Nuffield Farming Scholarships Trust

A Yorkshire Agricultural Society Award

Why Build with Straw?

Carol Atkinson

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Contents

Disclaimer

This report, its conclusions and recommendations, are my own views and not necessarily a reflection of the views of The Nuffield Farming Scholarships Trust or the Yorkshire Agricultural Society.

1. Executive Summary

Straw is remarkably strong and durable. It is practical and functional yet can be beautiful and stylish. It's renewable, locally available, cost effective and plentiful. But most importantly, it is a material with very low embodied energy, it reduces the energy demand of a building because of its super-insulating properties and it locks up carbon for the life of the building (which when designed and built well, can be a very long time).

I was already convinced of this before I applied for my Nuffield Scholarship. My question was "how could I convince others of the benefits of building with straw?"

As I travelled through the United States of America, Canada and mainland Europe, meeting many inspiring straw bale builders, the similarities became apparent. They were all, in their own quiet but determined way, dedicated to a more sustainable lifestyle, pushing the boundaries, continually questioning, expanding their knowledge and unselfishly helping others to do the same. They lead by example and slowly but surely things are changing from the grass roots level. It's not authorities leading the way (sometimes they get *in* the way!) - it's the people on the ground bringing about change.

This is how straw bale building is becoming more popular – doing, learning, sharing.

There are no huge straw bale building empires in the world. This goes against the ethos of a sustainable lifestyle. The leaders in the natural building world know that it's about local materials and local skills. It is a mix of old fashioned values combined with the very effective use of modern communication technology to share knowledge. It was the same in the sustainable agriculture world that I dipped into on my travels - a growing network of people who talk *and* do. They talk to inform or enquire but they practice what they preach too.

There was something else I wanted to get to grips with during my study. "What are the carbon and energy consequences of current uses of straw in the UK?" and "How do the numbers stack up?"

Currently, the UK Government supports the burning of straw to generate electricity through the renewable obligation certificates they pay to power companies. I examined the carbon and energy implications of burning versus building – in year one, building with straw is 2.5 times better from a carbon point of view than burning it in place of coal. In addition, in less than 5 years the insulation afforded by using straw in a building could save the same amount of carbon again and so on *every* 5 years.

Burning straw is not a good thing to do. Government should remove support from burning and encourage building instead. **The evidence is unequivocal – we must burn less straw and sequester more.**

But there was another, unexpected realisation - straw is a valuable resource to agriculture and I, like many others, was guilty of not fully appreciating this fact. Straw is widely viewed as a waste or an insignificant by-product at best. We have so much straw that we take it for granted. However, like many other things that we have regarded as waste in the last 30 years or so, it is time for reassessment. As growers are forced to use less manufactured fertilisers and chemicals, the value of returning straw to the land will be realised. Incorporating straw, either directly behind the combine or preferably via farmyard manure, has important nutrient, carbon and, most importantly, soil structure benefits.

Straw is a valuable resource.

2. Introduction

2.1 History of straw bale building

Straw and other natural fibres were used in man's very early buildings. Bales, however, were first used in the USA in the late 1800s after the invention of the baling machine. European settlers on the Nebraskan Plains had no timber with which to build their homes so they stacked their bales for shelter. The oldest straw bale house still standing in Nebraska today was built in 1903.

In the 1940s a combination of war and the popularity of Portland cement led to the virtual extinction of straw bale building – until a revival by US green building pioneers in the 1970s.

2.2 My background

I live with my husband Richard and our two sons, near Eastrington, a small village in the Vale of York. We have 200 acres of grassland on which Richard runs a 120-cow single suckled beef herd.

For over 20 years I commuted to work in a distant office by day and worked back home as farm administrator/odd job person most evenings and weekends. Increasingly I felt that my best efforts were being put into someone else's business rather than our own and I also felt disconnected from the community in which we lived. So with an ever-growing burden of paperwork and rules and regulations to contend with on the farm the decision was made in 2004 to leave the comfort of paid employment to concentrate on the job at home.

With the aim of finding a diversification idea, I enrolled as a part-time student on a Masters degree course in environmental architecture. I had always had an interest in the subject area but never the time to pursue it. My study was based at the Centre for Alternative Technology (CAT) in Wales from 2005 – 2008 and this is where my interest in using straw for construction began.

Although we no longer grow cereals on our farm, most of our neighbours are large-scale arable farmers. We buy wheat straw from them to use as winter bedding for our cattle. There is an abundance of wheat straw in our locality – in theory, a plentiful raw material around which to develop a new strand to our business.

We decided to build a straw bale holiday cottage on the farm (pictured below) – we would learn the techniques in the process, we would have a new holiday let business and we would hopefully have a building that would showcase straw bale construction. It would also form the basis of my research thesis into the thermal performance of such buildings.

The Straw Bale Cabin - our first straw bale building completed in March 2007. At only 10m by 4m and built on a caravan chassis, this was an ideal starting point for us. The resulting one bedroom "mobile" straw bale holiday home is performing well – and proving a popular tourist destination on our East Yorkshire farm.

