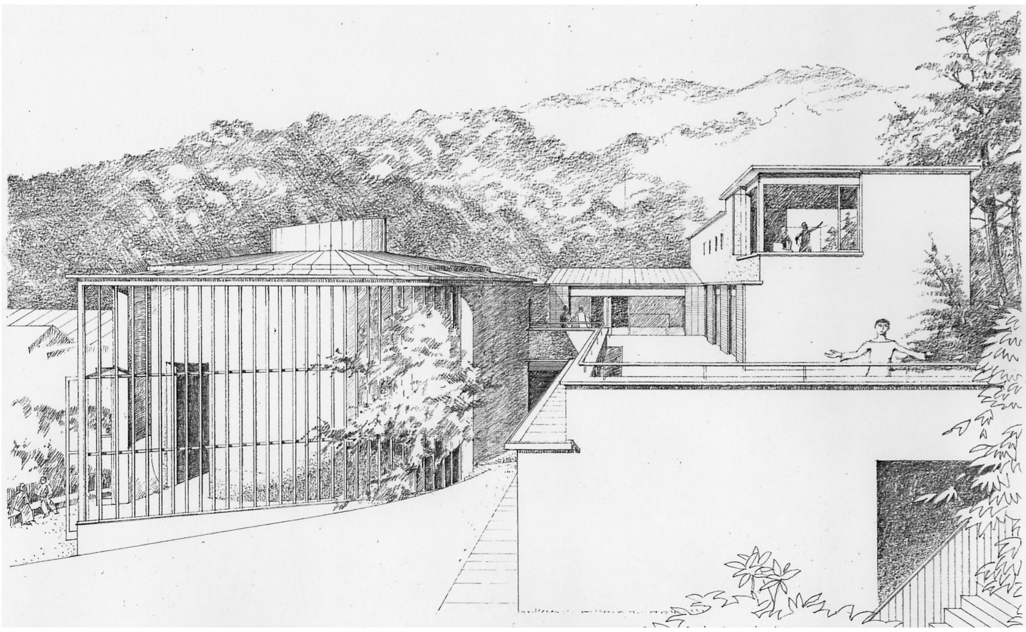
Pic. 3.10
Early sketch of the WISE (sketch by David Lea)

Design requirements included: minimising energy in operation building, minimising water use operation, maximising on-site energy generation from sustainable sources, trial new devices, minimising embodied energy, minimising 'embodied water', using innovative materials, use certified sustainable materials (e.g. FSC timber), monitoring performance against above list (including management of waste & energy during construction). This has done by some CAT students.

Pic. 3.11
WISE North section (drawing by David Lea)



Pic. 3.12
WISE North view (drawing by David Lea)



Description

WISE had to demonstrate ecological principles. so it offers courses on ecology and architecture. With the realization of the CAT has been able to make a consistent large-scale demonstration of ecological architecture. The building proves that energy saving requires no architectural compromise, no necessary meanness, ugliness, or loss of quality. It also shows how energy-saving devices can be integrated without affecting the whole design or spoiling it with add-ons.

Pic. 3.13
The WISE building (miesarch.com)

The building sits at the North-East corner of the quarry site, entered rather modestly via the courtyard of the old factory building. Its first main room is an extension of the factory's restaurant, but the new architecture already asserts itself with a generous door at the end of a glazed loggia, and the roof-light along the inner wall brings radiance. A stair leads to a door in the North-East corner connecting with the entire complex. You find yourself in an airy foyer that is caught between square courtyard to the left and the great round lecture theatre with its concentric of top-glazed room on the right.

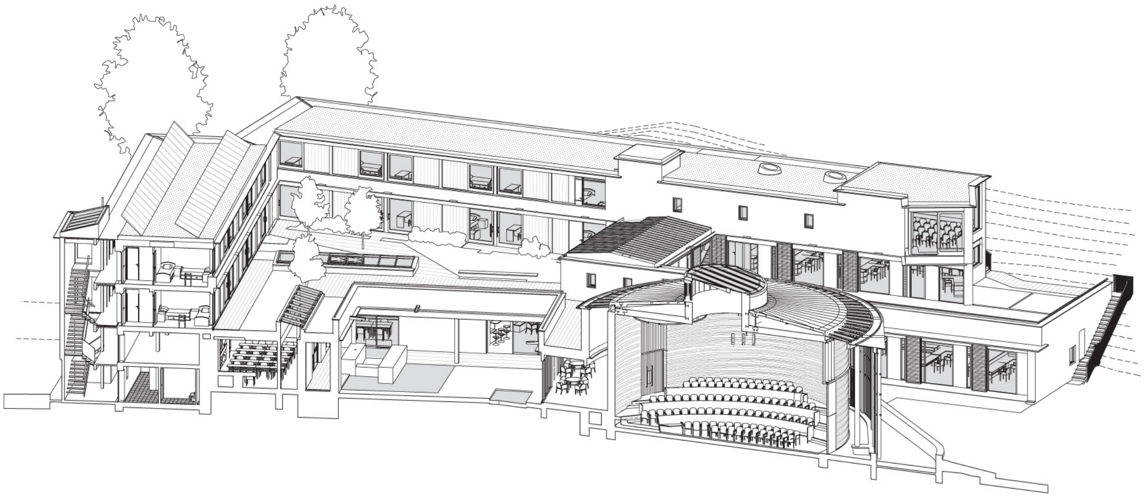
The courtyard has a Zen appearance, with slate-lined ponds and a couple of rocks over through the gravel. Gargoyles from above trickle water into shallow pools.

Pic. 3.14
Courtyard in Japapnese style
(Photo by V.B.)

Although mainly a space for visual contemplation, the court is used as a simple light-well space by the timber-decked loggia that defines the walk to the workshops. An internal corridor would have destroyed the simplicity of the organisation, and students are sometimes expected to brave the open air when accessing other parts of the complex. Access to bedrooms is also through open-air galleries, these are helpful in avoiding air-conditioning in that part of the building.

Pic. 3.15, 3.16
Corridors that reaches the bedrooms
(Photos by V.B.)

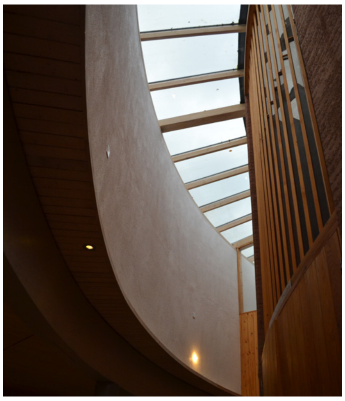
The huge circular lecture theatre was a request of the client. It is important for the visual balance of the whole complex and makes a worthy mix to the squareness of the court, subscribing to an old architectural rhetoric of gathering people for a unifyng event, as with a medieval chapter house or a Greek theatre. The chamber is defined by a thick drum of rammed earth, a material nearly as solid as concrete and layered up in the shuttered to produce a raw red-brown surface. With a carefully chosen mix and good compaction, its mass provides structural, acoustic as well as thermal functions, but just for a feature of the embodied energy of concrete. As long as it doesn't get wet, it is perfectly durable.

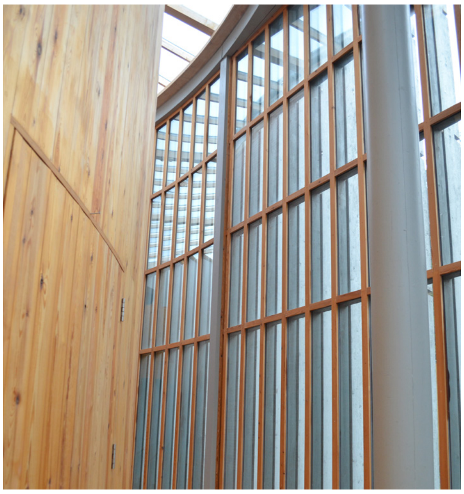


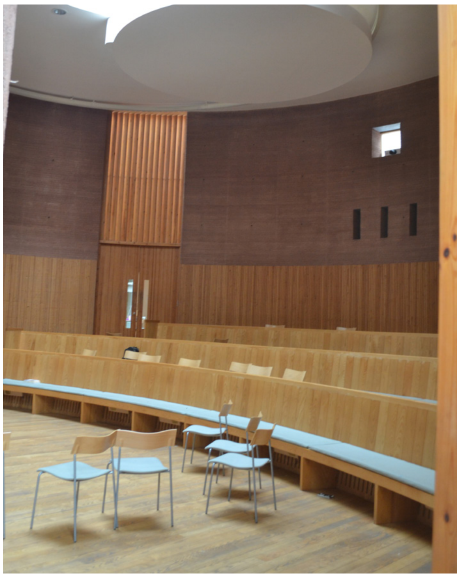
Pic. 3.17
3D section
(gse.cat.org.
uk)

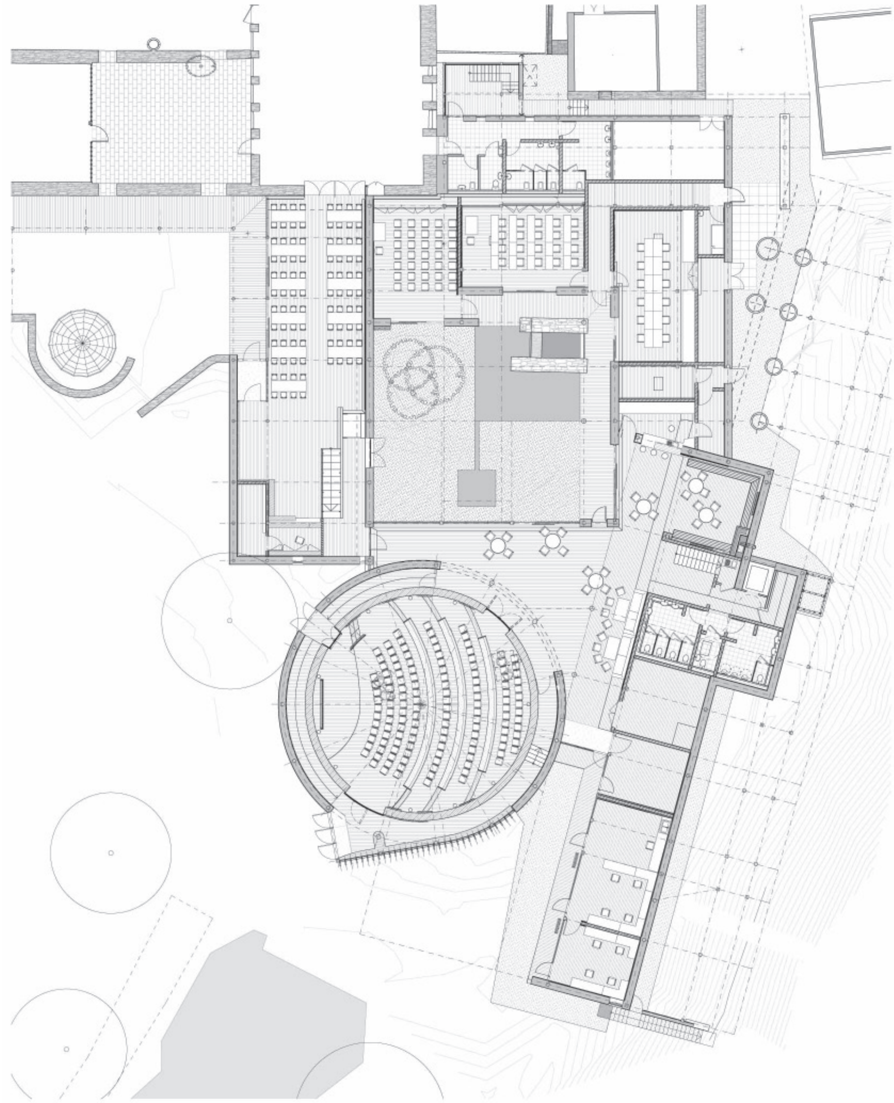
Since the theatre is needed for both lectures and film projections, the stage is set to one side, embraced by curved and hanging seating. Daylight is obtained through a central oculus, that can be closed by a huge panel, as a moon disc. On the South side there is also a very high sliding door that can be opened to the ambulatory and to the corner windows, which bring in sunlight to heat the drum. The top-lit ambulatory provides a ramp down to the stage, and top glazing throws strong light on the red-brown wall.

Pic. 3.18, 3.19, 3.20, 3.21, 3.22, 3.23 Internal and external pictures of the lecture theatre (Photos by V.B.)









Pic. 3.24
Wise building
Ground floor
plan
Scale 1:500
(training Pat
Borer&David
Lea design)

In plan, the drum mediates between North and West wings which follow the old building and central court, and another sloped wing to the East.

The twist of angles opens up the foyer as crossroads and social centre. The corner looking South into the court has been made sociable with a bar and seating area.
The stairs are ahead of the foyer in line with the edge of the court. On the right you climb to a view of the Southern roof terrace and the hill beyond, to the left is the office entrance, and to the full left another stair to the upper bedrooms. Windows behind reveal the stack of waste slate. The strategically-placed rooflights and windows continue right to the end of the upper East wing, where the bay window of a seminar room angles itself towards the valley view. All this means not only that the whole place is daylit most of the time, but also that you are conducted by inviting vistas through a spatial sequence. This concern, increasingly rare as architects neglect plan in favour of image, is typical of Lea.

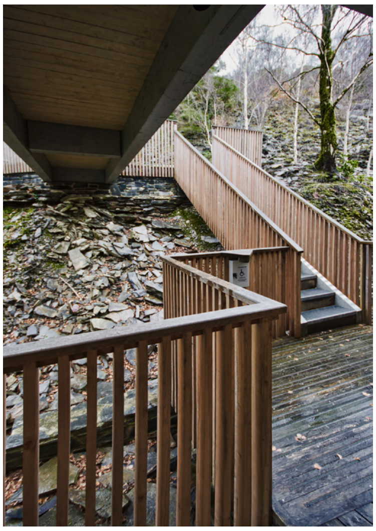
Pic. 3.25
Southern roof terrace
(Photo by V.B.)

Pic. 3.26
Entrance room
(Photo by V.B.)

Bedrooms are approached by access galleries; to the East they face the slate slope, to the North they are screened off from untidy service yards by wooden slats. These open walks allow for cross ventilation but also make the bedrooms seem more detached from the social hub. The usual awkwardness of biting a bathroom out of a corner of the bedroom has been avoided, for the entry zone has a bathroom on one side and cupboard on the other, developing a double-door threshold. This adds sound privacy, gives a more layered view, and makes the room a more flexible space to accommodate various size beds.