As both the process and the end result were a resounding success, our eldest son Sam, who had just completed his joinery apprenticeship in Hull, came back to the farm in 2008 to build our second, larger cottage. This would further develop his construction knowledge and would double the holiday let side of the farm diversification.

The Straw Bale Cottage - our second straw bale building completed in August 2009. It is a permanent two-storey construction with internal floor area approximately 120m^2. Accommodation comprises a large kitchen, lounge, study, porch and cloakroom with shower on the ground floor and 2 large bedrooms and bathroom upstairs. The straw bales are load bearing – they carry the weight of the roof and upper floor.

After completing the cottage in 2009, Sam set up his own natural building company and has been busy since, building with straw bale for several Yorkshire clients.

2.3 An overview of my study

As we have seen, interest in building with straw is growing, but the UK still lags a long way behind the rest of the world. On my Nuffield travels I hoped to meet straw bale

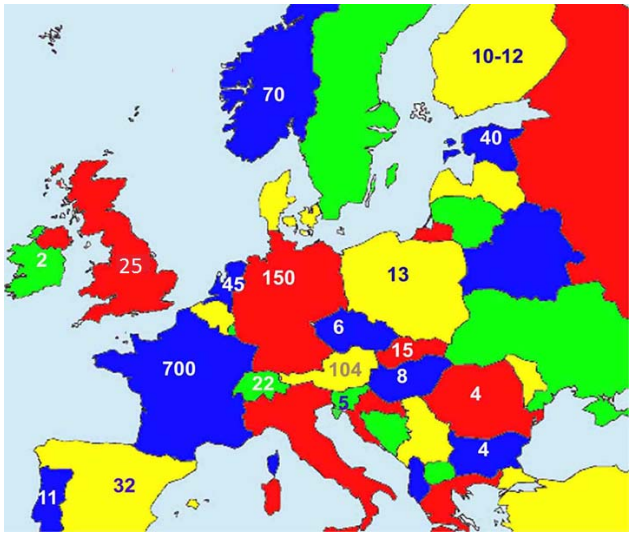
proponents far more knowledgeable than I who could help me develop and promote a greater use of straw in construction back home.

I also wanted to explore more about the energy and carbon implications of building with straw compared to other current uses for it. At my original Nuffield interview in London, a member of the panel had posed a similar question. It seemed appropriate then, to take this opportunity to delve further into the carbon and energy issues.

Since the 1970s revival, there are now thousands of straw bale buildings in the United States. A visit here was a must on my Nuffield travels.

As Internet searches for straw bale studies frequently came up with Canadian references, a visit to straw bale buildings and research establishments in Canada would be the perfect end to a North American trip.

Building with straw bales is also gaining popularity in mainland Europe. The oldest European straw bale house was built in France in 1921 and the map below indicates that the idea is catching on there.



This is an approximate guide to the number of straw bale dwellings in Europe. It has been prepared by Professor Burkard Rueger of FASBA (the German Straw Bale Association www.fasba.de) from information gathered through the European Straw Bale Network www.strawbale-net.eu

3. Visits in the straw bale world

In seven weeks of travel with Nuffield I have been to California, Oregon and Nebraska in the USA, to Manitoba and Ontario in Canada and to Belgium, Switzerland, Italy, Austria and Slovakia. I've been welcomed into many amazing straw bale family homes. I have also seen straw bale offices, shops, dormitories, schools, a church, visitor centre and even a straw bale winery in California. I was lucky enough to meet architects and professors, homeowners, builders, trainers, contractors and farmers who freely shared their wide-ranging experiences.

With regard to the buildings I encountered, you wouldn't believe there could be so many variations! As I have travelled, I have seen;

- walls with bales stacked flat and others with bales stacked on edge
- bales of rice straw, wheat and barley straw and even baled up prairie grasses
- bales have ranged from very dense to not so
- small bales, Hestons, mini Hestons and even round bales (good when columns are required!)
- load bearing constructions, timber frame, steel frame and hybrid forms
- I've seen plastered bales (with and without mesh reinforcement), timber clad bales and in some instances just bales!
- bales have been predominantly in walls but also in floors and ceilings
- some owners prefer a curvaceous finish to walls, others prefer perfectly straight edges and others combine both
- some of the buildings I have seen have been built on a very small budget indeed and, at the opposite end on the spectrum, there have been some very expensive or extravagant buildings
- there are self-built, community built, specialist or general contractor built and pre-fabricated buildings – including brand new straw bale buildings, extensions and renovations to existing buildings – both domestic and commercial
- some have been constructed within strict codes, some to voluntary standards whilst others have escaped regulation altogether.

The possibilities with straw bales, it seems, are endless. People all over the world are using their ingenuity and locally grown materials to build in an environmentally responsible manner.

There follows, in date order, photographs and notes from each of my visits. I can't thank my hosts enough for their insights and kind hospitality – they are leading the way. There is further information and web links in Appendix A.