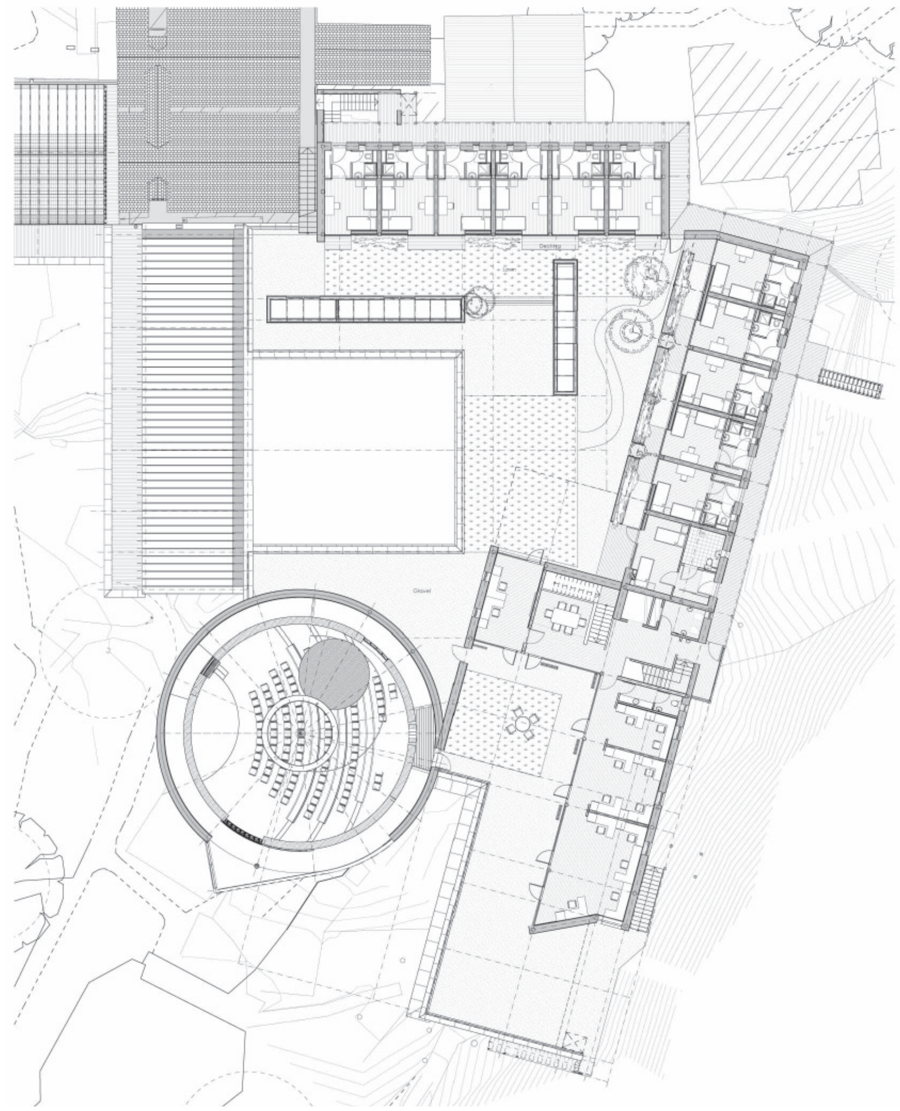
Pic. 3.27
A bedroom at the first floor
(Photo by V.B.)

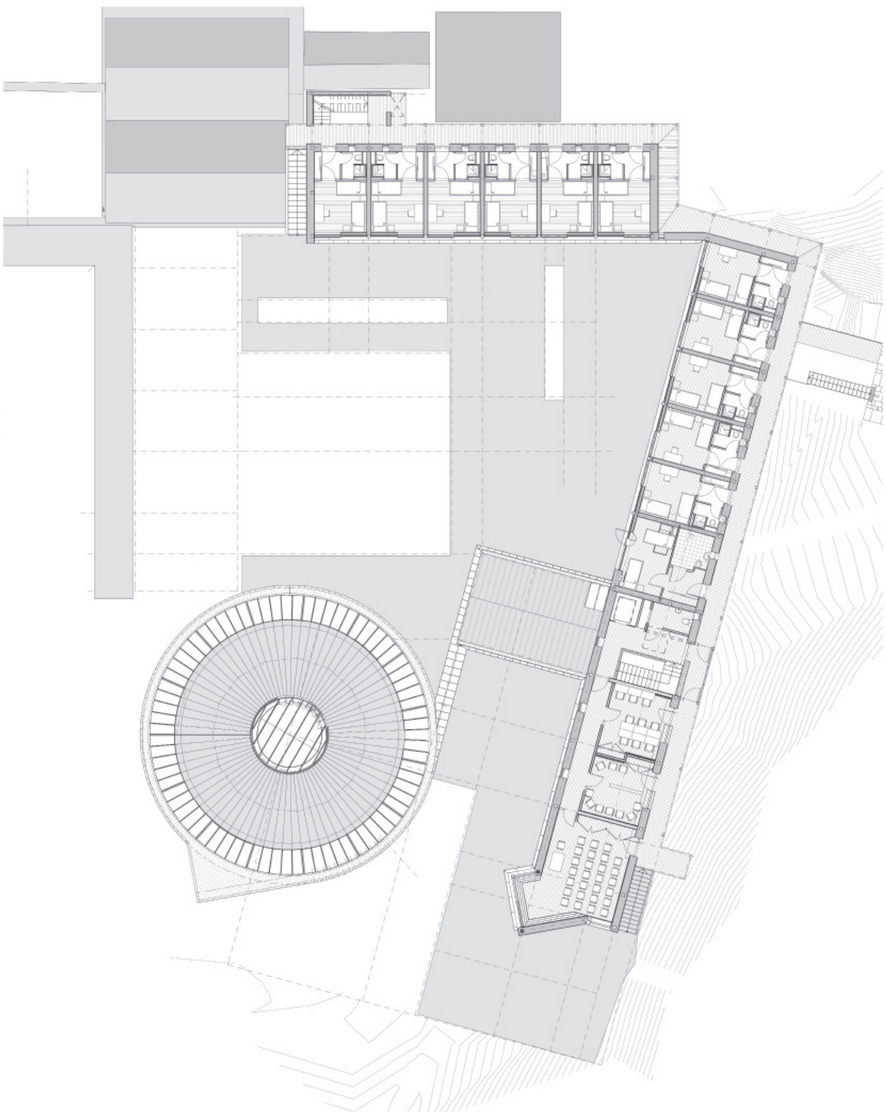
Pic. 3.28
Slate slope facade
(Photo by V.B.)



Pic. 3.29
Slate slope
(Photo by V.B.)

Pic. 3.30
Wise building
First floor plan
Scale 1:500
(training Pat Borer &David Lea design)





Pic. 3.31
Wise building
Second floor
plan
(training Pat
Borer &David
Lea design)

Materials

Every building material has been chosen to minimize the environmental impact and the energy loss both for construction and building operation. Very high standards have been followed to guarantee the durability of the thermal insulation and an efficient air seal. Everything designed to maximize the natural lighting and natural ventilation. Windows ensure natural light and the accumulation of passive solar heat. Hot water is provided by solar collectors on the roof of the building which can be implemented by the CAT's firewood cogeneration plant.

Pic. 3.32, 3.33
Solar gain in
Wise building
(photos by
Pat Borer)

The sustainability brief was rigorous, with everything possible measured, including the fuel use of visiting consultants. Apart from rammed earth, the other notably innovative material was hemp lime, in lightweight solid walls finished with lime render.

It has the virtue of simplicity, producing a highly insulated, low energy content wall that needs no membranes. The combination was built up around a timber frame, but Borer and Lea thought it could be used on its own.

The first designs came up in 2001 but the construction was started in 2006, clearing the area and levelling the ground and then dragging to build the foundations.
The foundation had to be in reinforced concrete to achieve the required strength and stiffness. They spread the building load over a wide area and are stiff enough to endure some movement of the ground.
Unfortunately the slate rejects in the subsoil couldn't allow a limecrete foundation. Cork was used to prevent cold bridging and because of its water resistance (it can be used in situations where many other natural insulation materials would be unsuitable).

As a policy, the CAT avoids cement as much as possible, due to its very high embodied energy. It was decided to use limecrete, in almost every all non-structural part: aggregate was obtained from in Much Wenlock - a little town near the Wales border, 112 km away from CAT - , sand Condover quarry (97 km) and lime by Setra Marketing Ltd. To minimize the embodied energy, the architects decided to change 50% of Portland cement for Ground Granulated Blast Furnace Slag (GGBS)[1].

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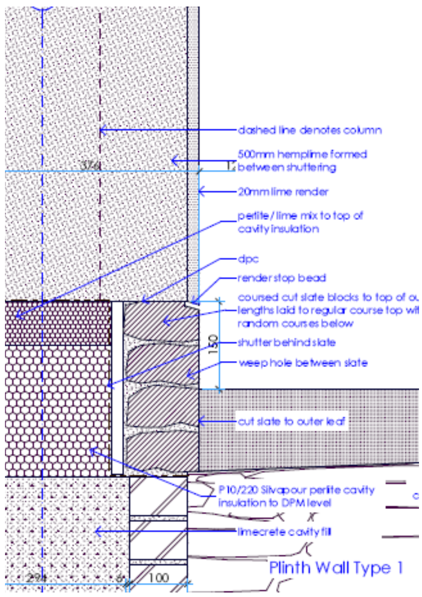
1 This is a by-product of the iron and steel industry and used to be considered waste

The slates used to build the walls of the courtyard are from a demolished quarry building in Blaenau Ffestiniog because these on site were not suitable for decorative facing.

Pic. 3.34 Section of a slates wall (gse.cat.org.uk)

Sand lime bricks were used to construct the plinth walls that support the structure. They are autoclaved and have a lower embodied energy than standard clay bricks.
Due to the number of bricks involved it has been necessary to create brickwork forms. Some of them have a cavity wall filled with perlite to provide insulation.



Pic. 3.35, 3.36 Perlite insulation and wall detail drawing (Photos by Pat Borer)

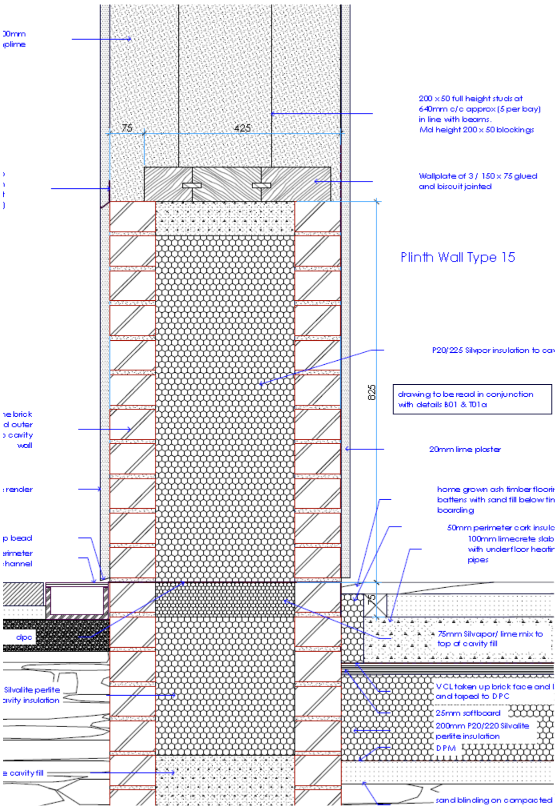
Shuttering was also used to create rammed earth blocks for the circular Sheppard Theatre - the lecture room - and also for internal partition walls on the ground floor, adding extra thermal mass to the building.
To give strength to the wall mechanical compaction was needed to bond clay molecules with the aggregate. Earth material was brought from Llynclys Quarry near Oswestry.

For the theatre walls special shuttering with an adjustable radius were used. Earth was added in 150mm layers and compacted by hand. The wall was built in sections, two of them with full height gaps for doors.

The Rammed earth wall supports the roof, but doesn't form the external walls, as there is a corridor around the theatre, – these are timber-framed glazing and hemp and lime.

Pic. 3.37 Rammed earth wall theatre (gse.cat.org.uk)

Hemp lime was sprayed against temporary shuttering to completely enclose the timber frame and create walls 500mm thick. This provides a high degree of insulation and air tightness whilst remaining breathable. In the WISE building it has been mixed with cement (~15%).



Pic. 3.38 Hemp-lime 500mm external wall detail drawing (Photo Pat Borer)

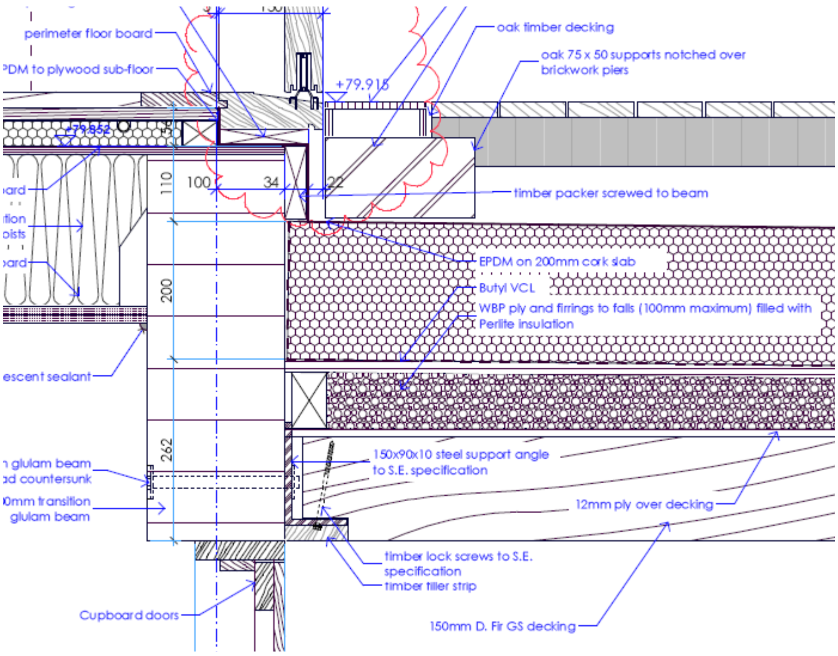
	External walls (non-loadbearing): 500mm hemp-lime
1	20mm two coat hydraulic lime render internal
2	15mm Heraklith permanent shuttering
3	Studs 100 x 50 at 1200mm c/c on 200 x 50 wallplate
4	Wallplate on plinth 200 x 75 spanning between & screwed to glulam columns
5	Rails to support wainscot boarding 2 / 75 x 50
6	HEMCRETE sprayed against permanent shutter 500mm thick
7	20mm two coat hydraulic lime render external

Timber was used in many ways throughout the building. The structure involved glulam columns and beams (although it contains formaldehyde glue, the finished product can be seen as much more sustainable than alternatives in steel or concrete). The roofs structure is composite timber I-beams. Floors were assembled from solid softwood panels. The stairs were boarded in home-grown ash, claddings are of larch, handrails of oak. Walking around the building one appreciates a constant concern to show real materials.

Pic. 3.39 Glulam wise structure under construction (gse.cat.org.uk)

The roof was insulated with cellulose (recycled paper) plus a cork layer. The terrace roof decks are insulated with a 250mm cork panel. The Sheppard Theatre's roof is covered with sheets of stainless recycled steel that is durable and recyclable.

Pic. 3.40, 3.41 Cork slab in flat terrace detail drawing and a photo of the same element during construction work (Photo by Pat Borer)



	Flat terrace roofs (Solid):
1	Deck of 150 x 50 at 50mm c/c lower edge planed
2	12mm sheathing plywood
3	Firrings & 12mm plywood to falls
4	Vapour control layer Butyl rubber
5	Insulation 250mm cork
6	Single ply membrane EPDM
7	Roof finishes substrate
8	Roof finish

Energy

The WISE building was designed for low energy consumption. Electricity is mainly provided from on-site renewable energy sources including solar photovoltaic panels, hydro and wind turbines. The CAT 's electrical system is isolated from national grid in the event of a power failure the renewable generators continue to operate like an island grid system. Sunny Backup inverters regulate the power generation according to the demand ensuring continuous efficient operation of generators and maintaining power at essential loads (details data in the attachment D). The back-up battery is sized so to provide power for at least 3 hours. If the batteries become low, less critical appliances are disconnected to make sure energy is available for the WISE emergency lights, servers and telephone system.

The WISE also hosts an impressive array of solar thermal collectors which contribute to the domestic hot water needs.
Hot water for the en suite shower rooms is produced by an array of solar water heating collectors on the roof of WISE. Additional hot water and space heating come from wood-fuelled heating systems also in place at the CAT.

Mechanical ventilation with heat recovery is used in the WISE lecture theatre and in bathrooms and toilets. Low energy extraction and delivery fans help us to keep the energy usage minimal whilst meeting building regulations that require a minimum fresh air delivery to bathrooms and toilets[1].

1 http://info.cat.org.uk/questions/wise/how-was-natural-passive-stack-and-mechanical-ventilation-used-wise/

Since the lecture theatre can hold up to 180 people, it has the potential to become stuffy and for carbon dioxide levels to increase, resulting in sleepy students and users. The mechanical ventilation helps to avoid this at peak loads.

The solar radiation that hits the glazing heats the corridor space and is absorbed by the massing walls of the lecture theatre. Heat is stored and then slowly released when the building cools overnight, buffering the indoor temperature.

Chapter four

Conclusions

This essay wants to show the knowledge in construction, materials and technology in two examples by "green" architects. David Lea and Patrick Borer design following principles that try to take advantage from nature: orientation of the building and the spaces, environment, local materials, no treatments, comfortable spaces and no pollution air. These aspects have to be added to secondary standards as the consumptions, maintenance, waste and disposal.

I've presented two architects that give to architecture a good provision and must be known mostly.
The research has been done thanks to the data given by the architects and the clients, documents found at the RIBA Library in London and some articles on the web. These data has been processed with some tools (as the ICE - Inventory of Carbon and Energy, 2011 - from the University of Bath's and the ÖKOBAUDAT platform by the German Federal Ministry of the Interior, Building and Community) and compared to obtain the results. Data were redistributed because the value were too generic but not negligible (they are not referred to the building construction year because there weren't sources reliably and has been estimated the value for some items.

Segger house and Peniarth Uchaf are so different but show also similar aspect. This is also because Pat Borer worked on both.
Segger house, which won a RIBA award, shows what David Lea thinks architecture is: an architecture in its appropriate place that, in the way it is built, does not waste the planet's resources. Everything is reduced to basics: materials are as close as possible to their natural state, the structure is essential and rational, light is one of the focuses.

It shows clearly his ability in designing. About the technology aspect there were few troubles with the builders and some works have not been done successfully. This shows that this project couldn’t be done without the knowledge of Pat Borer.
In the other hand, Peniarth Urchaf demonstrates the ability in technical field and also diligence on Pat Borer’s design. The spaces are well distributed and the natural light came through and give to the space his importance. The old trusses barn retrieve the ancient building but present also a very interesting reading of the ambience that, in my opinion, highlights a new feature in Borer’s work.

Living in a 2018 high-tech house with every comfort as air conditioning, home automation and other technological aspects doesn’t necessarily mean to have a high performance living, and anyhow it is not the only building solution you can adopt. Both buildings analyzed in this research point out that using their own materials is less expansive than the high-tech ones and reduces all the pollution coming from transport. The use of renewable materials - as more as possible sustainably produced - gives importance to these examples. Moreover, living in a space with natural materials (avoid also petro-chemical materials) with no treatments give to the occupants an healthier life - Segger said me that they perceives the difference in the air. The local production and transformation of materials also increases and helps the local economy.

I’ve compared these results with the thesis *"Valutazione della sostenibilità dell’ecovillaggio Sieben Linden: impronta ecologica, embodied energy, embodied carbon"* that shows the EE and EC value of some German building.
Here the result of a 180 m^2 house, Wegmann-Gasser house in Glarus by Werner Shmidt.

The examples examined are low-impact environmental houses built using materials and technology with small carbon footprint and little energy consumptions. This is evincible by the comparison between the data obtained and the ones given by the Harpa Birgisdóttir et al., that proves our buildings as affordable levels of embodied energy and carbon footprint. This was possible also thanks to the wide presence of local materials and the wishes of the owners. It has been a huge challenge for the architects that experienced all the solutions. What the two architects designed and proved in the WISE they endeavor to fit in a simple house.

	Weight [t]	EE [GJ/m^2]	EC [tCO_2/m^2]
Blaencamel	119.812	1.67	0.12
Peniarth Uchaf	324.43	2.75	0.11
Wegmann-Gasser	239.32	5.33	0.36

As it is shown by this result the two Welsh buildings have really EE and EC low values compared with Wegmann-Gasser. Peniarth Uchaf is the heaviest one probably because there are many stone wall and also about the larger total useful floor area (it is 280 m^2). It is unexpected that this house is also the one that has the lowest EC value althought some materials are local but not from the building site.
Looking at the table on p.45 and p.76 it is clear that the higher CO_2 emission in both of the case studies are from the stones. It can be reduced, as Peter Segger is trying to do, maybe with electrical tractor or maybe, avoiding certain type of transport inside the propriety (for both of the building there were used stone already on the land owners).

The interesting data is the Blaencamel EE where appears what was expected a low value. This is what Lea would like to point out and it is a great success and result.
It was just the 1997 when started the project with no idea of what will be change in the world of green/stastainable architecture. Now it can be a very good example of low EE and EC architecture. As it is the Peniarth Uchaf one.

I think that both the ‘experiments’ are well succeeded. It can be important to study more in deep both the architects to understand better and give them the importance they deserve.

The WISE was by futhest ambitious project. The Centre at CAT wanted to prove that non-conventional materials could be adapted to suit mainstream construction, and in doing so establish a new era of eco-building. WISE represents a tectonic shift in the way eco-building is approached. Proving that green construction can be achieved on a large scale by mainstream contractors, this project paves the way for the adoption of more sustainable practices. This building blends Lea and Borer. In this research it was interesting to know if each of them, taken individually, could have afford a similar challange.

Lea and Borer have a huge knowledge of green timber and also method of assembly that is not to underestimate. It can be interesting to study more of their buildings, because they built a lot, and observe the different construction technique used to understand and get improved.

Attachments

Summary of Technical Data Sheet

WARMCEL®
Insulation For Timber Frame

Product designation:	Product composition / construction
WARMCEL	Cellulose Fibre Insulation

Property	Measured Values	Standard
Thermal Conductivity Lambda 90/90 23°C/50%RH	0.038 W/mK	EN 12667 EN ISO 10456 EAD 040138-00-1201
Reaction to Fire	Class E	EN 13501-1 + A1
Resistance to Mould Growth	Class E	Annex F of EN 15101-1
Specific Airflow Resistance a) bulk density 45.0 kg/m^3 b) bulk density 60.0 kg/m^3	≤13 kPa*s/m^2 ≤18 kPa*s/m^2	EN29053
Critical Moisture Content	75%	EN 1609 method A
Settlement in walls & between rafters	See table on next page	Annex B.2 of EN 15101-1
Settlement by shock	≤9% (@ 30kg/m^3)	Annex B.3 of EN 15101-1
Settlement by humidity a) bulk density 30.0 kg/m^3 b) bulk density 50.0 kg/m^3	>25%; SH 30 >10%; SH 10	Annex B.1 of EN 15101-1
Density		See table on next page
Specific heat capacity	2020 ± 6% J/kg.K	EN ISO 8990, EN 675

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CE EOTA

Key issues related to Annex 57:
1. Strategies for building design
4. Embodied energy and greenhouse gas reduction strategies – Material/component level

Case study UK5
Lingwood development - UK

EBC Energy in Buildings and Communities Programme

KEY OBSERVATIONS

A house constructed using a panellised timber frame construction, had 26% lower embodied energy and 34% reduction in embodied greenhouse gas than the equivalent traditional masonry house.

Embodied greenhouse gas savings in buildings' construction can be made by:

- increased offsite components' manufacturing
- selection of sustainable materials or materials with reduced environmental impact

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OBJECTIVES OF CASE STUDY

To quantify the energy and greenhouse gas embodied in the construction and technologies of low carbon homes compared to conventional new build houses.

To identify the importance of embodied energy and greenhouse gas in the built environment on a national level.

BUILDING KEY FACTS

Intended use: Housing (affordable rent/shared ownership)

Two house sizes: 71/83 m^2 internal floor area

Location: Lingwood, Norfolk, UK

Building year: 2008

Design and construction by Flagship Housing Group Ltd

Project phase studied: Design and Construction

Structural material: offsite engineered structural panel timber frame

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SYSTEM BOUNDARIES AND SCOPE

Building life cycle stages included in the study, according to EN15978

A 1-3 Product stage			A 4-5 Construction process stage		B 1-7 Use stage							C 1-4 End-of-Life				D Next product system
Raw material supply	Transport to manufacturer	Manufacturing	Transport to building site	Installation into building	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport to EoL	Waste processing	Disposal	Reuse, recovery or recycling potential
X	X	X	X	X						X						

LCA BACKGROUND

Reference study period: 20 years. A 20 year time period was selected because no significant refurbishment or replacement of the homes and the technologies used in them would be required. It also coincided with the available projected data for decarbonisation of the electricity supply.

Sources and Databases used: published Government carbon emission factors, The Inventory of Carbon and Energy (ICE) version 1.6a, EcoInvent database, U.S. Life-Cycle Inventory (USLCI).

Standards/guidelines: ISO 14040/44: 2006

REFERENCES

Monahan, Jennifer (2013), Housing and carbon reduction: Can mainstream 'eco-housing' deliver on its low carbon promises?, PhD thesis, School of Environmental Sciences, University of East Anglia, UK.

Monahan, J. and J.C. Powell (2011), An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework, Energy and Buildings 43(1)

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The analysis of embodied energy and greenhouse gas is based on one of the Lingwood case study houses, a three bedroom semi-detached house of 83m^2 internal floor area. **Three scenarios** are used: (1) the Modern Methods of Construction (MMC) case study as constructed with a larch facade; (2) the larch as a facade material is substituted by brick; and (3) a conventionally constructed house using masonry cavity construction.

Production and construction stage modelling:

The study includes the cradle to site emissions from the following: materials and products used in construction, final transport of the materials and products to site, materials' waste produced on site, transportation of waste to disposal and fossil fuel energy used on site during construction and in components' manufacturing. The calculations don't include internal elements, such as walls and doors, finishes, such as paints, plasterboard, skirting board and fittings, such as bathrooms, lighting and kitchens. The study assumes these will be identical for all of the compared construction types and can therefore be excluded from this analysis.

Use and operation stage:

A calculation of whole house energy and greenhouse gas were undertaken for the basic case study. The calculation was carried out using National home Energy Rating (NHER) Plan Assessor V4.2.28 software incorporating SAP 9.81 (BRE 2005). Moreover, meter readings were taken from the electricity and gas consumer units, water meters and PV inverters, providing quantitative data on actual energy used, total water consumption and annual PV production.

BUILDING DESCRIPTION

THE DEVELOPMENT

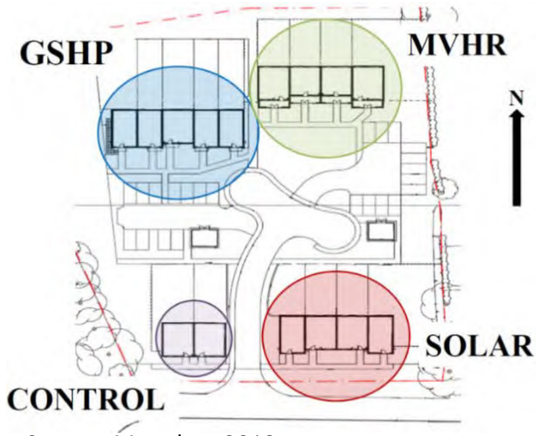
The case study comprises 15 newly constructed low energy affordable homes. They have been constructed using an off site engineered structural panel timber frame construction with additional insulation materials to exceed current minimum building regulation standards.

DESIGN STRATEGIES

Design aspects included high levels of insulation and airtightness, ventilation via vents incorporated into window frames, optimised solar orientation, energy efficient gas boilers, LZC (solar hot water, photovoltaics, and ground source heat pumps), dedicated fixed low energy lighting, offsite manufactured timber frame, larch weather boarding and FSC certified timber.

There was also a reduced use of high embodied energy materials, such as masonry and concrete. There are communal recycling facilities and water efficient strategies (grey water use and low water use) in place. Finally, the aim was to keep the development at **affordable levels**, both to build and to run.

The 15 homes comprised four blocks of terraced homes all constructed to the same specification using the same innovative offsite panellised construction system but each block had a different low and zero carbon (LZC) technology for providing heat or power. This is shown on the figure on the right. Two homes acted as controls with conventional condensing gas fired instantaneous combi-boilers (CONTROL); 4 homes had the same boiler in conjunction with solar hot water systems and photovoltaics for power (SOLAR); a third block also had the same gas boiler but with a thermal sunspace to the south facing elevation and a mechanical ventilation system with heat recovery (MVHR); in the fourth block they were all electric with a ground sourced heat pump providing all heating and hot water needs.



Source: Monahan 2013

CONTROL: homes acting as controls with conventional condensing gas fired instantaneous combi boilers

SOLAR: same boiler in conjunction as above, with solar hot water systems and photovoltaics for power

MVHR: same gas boiler but with a thermal sunspace to the south facing elevation and a mechanical ventilation system with heat recovery

GSHP: all electric with a ground sourced heat pump providing all heating and hot water needs.

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PRIMARY ENERGY AND EMBODIED GREENHOUSE GAS FOR 3 SCENARIOS: TIMBER VERSUS CONVENTIONAL COSNTRUCTION

Scenario 1: **Modern Methods of Construction** (MMC) case study as constructed

Scenario 2: Larch facade material substituted by **brick**

Scenario 3: Conventionally constructed house using **masonry** cavity construction

This study found that a house constructed using a panellised timber frame MMC construction, had 26% lower embodied energy and 34% reduction in embodied greenhouse gas than the equivalent traditional masonry house. This is mainly attributed to the use of materials, in this case softwood timber in the wall component, with relatively lower embodied greenhouse gas and lighter mass requiring less substructure than conventional.

Despite the different construction method, the percentages of materials' contribution to embodied greenhouse gas compared to waste, energy and transport is quite similar in all 3 scenarios. Scenarios 1 and 2 are presented in the figures below.

Total Primary Energy consumption:

Scenario 1: 5.7 $GJ/m^2_{\text{usable floor area}}$

Scenario 2: 7.7 $GJ/m^2_{\text{usable floor area}}$

Scenario 3: 8.2 $GJ/m^2_{\text{usable floor area}}$

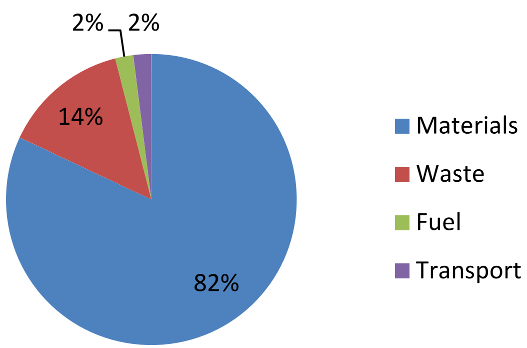
Embodied greenhouse gas :

Scenario 1: 405 kg $CO_2/m^2_{\text{usable floor area}}$

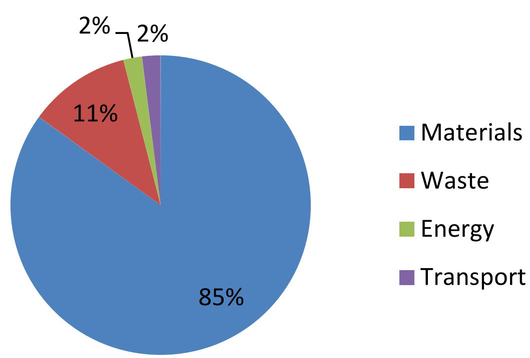
Scenario 2: 535kg $CO_2/m^2_{\text{usable floor area}}$

Scenario 3: 612 kg $CO_2/m^2_{\text{usable floor area}}$

Scenario 1 Embodied greenhouse gas contribution in construction (%)



Scenario 2 Embodied greenhouse gas contribution in construction (%)



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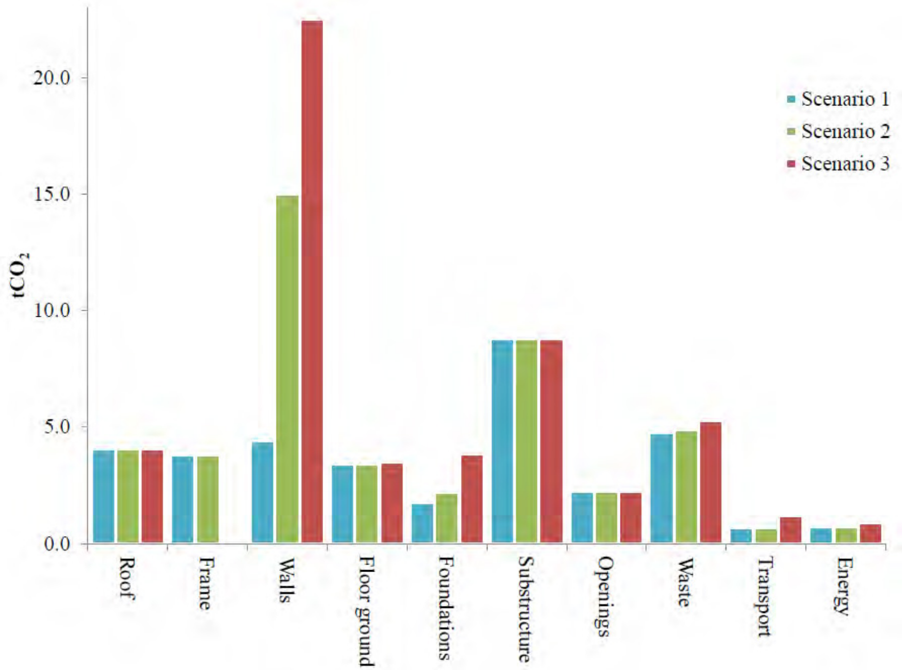
PRIMARY ENERGY AND EMBODIED GREENHOUSE GASES FOR 3 SCENARIOS: EMBODIED ENERGY AND GREENHOUSE GASES BY BUILDING PART



Source: Monahan 2013

Reductions in embodied greenhouse gases can be made by increasing the amount of manufacturing off site and by reducing the amount of waste on site.

Despite the high proportion of timber throughout the structure, half of the materials related embodied greenhouse gas is associated with the construction of the substructure, foundations and ground floor. The relative importance of these substructural components reduces with the increase of greenhouse gas intensive materials in other components, for example in Scenario 3 the proportion attributed to these elements is lower than 35%. Finally, reductions in embodied greenhouse gas can be made by increasing the amount of manufacturing off site and by reducing the amount of waste on site.

Attachment C
Peniarth Uchaf
(Photos by Peter Jones)













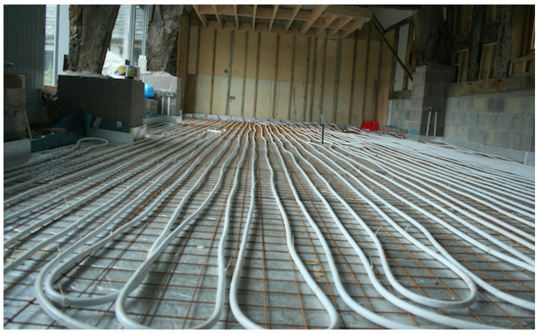
AHE



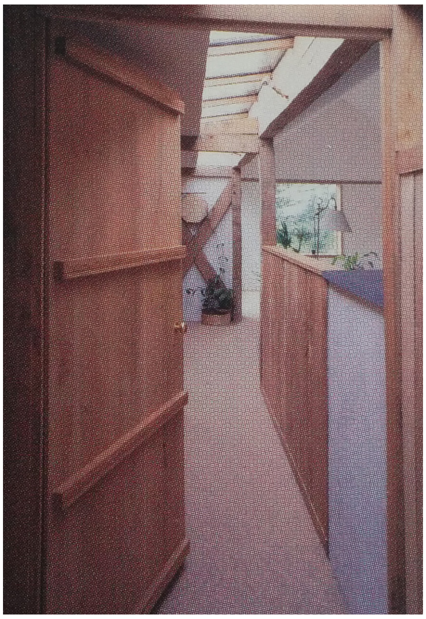








Blaencamel
(Photos by David Lea)



Microgrid system at Centre for Alternative Technology

J. Kuriakose, *Senior Electrical Engineer, Centre for Alternative Technology*, and *member IET*

I. INTRODUCTION

The Centre for Alternative Technology (CAT) is a pioneering research and demonstration centre that inspires, informs and enables practical solutions for sustainable living. CAT has established a worldwide reputation as the leading organisation demonstrating environmental technologies.

In association with the Wales Assembly Government, CAT has recently developed the £6 million Wales Institute for Sustainable Education (WISE) facility. CAT will be building on nearly 40 years of experience in new energy systems thinking, to create a unique 'experimental site' offering training up to Masters and doctorate level through the Graduate School of Environment (GSE). CAT has also become a 'hub' for the new National Science Academy, aiming to encourage the up-take of Science, Technology, Engineering and Mathematics (STEM) subjects across society, but with particular emphasis on engaging young minds.

In 2010, CAT presented its Zero Carbon Britain 2030 (ZCB2030) scenario to the UK Parliament to help show one potential path by which we can eliminate fossil fuel emissions over a two decade period. By synthesising cutting-edge findings from leading researchers ZCB2030 presents a scenario that demonstrates how we can combine detailed knowledge and experience from the built environment, transport, energy industry and agriculture into a national framework offering a coherent vision. The strategy document also discusses the widespread deployment of existing technologies to harness massive indigenous renewable energy assets, and goes on to look at the issue of supply and demand management through smart grids and microgrids.

CAT's renewable energy grid system was independent of the National Grid, generating mostly by wind, solar and hydropower; it therefore required some form of demand management. Although back in the early 1970s a micro-processor controlled smart grid technology was not available, CAT achieved a very high penetration of renewables into their independent grid systems via a "proto-smart" grid system. All appliances which had high electrical energy demands such as photocopiers and washing machines were literally 'negotiated' between users around the seven acre site using a vocal intercom.

II. MICRO GRIDS AND THE CAT SYSTEM

A microgrid is a small scale power supply network designed to provide power for a small area such as a rural, academic or public community or an industrial/trading/commercial estate. Power is generated from a collection of decentralized energy technologies and connected at a single point to the larger utility grid. Micro-grids are essentially an active distribution network because they combine different forms of generation and loads at distribution voltage level [1].

The CAT microgrid concept is an advanced approach for enabling integration of a mix of renewable generation technologies of various sizes, levels of energy storage, etc. into the national electricity grid. The schematic for the CAT micro grid is shown in Fig I. It consists of electrical loads and generators connected through a low voltage distribution network. There are three types of load supply points known as raw mains, precision mains and emergency loads. The loads from the emergency supply are of high priority and raw mains loads are of least priority.

The micro grid is coupled with the utility grid through a main circuit breaker and a single, high-speed switch (G59 relay) which is used for disconnection from and synchronisation to the grid as per the UK regulations for exporting power.

III. OPERATION

The CAT micro grid is operated in two modes: grid connected and stand alone. In grid connected mode, the micro grid remains connected to the utility grid either totally or partially, and imports or exports power to or from the utility grid. The micro generators provide power to all the loads, and excess power is exported to the utility grid through the main controller. At the same time, the main controller continuously checks various parameters of the utility grid including voltage and frequency.

If any of the permissible parameter limits are breached or in the event of a utility grid failure, the micro grid switches over to stand alone or island mode while still feeding power to both the supply points. The same can also be achieved by either opening the main circuit breaker or automatically disconnecting the G59 relay. The main controller then makes sure that the generators will continue to operate as a stand alone grid system. The main controller along with the generator controller will then regulate the power generation according to demand.

IV. RENEWABLE GENERATORS AND GENERATOR CONTROLLERS

There are various types of renewable generators including wind, hydro, photovoltaic and an energy storage facility, with biomass CHP as a future option (table 1), spread over 40 acres of land. All the micro generators have their own electronic control system (generator controller), metering and protection functions. The micro generators and energy storage are connected to both the supply points through generator controllers (GC) and the main control system (MC). The average annual energy use of CAT is 180 MWh of electricity and 700 MWh of heat. Fig 2 shows the 2011fortnightly energy generation of CAT.

TABLE I
CAT RENEWABLE GENERATORS

Generator Technology	**Rated Capacity**
Main PV Roof	20 kWp
Power House PV	1.75 kWp
Proven wind turbine	600 watts
Top Hydro	3.5 kW
Bottom Hydro	4 kW
Biomass CHP	100 kWe and 250 kW heat

A. Main PV Roof

The 20 kWp PV roof was installed in two phases. The first phase of 13.5 kWp was installed in 1997 by CAT and EETS (Energy Equipment Testing Services), based in Cardiff, as part of the DTI New & Renewable Energy Programme and the European 'THERMIE' programme. The installation project was to prototype a new system to integrate unframed PV laminates into the roofing system. A report detailing the installation was published by the DTI (Department of Trade and Industry)[2].

The roof is installed with 180 BP 75Wp monocrystalline modules, and was refurbished in June 2010 and re-configured into 12 strings, each consisting of 15 modules in two rows, to minimise shading losses and to bring the wiring up to the latest regulations.

The system has been fitted with five Fronius IG series inverters one off 4kW and four off 2kW, balanced evenly between the three phases. The reason for using smaller single phase inverters was to provide six test rigs to teach qualified electricians how to install PV systems, on the City & Guilds 2399 course "Installation & Testing of Domestic Photovoltaic systems".

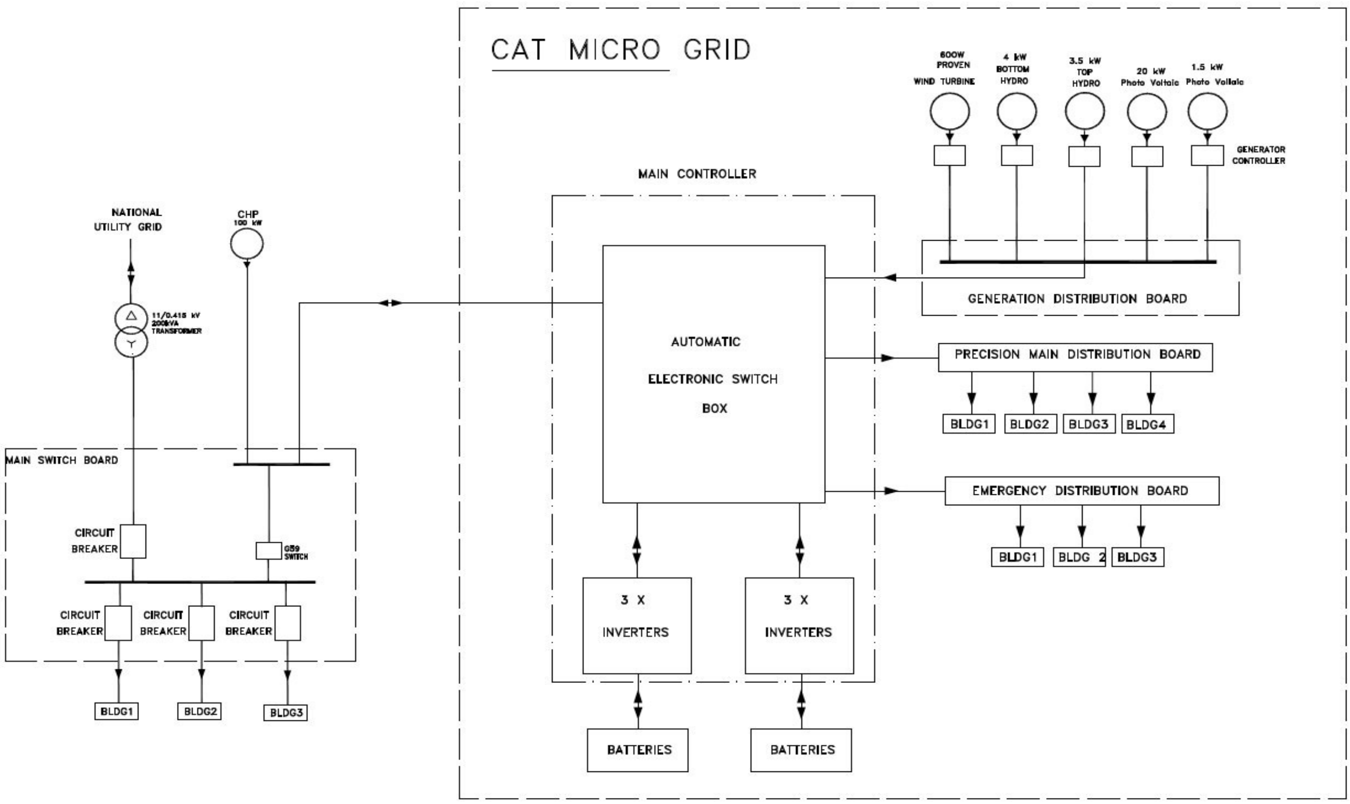


fig 1. Microgrid schematic

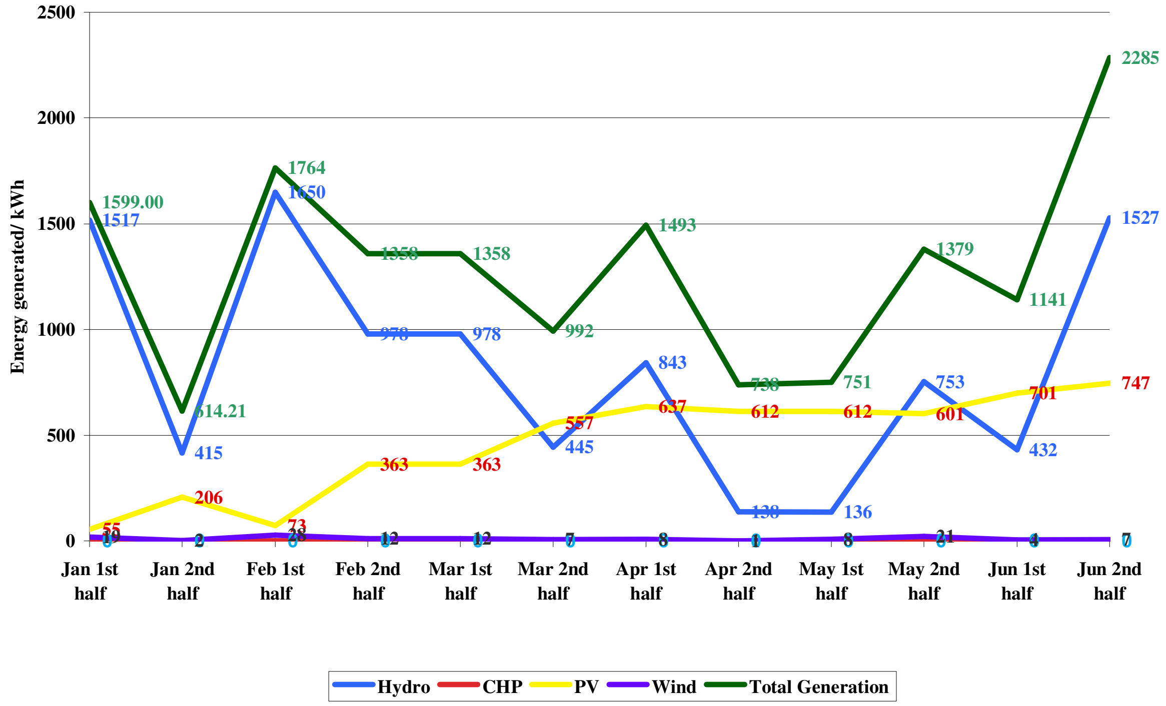


Fig 2. Fortnightly energy generation of CAT

The second phase of the roof consists of 78 Romag powerglaz monocrystalline modules to make a total of 6.5 kWp. This was installed in 2007 and configured into five strings of 12 modules each and one string of 18 modules. The system has been fitted with one Fronius IG series inverter, one SMA SB 1700 inverter and one Mastervolt XS2000 inverter balanced evenly between the three phases.

B. Power House PV

The 1.75 kWp power house PV roof was installed in 2006. The roof is installed with 14 Kyocera 125Wp monocrystalline modules, configured into one string. The system has been fitted with an IG 15 Fronius inverter.

C. PV Inverter Efficiency

The efficiencies typically quoted for inverters only reflect DC-AC conversion efficiency, and don't indicate the efficiency of the maximum power point tracking (MPPT) circuit in the inverter, which varies considerably between brands, and would affect design decisions. They propose a total efficiency which is the sum of the MPPT and DC-AC efficiency [6].

Fig 3 shows that most of the solar energy available occurs at below 500W/m^2 and hence that any system would need to make maximum use of low irradiances to achieve good annual performance. The graph shows peaks of Irradiance at 0.05, 0.1 and 0.275 W/m,^{2} which are significant in modelling inverter performance. The array is also significantly shaded by hills, trees & buildings (in descending order) as shown in Figure 4, therefore all of the strings will encounter shading at some point. This indicates that the efficiency of the inverter needs to be considered with other factors as well [5].

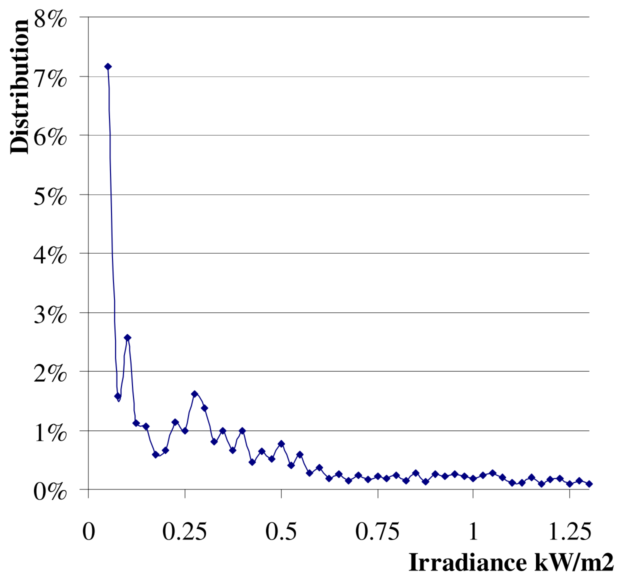


Fig 3. Direct Irradiance Distribution for the CAT site.

The average yearly generation from PV is currently 10,000 kWh. The reason this value is less is than the Standard Assessment Procedure (SAP) value is because the PV roof is used for the PV installers course frequently in summer.

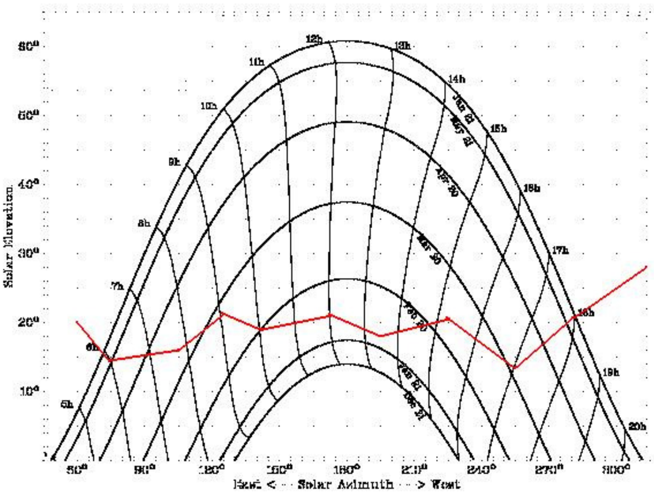


Figure 4: Sun Path Diagram for CAT (Lat52.62 Long-3.83), showing shading of 20kW PV Arrray (red line), 180^o = due south.

D. Hydro Turbines

There are two hydro turbines working onsite, both connected to the microgrid. Bottom hydro is a pelton wheel with an asynchronous generator rated at 4 kW. The top hydro is also a pelton wheel coupled with a synchronous generator rated at 3.5 kW. The top hydro used to be a stand alone system with a single manual valve. In 2009, this was converted to a grid connect system using a rectifier and a grid connect Windy Boy inverter 3800. The inverter was set up to work for the hydro hydro turbine on a set point of the power/voltage curve of the inverter, where the hydro turbine's manual valve is at the fully open position.

E. Proven Wind Turbine

The wind turbine is rated at 600 watts and was originally installed as a stand alone wind turbine. This was converted to a grid connected system in 2010 through a rectifier and a SMA Windy Boy LV1100 grid connect inverter. The site of the wind turbine is not the best available windy location, which is evident from the wind speed distribution data of the site (fig 5). Although a full year's output from the wind turbine is not yet known, calculations show the turbine should generate about 205 kWh. So far in 2011 it has generated 134 kWh. One reason for better generation considering the location is because of the high inverter efficiency at lower wind speed as seen in Fig 6

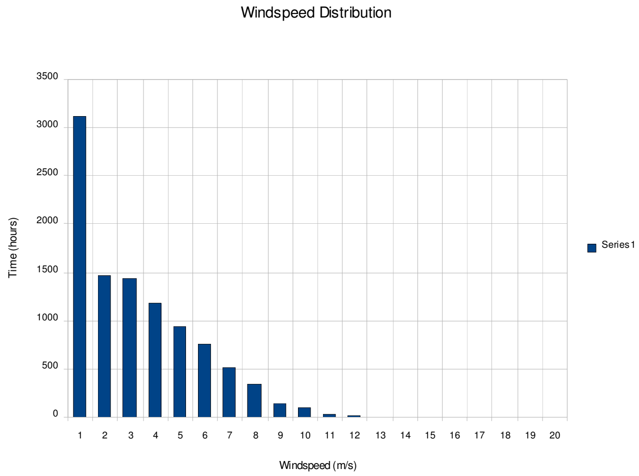


Fig 5 wind speed distribution data

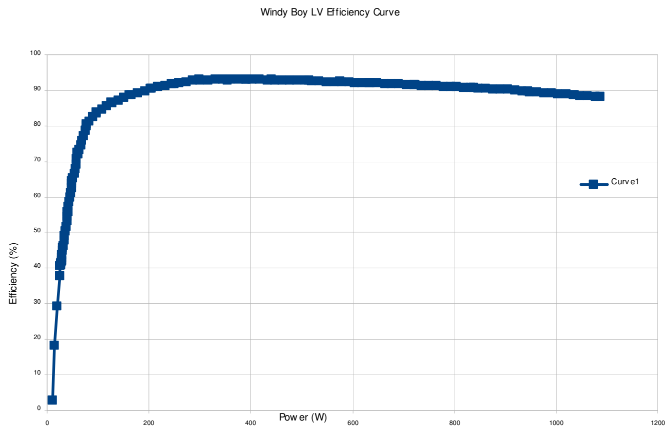


Fig 6. Proven Inverter efficiency curve

F. Biomass Combined Heat and Power (CHP)

The CHP consists of a high speed synchronous generator coupled to a power converter rated at 100 kW. CHP is currently not connected through the main controller but is intended to be connected later on.

G. Generator Controller (GC)

The main function of the GC is to autonomously control the power flow and load voltage profile of the generator in response to disturbance and load changes. The GC also makes sure that the generator rapidly picks up its generation and its share of load in stand alone mode, and automatically switches back to grid mode with the help of the main controller (MC).

This feature makes it possible to add more generators to the micro grid in the future without affecting the control and protection of existing units. This way the GC will not interact with other GCs in the micro grid or override the main controller directives [1]. The details of the GC inverters operational at CAT can be seen in Tables 2 and 3.

H. Main Controller (MC)

The main controller, which consists of inverters and an automatic electronic switch box, executes the overall control of micro grid operation and protection through the GCs. Its main function is to maintain specified voltage and frequency to the load end, ensuring energy optimisation for the micro grid. The main controller also performs the protection co-ordination of the micro grid, the power dispatch points and voltage set points for all the GCs [1].

TABLE 2:
PV INVERTERS

Company	Model	Nominal AC Power	Maximum AC Power	Maximum DC Array Size	Euro efficiency	Maximum efficiency
		W	W	W	%	%
Fronius	IG 15	1300	1500	2000	92.2	94.2
Fronius	IG 20	1800	2050	2700	92.3	94.5
Fronius	IG 30	2500	2650	3600	92.7	94.5
Fronius	IG 40	3500	4100	5500	93.5	94.5
Mastervolt	XS2000	1600	1725	1800	94	95
SMA	Sunny Boy 1700	1550	1700	2050	91.8	93.5

TABLE 3:
OTHER INVERTERS

Company	Model	Nominal AC Power	Maximum AC Power	Maximum DC input	Euro efficiency	Maximum efficiency
		W	W	W	%	%
SMA	Windy Boy 1100 LV	1000	1100	1210	90.4	92
SMA	Windy Boy 3800	3800	3800	4040	94.7	95.6
SMA	Sunny back up 5000	5000 W	7200			95

V. LOAD SHARING THROUGH FREQUENCY CONTROL

The main controller ensures smooth and automatic changeover from grid-connected mode to stand alone mode and vice versa as per necessity, which is similar to the operation of an uninterrupted power supply (UPS). During grid connect mode the loads are supplied both from the utility grid and micro generators [1]. During stand alone mode, the inverters from the main controller exert a frequency control over the generator controllers. This changes the operating point to achieve local power balance at the new loading. If there is more generation than demand then the frequency rises, which compels the generator controller to switch off the micro generators. Conversely, when the generators are switched off, and if there is enough demand, the frequency goes down, which triggers the generator controller to switch on the micro generators.

VI. PROTECTION FUNCTION

The electronic switch box responds to utility grid faults and loss of mains scenarios in a way that ensures the correct protection of the micro grid. During a utility grid fault or other electrical disturbance the electronic switch box immediately switches over to stand alone mode.

VII. PRIORITISATION OF LOADS

Microgrids will not only allow for the optimisation of power sources, but also power uses. The CAT micro grid system prioritises vital communications, computer servers and emergency lights, while cutting power to other appliances. When the micro grid is working in stand alone mode and there is no generation at all, all the energy will be coming from the battery store. The battery store ensures that in the unlikely event of no wind, sun or water, and where none of the generators produce any electricity, there will still be power for at least 3 hours at maximum load. At the same time the main controller continuously checks the utility grid to reconnect. In this mode, after a certain period of time when the available battery energy has decreased, the system will disconnect the precision mains supply and continue delivering power to the emergency supply for an additional hour.

VIII. KEY EXPERIMENTS DONE

CAT is a living laboratory exploring solutions through various experiments. The outcomes of these experiments will feedback to our research for further development. The microgrid is the latest ongoing experiment by students and staff at CAT.

The recent addition to the microgrid is the centralised data server for energy monitoring and weather data. Using this data the energy mix and how the energy is used are illustrated as shown in Fig 7.

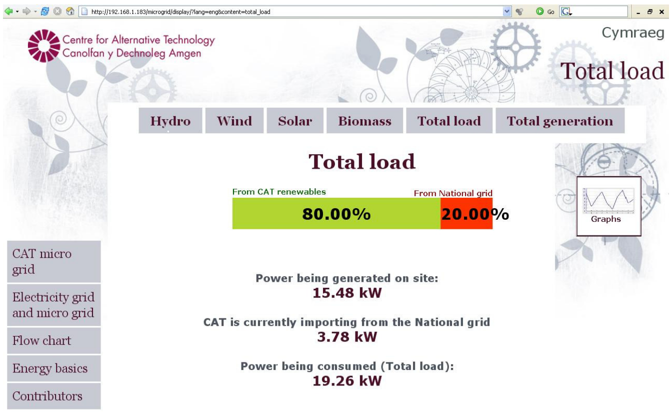


Fig7. Energy Mix

One of the major experiments carried out at CAT was operating the microgrid on island mode for an entire month. This provided useful insights on the storage timings with various load patterns and how long the microgrid can keep going with renewables on stand alone mode. The month selected for the experiment was a particularly bad month in terms of weather conditions. Certain days were really cloudy with hardly any sun and at the same time it did not rain much. The long dry spell reduced the water level in the lake.

The combination of hydro and PV was able to meet demand for most of the day time hours, but during the night the system had to rely on batteries. There were a few sunny days as well however, when demand was lower than generation, and hence the PV generators often shut down as the batteries were already fully charged. Fig 8 shows the PV switching patterns on a sunny day, with many peaks and troughs as the battery fully charged when demand was low.

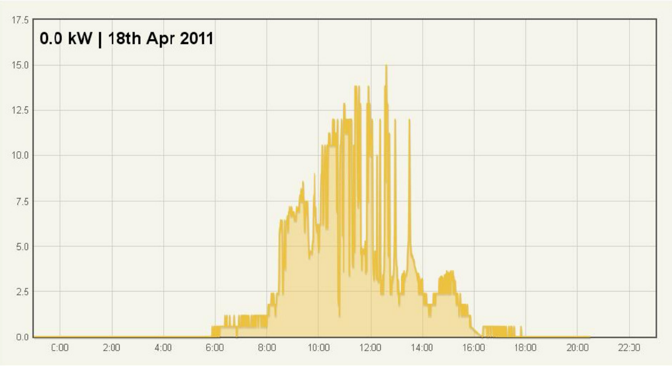


Fig 8. Main PV roof generation profile

IX. FINDINGS FROM EXPERIMENTS SO FAR

One of the challenges is integrating the system with weather mapping to allow accurate prediction of renewable energy generation. Accurate weather prediction is critical in knowing the best times to run the hydro turbines and biomass CHP. In future it will be more important given the price fluctuations of energy. This will also provide the opportunity for extra storage and selling back to the grid at the best price. The experiments gave us insights on how important it is to have weather forecast information when making decisions about system operation.

Other studies include analysis of the wave form of the main controller and how it affects the generator controller. It was found that the harmonic distortion of the output voltage goes to 4.8%. Since the inverter AC filter circuits vary between manufacturers, the synthetic wave form generated by the microgrid created some issues with the Fronius inverters. Whenever there was switching from grid mode to island mode there was an overvoltage of about 275 volts for 30 microseconds as illustrated in Fig 9. Apart from the voltage change the frequency also rose to nearly 80 Hz.

Students from the GSE will be undertaking research on power quality issues such as transient voltages and harmonic distortion during inverter switching.

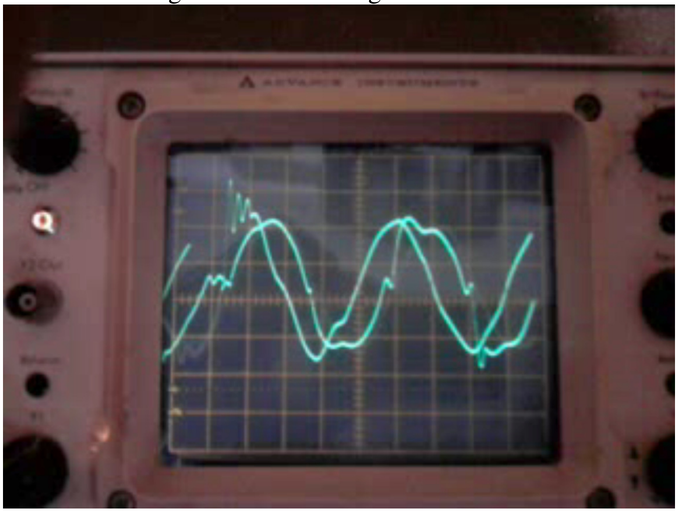


Fig 9 Main controller switching waveform

X. FUTURE MICRO GRID EXPERIMENTS

The next phase of the CAT micro grid involves connecting the biomass CHP to the system. Since the CHP generates heat along with electricity the heat load must be balanced. The selection of the operating period and operating power level is quite complex, as it depends upon the cost of fuel and electricity import/export, along with demand for heat and electricity.

The generator controller of the CHP must prioritise heat or electric energy because the demands for these loads might not coincide all of the time. This requires setting up adequate energy storage for both heat and electricity to ensure efficient operation of the plant.

The visitor centre is planning to install electric vehicle charging points in the CAT car park for visitors to use. These charging points will connect to the microgrid system along with the existing two heat pumps. Linking the heat pumps, Plug in Electric Vehicles (PEV) and a "smart fridge" will enable a more flexible use of loads, and will be a useful tool for students to model the balancing of supply and demand based on weather data.

A. Search for Collaborators from the Industry

CAT is now seeking new partners and collaborators from industry and academia in trialling new equipment and techniques for further research on emerging technology, including smart appliances with dynamic demand controls. One of the main smart appliances under consideration is the new innovation by True Energy called Sure Chill technology. This groundbreaking refrigeration technology accesses electricity when it is cheapest and more readily available, and can maintain low temperatures for over 10 days without any power at all.

Future ideas include making the entire visitor centre a living laboratory where the visitors are part of the experiment. This would be offered to specialist groups, school groups, businesses and the general public. The system would be able to provide data on visitors' smart phones so that they can find out in detail about renewable generation in real time. From the data they should be able to predict how much generation can be possible from the weather forecast and the predicted demand.

XI. TECHNICAL AND FINANCIAL ADVANTAGES OF A MICRO GRID

Transmission and distribution congestion in the utility grid is growing, with energy demand outpacing investment in new or improved transmission facilities. Power interruptions to high energy users in industry due to line overloading are increasing and many users currently rely on fossil fuel based backup power systems to ensure an uninterrupted energy supply [9].

Smart micro grids can assist a higher penetration of renewables into the grid. These more efficient, distributed generators will reduce dependency on fossil fuel based centralised so that carbon emissions can be reduced.

The electricity requirements of local demand will be met locally with a reliable and uninterruptible power supply. The management of reactive power and voltage regulation at the micro grid level can assist utility generators in generating energy at their optimum capacity and efficiency [1].

Smooth voltage regulation at local level reduces transmission (feeder) losses [9]. Transmission and distribution network losses are currently about 9% in the UK. Micro grids could reduce the maximum demand on the central generation system, leading to large savings in operation and long term investments [10]. The physical proximity of consumers to energy generation sources may also help to increase their awareness of energy usage [3].

XII. TECHNICAL AND FINANCIAL CHALLENGES FOR THE MICRO GRID

There is a widespread lack of experience in controlling a large number of micro resources. In particular, maintaining the power quality and balance, voltage control and system fault levels all pose challenges to operators [7].

Further research is needed on the control, protection and management of the micro grid, and standards addressing operation and protection issues need to be developed further. [1]. Furthermore, wider systems of support for micro grids still need to be developed. For example, specific telecommunication infrastructures and communication protocols need to be developed to encourage better communication between distributed generator controllers and the main controller, as well as between various micro grids. [1]

A. Financial Costs

Presently the capital costs for Distributed Generation (DG) solutions and micro grids are high, with much of the technology still at the development stage. The relative costs of micro grids depend upon the balance of a number of factors. The plant capital costs per GW are typically lower for centralised generation. It is generally believed that transmission and distribution infrastructure costs would be lower with an increased number of micro grids. However, the location-specific nature of the DG and micro grids means that it has not been possible to model this effectively.

Although generation costs for DG technologies are high compared to centralised generation per GWh, the addition of the DG technology to the grid network will reduce the overall system costs. The total costs are likely to be approximately the same if we retain a framework where the micro grid is a complement rather than an alternative to centralized generation. [4].

A 30 kW microgrid established at the Centre for Alternative Technology integrating wind, hydro and PV with 3200 Ampere hour (Ah) battery store cost about £60,000. This excludes the cost of generators and grid connection.

XIII. ANCILLARY BENEFITS OF MICRO GRIDS

A micro grid is one way to deal with an energy shortage during peak demand by prioritising loads and selectively cutting off power to certain loads [8].

More generally, micro grids help to reduce the stress on transmission lines because they share the energy locally. This requires energy storage systems across the country to capture energy whenever there is excess energy generated especially during night time. As battery technology improves, having storage systems spread across the national grid through an interconnected micro grid will achieve the greater stability and controllability that comes with a distributed control structure. Connected micro grids could take advantage of short-term selling opportunities with a choice of "spinning reserve". Spinning reserve is the extra generating capacity available in the generator by increasing the power output that are already connected to a power system generating at lower than full power output. Micro grids could also provide short term operating reserve (STOR), back up capacity and Black Start (start up) facility. Black Start is the procedure to recover from a total or partial shutdown of the national transmission system.

XIV. MICRO GRIDS AND POLICY

The micro grid debate can be seen as part of two wider debates, one about the role of distributed generation and the other regarding the role of 'smart grids'. Both of these developments offer clear potential benefits, but they also have costs.

Sustainable distributed generation is a great asset for the process of decarbonising nationally. Furthermore, it provides additional generation capacity for a potentially faster connection grid network, with the opportunity to help power our society and economy. It is generally not the most economically attractive option in terms of direct capital costs. However, it does have social benefits, including decreased energy demand by building occupants. Also DG is generally set up by individuals and communities who can benefit from the very considerable economic support of the Feed in Tariff.

One question for future research is to what extent micro grids can provide further load balancing, especially when actively managed in the smart grid system.

XV. REFERENCE

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Jaise Kuriakose was born in India. He graduated from the Mahatma Gandhi University and studied at Middlesex University.

His employment experience includes industrial consultancy in India on power stations, airports and technical parks. He currently works at Centre for Alternative Technology on renewable energy systems. His special fields of interest included integration of renewable generators to the grid, micro grids and smart grids.

Attachment E

Blaencamel costs

Type of work	Price in £	
Prelims	£	2,339.00
Demolitions	£	225.00
Renovations	£	860.23
Excavations	£	524.13
Concretor	£	2,198.85
Stone brick block	£	8,211.35
Carpenter	£	10,934.00
Roofer	£	11,514.30
Joiner	£	15,789.61
Door forniture	£	754.70
Finishes	£	17,926.72
Sanitary Fittings	£	1,588.10
Insulation	£	2,000.00
Drainage	£	2,059.19
Plumber	£	8,273.74
Ventilation	£	560.75
Electrician	£	5,420.00
External	£	3,065.60
Drainage unforeseen	£	7,754.75
Total	**£**	**102,000.02**

Blaencamel bill of quantities

Page No	STONE/BRICK/BLOCK F	material	ref. no./ grade	finish	section/ unit size	length		rate	£
	WALLING								
F1	External 'rain-screen' walls to extension	Stone	Coursed random rubble		350 wide	81.90	sq.m m	35.40	£2,899.26
	Labour only dry stone							prov	£500.00
	Stone								
	ce walls	Stone	coursed random rubble		350 wide				inc. above
	ngs	Ffestiniog		riven	25 x 450x random	47.00	Lm	31.06	£1,459.92
		Slate			lengths 450 min.				
4	Cills	Slate		riven	25 x 200	3.80	Lm	37.85	£143.83
F5	Pipe sleeves for services through wall								£20.00
F7	Upstand at edge of slab	Dense concrete			215x440x140	60.00	no	1.50	£90.00
F8	" " " " below cills	"			150x440x 140	50.00	no	2.20	£110.00
F9	Sub-cills/cappings to upstand	Slate		riven	35 x 200 x random	12.00	Lm	49.87	£598.44
	Grid lines 2A-B, 2D-E, 3A-B, B1-2, D1-2				450mm min.				
F10	Chimney: below floor level	Aerated concrete			215x440x100	42.00	no	1.15	£48.30
	: in rafter zone	block			" "	10.00	no	1.55	£15.50
	: elsewhere	Dense concrete			215x440x100	180.00	no	1.98	£356.40
	Concrete padstones					**2.00**	**no**	**15.00**	**£30.00**
	Form fire place in brick						**item**		**£215.00**
	Flue damper						**item**		**£35.00**
F11	Lintel over hearth	R/C or stone			215x100	1.40	no	32.00	£44.80
	Mantel shelf	Slate			25 x 200	1.45	no	38.90	£56.41
F12	Hearth - dimensions as shown BC/A19	Slate		riven	40 x 500	3.20	Lm	121.88	£390.00
	Shelf in fuel recess	Slate		riven	25x 330x 600	3.00	no	37.70	£113.10
	Support block work for shelf etc.						**item**		**£115.00**
F13	Fireplace flue by:	Clay	YJ16		300mm sq.	8.00	no	29.30	£234.40
	Hepworth Building Products								
	Hazlehead								
	Stockbridge								
	Sheffield								
	SS30 5HG								
	Tele: 01226 763561								
F14	Air Supply Ducts:								
	Cavity liners by Hepworth (as above)	Terracotta	YB12		215 x 140	27.00	no	3.25	£87.75
	Floor vents:								

	Rect. hole Air Bricks by Hepworth (as above)	Terracotta	YA12		215 x 215	2.00	no	14.06	£28.12 inc. later
	Hit and miss vents								
						2.00	no	26.50	£53.00
					25 x 150	2.00	no	26.50	£53.00
		Slate			25x150	1.50	cu m	78.95	£118.43
F16	Chimney coping	Slate							
	" "	Concrete	Gen 3 or ST4						
F17	Fill for voids in construction						item		£245.00
									£25.00
F18	Raise head of opening ED2							12.57	£125.70
	and form steps, slate treads					10.00	m2		
	Make good								
F19	Oil Tank Support Walls	Dense concrete block							
								To Collection	£8,211.35

Page No	CARPENTRY G Contractor to check quantities	material	ref no / grade	finish	unit size	length(s)		rate	£
	STRUCTURAL FRAME (nos. refer to gridlines)								
	No allowance for purchase or conversion of any timber. All timber supplied by client								
	Purchase of carcassing timber							Prov	£1,000.00
G1	Columns	Green Oak	40 Quarter Sawn or boxed Heart	Planed	125 x 125	28/2700	no		
G2	Diagonal braces 1-2	"	"	"	175 x 75	4/2800	no		
	" " 3-4, 5 -6	"	"	"	175 X 75	14/2600	no		
G3	Cross Beams 1-2	"	"	Sawn	150 x 75	5/1800	no		
	" " 3-4, 5-6	"	"	"	150 x 75	9/1500	no		
	" " 2 - 3 can be jointed	"	"	"	150 x 75	2/5100	no		
	" " 4 - 5 D,.C & above partition	"	"	"	150 x 75	3/3900	no		
G4	Eaves Beams i (4500 finished)	"	"	"	175 x 125	6/4800	no		
	" " ii	"	"	"	175 125	6/3700	no		
	" " iii	"	"	"	175 125	4/3900	no		
	" " iv	"	"	"	175 125	6/3300	no		
G5	Ridge Beams 2 - 3	"	"	"	225 x 100	4/4100	no		
	" " 4 - 5	"	"	"	200 x 100	3/4100	no		
G6	Principal rafters 2 -3	'	"	"	100 x 100	8/3300	no		
	" " 4 - 5	"	"	"	100 x 100	8/2600	no		
G7	"Buttress" Block Pieces 1-2A, B,D,E	"	"	"	200 x 60	4/1700	no		
	" " " 3-4A, B/5-6B	"	"	"	200 x 60	3/1400	no		
	" " " 1-2C/3-4 & 5-6 C,D,.E	"	"	"	200 x 60	7/1000	no		
							item		£4,680.00
	SECONDARY FRAMING	Green Oak OR	40	Sawn					
		Softwood	SC3	Sawn					
G8	'A' Rafters 2 - 3				150 x 50	70/3300	no		
						231.00	Lm	1.95	£450.45
	" 4 - 5				100 x 50	54/2600	no		
						140.40	Lm	1.80	£252.72
G9	'B' (Ceiling) Rafters 2 - 3				50 x 50	62/3300	no		
						204.60	Lm	1.65	£337.59
	" 4 -5				50 x 50	46/2600	no		
						119.60	Lm	1.65	£197.34

G10	Tilt fillet				50 x 50		160/2300	no		
							368.00	Lm	1.55	£570.40
G11	Ext. Wall Studs				50 x 100		110.00	Lm	1.80	£198.00
G12	Head & Cill Plates				150 x 50		13.00	Lm	1.95	£25.35
G13	Bearers below timber cills				45 x 45		15.00	Lm	1.55	£23.25
G14	Rendered Studwork 2A-B							item		£179.00
G15	Webs for spaced studs	hardboard	oil-tempered		6 mm			item		£223.75
	Webs for spaced rafters	"	"		6 mm					
G16	Sheathing for roof & walls	Bituminous Fibreboard	'4D' TG4		18 mm	1200x2500	247.00	m2	3.75	£926.25
	by: Falcon Panel Products Ltd									
	Terminal House									
	Station Approach									
	Shepperton									
	Middlesex TW17 8AS									
	01932 253011 (Mark Brady)									
	Fixings									
	Columns/GF slab									
G17	2 no brackets/column	mild-steel		galvanised	200 x 100x 8 angles 150 long		14.00	pairs	18.00	£252.00
G18	Bolts: 4/conn.	m/s	XOX bolt	"	M12 x 180		56.00	no	2.85	£159.60
G19	" 2/conn.	m/s	Chemical Anchors	"	M12 x 150		28.00	no	7.87	£220.36
					16 & 20 mm dia			no		inc.
G20	Frame joints generally:	oak pegs								
G21	Beam scarf joints:	mild steel	XOX bolts	"	M12 x 175		32.00	no	2.80	£89.60
G22	Principal rafter apex joint	mild steel	**XOX bolts**	"	M12 x 100		8.00	no	3.75	£30.00
G23	Principal rafter/beam joint:	mild steel	**XO screw**	"	M12 x 100		16.00	no	2.60	£41.60
G24	Transom/beam joint 2/conn.	mild steel	XOX bolts	"	M12 x 175		20.00	no	2.80	£56.00
G25	Lower wall plate/concrete block: 1/1200 mm	mild steel	Chemical Anchors	"	M10 x 100		44.00	no	6.94	£305.36
			"	"	M10 x 100		22.00	no	6.94	£152.68
										Omit
G26	Cills/concrete block	mild steel			50 mm					
G27	Secondary framing: nails	S/S	round wire		38 mm					
G28	Hardboard web/studs or rafters	"	"							
		"	"		125					
	Rafters/beams 2/conn.	"	"		100					**Omit**
	Stud framing 2/conn	"			125					
	Roof-light eaves/struts 2/conn							item		£150.00
	Other joints: nail or screws as appropriate									

Page No		material	ref. no./ grade	finish	section/ unit size	quant./ length	U	rate	£
	ROOFING NATURAL SLATING H.			CCA	12 x 40	371.40	Lm	0.40	£148.56
		Softwood		"	20 x 40	724.50	Lm	0.44	£318.78
		"			65 x 3.35				**Omit**
H1	Counter battens	Stainless	Roundwire						
H2	Battens	steel.			20 x 10	2,750.00	no	2.89	£7,947.50
	Fixings: Nails	Slates	extra heavies		20 x 15	60.00	no	4.35	£261.00
			"		12 x 10	400.00	no	2.07	£828.00
H3	Slates from:		Heavies						
	Cwt y Bugail Quarry								-£1,000.00
	Ffestiniog								
	Gwynedd LL41 3ND						item		£45.00
	Provisional saving with second hand slates				30 x 2.8				
		Copper or				**25.00**	**Lm**	**19.82**	**£495.50**
H4	Fixings: Nails 2/slate	S/steel		**Charcoal**			**prov**		**£100.00**
		Capped	**Redbank**						
	Ridge tiles,					3.00	Lm	27.35	£82.05
	Eaves vents					2.00	Lm	16.42	£32.84
H5	LEADWORK	Lead	Code 3			21.00	Lm	14.98	£314.58
	Soakers at chimney abutments	Lead	Code 4			3.20	Lm	18.47	£59.10
	Side & front flashings at chimney	Lead	Code 3			3.20	Lm	18.47	£59.10
	Flashing between transom, cills & slate wall coping	Lead	Code 3						
	Flashing over beam Gridline 1	"	"			7.80	Lm	15.78	£123.08
	" " " " 6								
	Flashings at ends of rooflights	"	"						
	gridlines B5-6, E3-4, E5-6					14.00	Lm	16.58	£232.12
	Flashings over transom	"	"						
	B5-6, B6-E6, E3-4, E5-6						item		£1,467.08
					0.4mm				
H6	Gutter between Grid Lines 1 & 2	Uginox	AE 304						
	" " " " 3 & 4, 5 & 6	Terned S/s							
	'Uginox' by:								
	Eurocom Enterprise Ltd, Index House,								
	St. George's Lane, Ascot, Berks. SL5 7EU								inc.
	Tel: 01344 23404					1 per gutter			"
H7	Flowband joints				0.4.mm & 0.6 mm				"
	(Fixings: Sliding cleats at 400mm cs.	Stainless steel			2.8mm x 38				"
	Nailed, 3/cleat, s/s ring shanked clout nails, large head								"
H8	Underlay - British Sisalkraft building paper		411					To Collection	£11,514.30
	All by approved specialist contractor								

Contractor recommends use of geotextile underlay as opposed to building paper and has allowed for the same.

Page	JOINERY L	material	ref. no./ grade	finish	section/ unit size	quant./ length	U	rate	£
	No allowance for purchase or conversion of any timber. All timber supplied by client								
L1	Rooflights & Gutter framing.								
	Eaves plate	Oak	Green	Sawn	60x 220	38.00	m	2.05	£77.90
	Glazing bars over terraces	"	Air dried	PAR	50 x 85 fin	22.00	m	3.20	£70.40
	" " " rooms	"	" "	"	50 x 75 fin	47.50	m	3.20	£152.00
	Cover strips	Oak	Air dried	PAR	20 x 50	69.50	m	1.75	£121.63
	fixing: woodscrews + cups	Brass			62 x 10G				£17.50
	End filler pieces over buttresses	"	" "	"	60 x 200± fin		item		£35.00
	Eaves fascias	"	Green	Sawn	25 x 240	24.00	m	2.15	£51.60
L2	Gutter Studwork	"	"		50 x 50		item		£225.00
	Deck for gutter	Ply	WBP		18 mm	23.00	sq.m	8.50	£195.50
L3	Glazing: Double Sealed Units, Low E,								
	upper pane toughened , lower laminated								
	toughened, lower laminated glazing system: MVP by		Kite marked		4 + 12 + 4		sq.m		inc. later
	Single glazed laminated						**sq.m**		**inc. later**
	Adshead Ratcliffe								
	Derby Road								
	Belper								
	Derby								
	Tel:01773 826661								
	Prime Timber to receive sealant		Arbo primer						
			2650						
L4	Bedding sealant	Butyl Strips	Arbo Seal GZ		15 x 3 mm				
	Bedding sealant capping	Silicone	Arbo Seal	Grey					
	& outer sealant		1096						inc. later
	Window & Door frames/linings.								
L5	WI (BC/A11)lining	Oak	Green	PAR	45 x 170 fin				
					45 x 180 fin		item		£57.00
L6	W2 (BC/A12) cill	Oak	Air dried	PAR	75 X 125 Fin				
	mullion	"	" "	"	50 x 62 fin		item		£78.00
	Studs below cill	"	Green	Sawn	50 x 50		item		£75.00
L7	W3 (similar to 2, but timber boarded below cill as elsewhere)						item		£87.00
L8	W4 (BC/A13) Linings	Oak	Air dried	PAR	45 x 140 (fin)				
	"				45 x 170 (fin)				

	[illegible]	"	"	"	45 x 160 fin				
L9	W5 (BC/D7) Linings	"	"	"	75 x 160 fin		item		£101.00
	Cill	"	"	"	45 x 170 fin				
L10	W6 (BC/A11)Linings	"	"	"	45 x 180 (fin)				
	"	"	"	"	45 x 225 (fin)		item		£82.00
	"	Oak	Air dried	Sawn	45 x 50				
	Shutter box frame	"	"	"	30 x 50				
	rails	"	"	"	20 x random		item		£98.00
	boards	"	"	Sawn	65 x 125				
L11	W7 (BC/A14) lining	"	"	PAR	62 x 65 (fin)		item		£87.50
	mullion								£52.00
L12	W8 similar to W3 but single fixed light								
L13	Weather seals to sliding windows: Manton		Molar Minor		6.5mm pile		item		£125.00
		"	"	"	75 x 100 (fin)				
L14	D1 (BC/A15) frame (side)	"	"	"	55 x 140 (fin)				
	filler pieces (side)	"	"	"	45 x 60 (fin)		item		£95.00
	Door stops						item		
		"	Green	Sawn	60 x 100				£35.00
L15	Filler piece over buttress	"	"	"	20 x 45 (fin)				
	Door stops	"	Green	Sawn	50 x 125		item		£65.00
L16	D2 (BC/A18) Head of frame	"	"	"	50 x 115				
	Filler piece	"	"	"	50 x 125		item		£65.00
L17	D5 (BC/A18) Head of frame	"	"	"	20 x 115		**prov**		**£250.00**
	Filler piece								
	D9 to be designed	"	"	"	60 x 100				
L18	D10 (BC/A15) filler piece over buttress	"	Air dried	PAR	45 x 60 (fin)				£85.00
	Doorstop	"	"	"	20 x 45 (fin)		item		£42.00
	"	"	Green	"	20 x 45 (fin)				
L19	D2,3,4,5,6,7,8 Doorstops								
	D11 (BC/D8); Priced elsewhere								
	Windows & Doors								
	Existing windows - generally								
L20	Remove sashes and overhaul to fit accurately						prov		£250.00
	and operate smoothly								
	Check putty and re-glaze if necessary								
	Check sash fasteners and replace if necessary								
L21	Existing windows - detail repairs						item		£125.00
	Repair as follows:								
	EW1 - repair outer casings								
	replace casements								

	replace cill								
	EW3 - repair outer casings								
	replace cill						item		£55.00
	EW4 - repair LH casing								
	replace cill						item		£95.00
	replace lower casement						item		£95.00
	EW5 - as for EW4								
		Including timber							
L22	New Windows & Doors to House								
	See BC/D 6								
	In position of: EW/6						item		£235.00
	EW/7						item		£200.00
	EW/8						item		£205.00
	Frame, sash, casings, cill	European	Class 1	PAR					
		Redwood							
	Glass	Float	BS 544	Clear	4 mm		item		£67.96
	Putty	Linseed Oil	BS 544				item		£10.00
	Weather Seals: Schlegel	"Zero Gap"		Grey			item		£29.87
	New Door D11 to House (BC/D8)								
	In position of: ED1						item		£125.00
	Frame, door	European	Class 1	PAR			item		£50.00
		Redwood							
	Glass	Float	toughened		4	9.00	no	7.75	£69.75
	Putty	Linseed oil					item		£7.50
	Seals: Schlegel as elsewhere		Aquamac 21				item		£31.25
L23	Windows & Doors in extension								
	W1 (BC/A11 & D3) fixed light	included elsewhere							
	W2 (BC/D3 & D4) Stiles	Oak	Air dried	PAR	45 x 50 fin				
	Sliding head	"	"	"	45 x 70 fin				
	Foot	"	"	"	45 x 80 fin		item		£125.00
	W3 same scantlings as W2						item		£75.00
	W4 (BC/D3 & 4) Stiles	Oak	Air dried	PAR	45 x 65 fin				
	Sliding head	"	"	"	45 x 85 fin				
	Foot	"	"	"	45 x 150 fin		item		£145.00
	W5 (BC/D7) head, foot, closing stile	"	"	"	35 x 50 fin				
	Stile	'	"	"	45 x 69 fin		item		£95.00
	W6 (BC/D3 & 4) Stiles	"	"	"	45 x 65 fin				
	Sliding head	"	"	"	45 x 85 fin				
	Foot	"	"	"	45 x 150 fin		item		£155.00
	W7 (BC/D3 & 4) Stiles	Oak	Air dried	PAR	45 x 65 fin				

	Foot								
	D1 & D2 Stiles	"	"	"	55 x 75 fin				
	(BC/A15, D1 & 2) rails	"	"	"	25 x 100 fin				
	boards	"	"	"	15 x 200 fin		item		£145.00
	D2, 3, 4, 5, 6, 7, 8, CD1 rails	"	"	"	30 x 50 fin		item		£125.00
	(BC/A18, D1) boards	"	"	"	20 x 200 fin		item		£220.00
							Prov		**£100.00**
	CD1 + 2								
		"	"	"	20 x 250 fin		item		£195.00
	CD3 boards	"	"	"	30 x 50 fin		item		£95.00
	(BC/A24) rails				55 x 100				
	D10 (BC/A15, D1 & 2) Stiles/head	"	"	"	55 x 200		item		£195.00
	foot								
L24	Glazing beads:			PAR	10 x 30				
	Sliding lights except W5	Oak	Air dried	"	15 x 15				
	D.10	"	"	"	10 x 40				
	W5	"	"	"	Various		item		£175.00
	Fixed lights glazed to frames								
	see relevant A drawings.								
L25	Double Glazed Sealed Units				4 + 12 + 4				£5,024.90
	Low-E all clear glass	float	Kite marked			**Reduce roof lighting to 500mm long**			
	W1 fixed. 2 panes toughened								
	W2 fixed " "								
	sliding " "								
	W3 fixed 2 panes plain								
	sliding " "								
	W4 fixed 2 panes toughened								
	sliding " "								
	W5 opening 2 panes toughened								
	W6 sliding 2 panes toughened								
	W7 fixed " "								
	sliding " "								
	D10 opening 4 panes toughened								
	Glazing system MVP as L4 above								inc.
	W8 single glazed plain	"	BS544	acid etched	4mm				
L26	Timber Partitions								
	(BC/A16,17,18)						item		£188.00
	Base Plates	Oak	Green	Sawn	50 x 125				

	Beam over D3 & D4	"	"	"	75 x 1[illegible]				
		"	"	"	75 x 125				£140.00
	Frames to D2,3,4 & 5	"	"	"	75 x 150		item		£120.00
	" " "	"	"	"	75 x 125	225.00	Lm	1.95	£438.75
	Ceiling joists	"	"	"	50 x 75	105.00	Lm	1.40	£147.00
	Studs & rails	"		Galvanised	12x 40 x 3 mm		item		£125.00
	Sliding Cleats - unequal angles	Mild Steel		Sawn, T&G	20xrandom widths		item		£896.00
	Wall boards	Oak	Green	"	"	80.00	sq.m	2.35	£188.00
	Floor boards	"	"	"					-£468.15
	Reduced cost# of boarding								£115.00
	Beads at head of boarding	"	"	"	25 x 25		item		
L27	Fixings								
	Screw, c/sink, pellet:	Stainless							
	Linings/Studs	Steel			75 x 12G		item		£39.00
	Door stops/frames	"			50 x 10G		item		£30.00
	D1 & 2 boards to rails	"			30 x 8G		item		£25.00
L28	Bead fixing: screws @ 300 cs	Brass			30 x 6G		item		£11.50
L29	Studwork/frames: Nails	Stainless Steel	Roundwire		100		item		£120.00
	Cleats/rails Screws @ 300 cs.	"	Domed headed		30 x 8G		item		£25.00
	Last wall board in section rails Screws	Brass			50 x 10G		item		£8.75
	Floor boards: Nails	"	Ring-shanked		62 x		item		£160.00
L30	PTFE strip for sliding units	PTFE			4 X 20		Lm	prov	**£200.00**
	" " " "	"			4 x 25		Lm		
		<u>I have only priced this provisionally because I could not find a supplier.</u>							
	fixings: Centre fixed, 1/300mm slotted holes	Brass c/sunk			25 x 6G		item		£25.00
L31	Glue for boarded doors	Cascamite							inc.
	FITTINGS								
L32	Utility Room (BC/A22,23)								
	Sink Unit								
	Shelves						item		£295.00
L33	Perimeter Drain cover strips	Oak		Sawn	35 x 120		item		£27.50
L34	Bathroom (BC/A20,21)								
	Duct							prov	**£115.00**
	Bath panel							prov	**£125.00**

		material	ref. n[illegible] grade	finish	section/ unit size			rate	£
	FINISHES M								
	VAPOUR CONTROL								
M1	Vapour check membrane by British Sisalkraft	Reinforced	411						
		Paper							
	Lap Sheets 100 mm, only at supports. Staple @ 200 cs								
	Seal paper to frames at openings in position								
	shown on drawings.					247.00	m2	2.57	£634.79
	Use double sided tape. Tape all joints in the								inc.
	membrane to prevent air movement.								
	Walls: inner face of stud								
	framing (Seal to posts & beams)								inc.
	Ceiling: underside of rafters								
	Gutters: underside of framing								inc.
									inc.
M2	Damp proof membrane to ground floor by:								inc.
	RIW Ltd		LAC		2 coats	155.24	sq.m m	4.91	£762.23
	Arc House								
	Terrace Road South,								
	Binfield								
	Bracknell, Berks.								
	RG12 5PZ.								
	Tele: 01344 861 988								
	Fax: 01344 862 010								
M3	INSULATION								
	Insulation to ground floor 'Jablite'	Expanded	SD/N		150 mm	131.58	sq.m m	7.27	£956.59
		polystyrene							
M4	Pipework flush floor ducts (BC/L15) by	Galv. steel	22 gauge						
	Pendock Profiles, Halesfield 19, Telford				200 x 50	16.00	Lm	18.30	£292.80
	Shropshire TF7 4QT Tel:01952 580590				Ply lids	17.50	Lm	10.23	£179.03
	Allow for all fixings, packing, tape to joints, covers etc.				Butt joints	8.00	no	3.97	£31.76
					Corners	4.00	no	20.64	£82.56
M5	SCREED				Fixings and labour				inc.
	To ground floor - tiled areas	1 cement	OPC		65 thick	31.04	sq.m m	8.65	£268.50
	- carpet areas	4 sharp sand	BS 1200		75 thick	100.54	sq.m m	8.85	£889.78
M6	Mesh for fixing heating pipes	mild steel	A98			131.58	m2	1.75	£230.27
M7	Matwells								
	See S for underfloor heating	Galv. steel				3.00	no	35.00	£105.00

	PLASTER								
M9	Lime plaster:								
		Lime render							
	Walls - Internal								
	Walls - external			Wood float	20 mm thick			provisional	£7,721.75
	Ceilings			"	"				
	Woodcemair slabs			"	"				
M10	SLATE FLOOR SLABS (BC/L15)								
	Slate from:								
	Gloddfa Ganol Quarry								
	Blaenau Ffestiniog								
	Gwynnedd								
	Tele: 01766 830 664								
	Lay random sizes in courses								
	Porch, Utility room, living room (part)	Slate							
	Boiler room, WC, Bathroom			Polished	12mm thick	35.00	sq.m	44.75	£1,566.25
	Glazed terraces to living room								
	Mortar bedding	1 OPC	1 OPC	"	"	16.00	sq.m	39.75	£636.00
		4 Sand			3mm ±				
	Grout	"			thick				
					5mm joints				
M11	SLATE WALL TILES								
	Tiles from:								
	Gloddfa Ganol Quarry								
	Utility room	Slate			225 x 225 x 10	7.00	no	2.95	£20.65
	Bathroom	"			225 x 225 x 10	0.00	no	2.95	£0.00
	Cloakroom	"			225 x 225 x 6	130.00	no	2.95	£383.50
M12	LIMEWASHING								
	Allow for mixing 4								
	colours internally:								
	Walls - internal	Lime putty +			3 coats	82.50	sq.m m	2.25	£185.63
	Walls - external	Water +			"	22.00	sq.m m	2.75	£60.50
	Ceilings	pigments			"	138.00	sq.m m	2.55	£351.90
M13	CARPETS (BC/L15)								
	Fine Boucle weave matting from	Sisal						Prov	£1,200.00
	Crucial Trading Ltd., The Market Hall, Craven Arms,								
	Shropshire SY7 9NY Tel. 01588 673666								

Page No	INSULATION P	material	ref. no./ grade	finish	section/ unit size	quant./ length	U	rate	£
	In Walls - Generally				200 thick	86.20	M2	9.16	
	In wall below W2				65 thick	2.50	M2	4.80	
	In wall below W3 & between								
	Utility area & Living room				75 thick	23.00	M2	5.05	
	In roofs				300 thick	144.90	M2	14.10	
	Below gutters				50 thick	33.60	M2	4.80	
	In external doors				25 thick	4.00	M2	2.50	**Omit**
		Sheeps wool					**Prov**		**£2,000.00**
P2	Jablite Floor Insulation - priced elsewhere								
								To Collection	£2,000.00

No		material		finish	section/unit size	quant/length	U	rate	£
	RAINWATER GOODS								
R1	Existing house: Inspect, repair, replace where								
	defective, existing RW goods.						prov		£75.00
	New sheet metal valley gutters priced elsewhere								
R2	Downpipes to valley gutters	aluminium			75mm dia.	3.00	no	57.12	£171.36
	Include for brackets, connections and fixings								
R3	Square gullies from:								
	Hepworth Building Products as elsewhere	terracotta	RGS10/1			3.00	no	33.46	£100.38
	Grids	alloy	IG2			3.00	no	7.50	£22.50
	RW pipe adapter		SA/11			3.00	no	4.79	£14.37
	Allow for concrete bases								inc.
	Branch	clay	SJ1/1			3.00	no	13.36	£40.08
	Surface Water								
R4	Terrace Perimeter Drains (BC/A13)	In situ conc.				11.50	Lm	11.50	£132.25
	Allow for cover support bars 1/1200mm max.	s/s			9mm dia.	10.00	no	6.70	£67.00
	Cover strips priced elsewhere								
	Branch for Study Terrace drain		SJ1/1			1.00	no	13.36	£13.36
	New soakaway to suit, min. 5m from extension					1.00	no	27.98	£27.98
R6	Straight pipe from: Hepworth as elsewhere	Vitrified clay	Supersleve			49.00	m	4.75	£232.75
	Rodding eye to water course					1.00	no	9.87	£9.87
	RW gullies to branches						no	allowed for earlier	
	Courtyard perimeter drain to new soakaway						no		inc.
	Study Terrace perimeter drain to branch						no		inc.
R7	Lay pipes in class D natural bed					49.00	m	1.75	£85.75
	DRAINAGE ABOVE GROUND								
	By Terrain or other approved manufacturer								
R8	Bathroom:								
	Soil pipe from duct to ground level	UPVC			110 min dia		1tem		£19.17
	Automatic air admittance valve in duct				110		1tem		£39.87
	WC branch to soil pipe				110		1tem		£8.80
	Waste from bath to SP				40		1tem		£21.50

	Waste from basin to SP			32		1item		£18.67
	Deep seal traps to all San. Fittings					1item		£18.75
	WC cistern overflow pipe to external wall			19		1item		£17.90
	Include for all necessary fittings & Fixings							inc.
R9	Cloakroom/Boiler room.							
	Stack + access plate in boiler room			110				£33.13
	Vent pipe from stack to top of chimney - include connection			75	5.00	m	8.65	£43.25
	WC branch to stack			110				£21.70
	Waste from basin to stack			32				£33.78
	WC cistern overflow to stack via tun dish			19				£27.89
	Condensate drain from boiler to stack			40				£33.00
R10	Utility Room							
	Stub stack & access plate			110				£15.47
	Waste from sink to stub stack			40				£16.54
	DRAINAGE BELOW GROUND							
R11	Open all manholes, clean out gullies, flush out gullies, flush out entire foul and surface water system and report to the Architect							£20.00
R12	Remove existing manhole as shown on Drg. BC/L2							£30.00
R13	New drainage by:							
	Hepworth Building Products Ltd	Vitrified Clay	'Supersleve'					
	Hazlehead							
	Stockbridge Sheffield S30 5MH							
	Inspection chamber VCIC with raising pieces as required	" "	SIC5	215mm dia.	1.00	no	127.53	£127.53
	Cover and frame	alloy	ISIC		1.00	no	21.50	£21.50
	Square back inlet hopper with trap	Vitrified clay	SH3/1		1.00	no	39.14	£39.14
	Hinged grate and frame	alloy	IH1		1.00	no	9.76	£9.76
	Connection to kitchen waste					item		£15.14
	Rest bends at foot of soil pipes	Vitrified Clay	SDBR1	100 mm	3.00	no	13.34	£40.02
	Rodding eye		SRPI/1		1.00	no	9.87	£9.87
	Branch		SJ1/1		2.00	no	13.36	£26.72
	Straight pipe + couplings from: Hepworth as above				21.00	m	4.75	£99.75
	Rodding eye to new inspection chamber			100	1.00	no	9.76	£9.76
	Bathroom to branch			100		no		inc.
	Cloakroom to branch			100				inc.
	Utility to MH			100				inc.
	Hopper to inspection chamber							inc.

S7	Hot Water Storage cylinder indirect type, uninsulated	copper				1.00	no	112.75	£112.75
	Thermostat for primary heat source BEAB		BS 3955						
	approved, strap on type								
	Immersion heater, 2 element copper sheathed + thermostat		BS 3456		3 Kw	1.00	no	39.36	£39.36
	Insulation (in timber box)	Wool			100 mm min	1.00	no	56.10	£56.10
S8	Pump						Item		£54.00
S9	Oil tank:								
	Move existing tank to new position					1.00	no	68.78	£68.78
	Base is taken for under section E concrete								inc. earlier
	Lay new oil line		10 metres allowed			10.00	m	9.97	£99.70
S10	Run Cold supplies from main to:								
	Sink (1 no)				15mm	10	m	5.65	£56.50
	WHB's (2 no)				15mm	25	m	5.65	£141.25
S11	Run Cold supplies from existing cistern to:								
	Washing machine (1 no)				22mm	15	m	6.85	£102.75
	Bath (1 no)				22mm	30	m	6.85	£205.50
	WC Cisterns (2 no)				22mm	8	m	6.85	£54.80
	External Standpipes (2 no)				15mm	10	m	5.65	£56.50
S12	Run hot supplies from new HW cylinder to:								
	Sink (1 no)				15mm	5	m	5.65	£28.25
	WHB's (2 no)				15mm	10	m	5.65	£56.50
	Bath (1 no)				22mm	25	m	6.85	£171.25
	Washing machine (1 no)				15mm	5	m	5.65	£28.25
S13	Run Flow and Return from boiler to:								
	Existing and new HW cylinders indirect circuits						item		£125.00
	Existing radiator circuit						item		£115.00
	WIRSBO Manifold						item		£35.20
S14	Floor ducts from boiler priced elsewhere								
	A98 mesh in screed priced elsewhere								
	Generally: Include for all necessary fittings & fixings								inc.
	Agree system design and pipe runs with Architect								
	before work commences								

Page No	EXTERNAL WORKS X	material	ref. no / grade	finish	[illegible]	[illegible]		rate	£
X1	Allow for dismantling length of existing garden wall								
	to give site access. Set stones aside for re-use								
									Omit
X2	Construct temporary site access	Crushed rock etc.							
									Omit
X3	Paving	Slate		Riven	min 25 thick		sq m m		
	Office terrace	Slate		Riven	"	9.00	sq m m	39.75	£357.75
	Courtyard	Slate		Riven	"	15.00	sq m m	39.75	£596.25
	Living room terrace	Slate		Riven	"	15.00	sq m m	39.75	£596.25
	Sub-base	Crushed rock	75mm sieve		150 thick	24.00	sq m m	2.95	Omit
		etc.							
	Base	Pea shingle	6mm		75 thick	24.00	sq m m	3.75	£90.00
	Lay paving with 10mm joints								
	Open joints in unroofed areas to allow free draining								
	Pointed in roofed areas. Point with semidry mix	6 Sand 1 OPC							
	rammed in, to avoid staining.								
X4	Walling	Stone provided							
	To new entrance court	by client			500 x 800 high		prov		£400.00
	To existing front terrace, replacing demolished wall				500 x 600 high		prov		£250.00
	Construct 3no. steps from parking to entrance court	Slate		Riven	As paving above	4.80	sq m m	39.75	£190.80
						3.50	Lm	59.87	£209.55
X5	Rebuild length of wall removed in X1 above, to match								
X6	Car Parking area						prov		£250.00
	Remove temporary site access and reuse material								
	Clear area and lay, to level of track:				minimum				
	Sub base	Crushed rock	to pass 75 mm		150 thick		prov		Omit
		etc.	sieve		75 thick		prov		£125.00
	Surface	Gravel	to pass 25 mm						
X7	Soil preparation & planting								
	Regrade and reseed site access across garden							To Collection	£3,065.60

Peniarth Uchaf costs

Carpenter and wood	slates	finishes	electrician	Pat Borer	consults	doug lomas	plumber
£ 19,889.93	£ 210.00	£ 500.00	£ 2,632.00	£ 2,761.25	£ 1,116.25	£ 1,650.00	£ 6,235.17
£ 13,005.20	£ 1,362.00	£ 5,000.00	£ 37.97	£ 385.00	£ 842.26	£ 1,384.00	
£ 5,002.00	£ 3,080.00	£ 35.42	£ 2,439.00	£ 5,138.46	£ 1,057.50		
£ 6,938.13		£ 640.00	£ 717.00	£ 1,231.40			
£ 10,738.18		£ 6.94	£ 611.51	£ 5,571.41			
£ 725.52		£ 20.00	£ 1,055.00	£ 2,503.20			
£ 12,279.04		£ 13,797.00	£ 35.00				
£ 10,463.61		£ 60.00	£ 1,968.75				
£ 14,058.61		£ 6.75	£ 656.25				
£ 19,428.67		£ 2,000.00	£ 1,575.00				
£ 13,082.92		£ 37.01	£ 1,415.40				
£ 11,115.07		£ 116.33	£ 6,090.00				
£ 7,749.17		£ 975.00	£ 1,393.63				
£ 7,438.91		£ 720.00	£ 412.38				
£ 1,230.00		£ 132.00	£ 781.60				
£ 13,777.51		£ 279.47	£ 311.10				
£ 5,273.47		£ 49.65					
£ 3,897.44		£ 2,560.50					
£ 8,654.08		£ 4,039.20					
£ 8,748.25							
£ 3,468.50							
£ 196,964.21	**£ 4,652.00**	**£ 201,616.21**	**£ 22,131.59**	**£ 17,590.72**	**£ 39,722.31**	**£ 3,034.00**	**£ 6,235.17**

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