3.1 European Straw Conference

The "European Straw Bale Gathering" held near Riemst in the Flemish region in the west of Belgium in August 2009 was my first scholarship trip. Hosted by a different nation every other summer, this conference brought together straw bale experts from Belgium, Austria, Germany, The Netherlands, Italy, Spain and France among many others. In 2009 the special guest was David Eisenberg from the United States of America. He has been working very hard for many years on straw bale building codes there. www.dcat.net

Straw bale demonstration by Casa Calida at the European Straw Bale Gathering, Belgium 2009.

The most memorable realisation from ESBG 2009 for me was that, as long as the basic principle of keeping the straw dry is adhered to, anything goes. At the far end of the scale were the German contingent – their buildings had to be very precise and strong – only one in a million could fail. Load bearing bale buildings are not allowed in Germany as there are too many variable factors.

At the opposite end of the scale were Tom Rijvens' kind of buildings – more organic in form, much less timber, natural sugars in the plaster and baler twine removed for example; probably built more with intuition than calculation. Both methods, and all those in between, seemed equally valid to me. I think we should appreciate the diversity. Each method has advantages but can learn something from the other method.

Worthy of note also was the young Belgian agricultural contractor who was invited to the conference. He specialises in supplying construction grade straw bales. He worked closely with local architects and builders to provide the bales how and when they wanted and had invested in new baling and leading equipment to facilitate this service.

3.2 Buildwell conference, San Francisco

Bruce King, a Californian structural engineer, wrote my favourite straw bale book[1]. When I heard that he was organising an eco building conference in San Francisco, I knew that this was the place to start my North American journey.

Buildwell 2010 was a very interesting conference with many eminent speakers in the field of natural building.

Bruce King opened the conference with an overview of where we are now – "*6.8 billion people living in the Earth's thin biosphere, only 5 miles deep (including our oceans and skies").*

He explained how the built environment uses most of the Earth's resources. For example:

> "*most high-grade metals have already been extracted. They are already in the 'human sphere' ……*
>
> *Industrial cities and their skyscrapers will be uninhabitable without fossil fuels. We have to invent the eco city of the future.*
>
> *Today's problems won't be solved with the mentality that created them.*
>
> *We must apply the underlying principles of*
>
> - *Short distance*
> - *Simplicity*
> - *Transparency*
> - *Cyclic (use again or return to earth)*
>
> *We must learn from nature. Spider's webs and seashells are examples of nature's efficient structures. We must design intelligently to make the most of the resources we have. We can learn from others and from the past."*

Bruce's words could apply as much to food and farming as to building.

[1] *Design of Straw Bale Buildings, The State of the Art.* 2nd edition 2006 by Bruce King. Published by Green Building Press ISBN 978-0-9764911-1-8

3.3 Rural straw bale home north of San Francisco

Rural straw bale home being constructed north of San Francisco, California by Vital Systems.

My first straw bale experience in California was courtesy of Tim Owen Kennedy. We visited a large, stunningly beautiful family home being constructed well off the beaten track by his experienced bale building crew.

During the conference, I was lucky to make the acquaintance of local straw bale expert Tim Owen Kennedy who took me out to see this project of his that was nearing completion. It was an amazing house in an amazing location. Here are a few of the things I learnt in my short time with Tim:

- Rice straw is the local material of choice - it can take 2 years to fully decompose in the field, so farmers prefer to have it baled out of the way.

- Normally we would use clay plasters *or* lime plasters because they have different freeze/thaw properties, which could cause layers of different materials to delaminate. Tim, however, has developed a way to combine the two so that the more ecologically beneficial clay plasters can be used more widely.

- Even very experienced builders have tiny hairline cracks at the window corners (well protected from the weather by the generous roof overhang though!).

- Even clients who go to the trouble to engage the best natural builders in the area don't heed all the experts' advice.

- Buildings on the West coast of America have to be able withstand earthquakes. Over the years very prescriptive building codes have been developed which make it difficult to incorporate new innovations in straw bale building.

- The natural building movement in the US do a great deal to help poorer communities at home and abroad.

3.4 Straw bale bedrooms at Commonweal Garden, Bolinas, California

Straw bale bedrooms at Commonweal Garden, Bolinas, California.

The second straw bale building I visited was tiny in comparison to the first and built by volunteers on a very limited budget. Straw Bales and reclaimed materials were used to create two cosy bedrooms for students of permaculture.

By a stroke of luck, as I headed north from San Francisco, James Stark was holding an open day at the organic farm he co-manages with his wife. Here was straw bale accommodation at the opposite end of the spectrum to the house I visited with Tim – a fine example of how straw bales can be used to build very affordable shelter. Although the bedrooms were simple in design and construction, the natural materials gave the interior a very special feel indeed.

3.5 Ridge Winery, Lytton Springs, California

My next stop was a large commercial straw bale building (over 1600m2) incorporating wine storage, distribution centre and shop (with organic wine tasting!). Points of note:

Wine barrels in the straw bale 18,000 square foot warehouse at Ridge Winery at Lytton Springs, Sonoma County, California built in 2004.

- The use of straw bale walls encourages use of other ecologically sound building strategies (passive ventilation, recycled timber, solar panels etc).

- Site and usage specific design considerations are important too, such as large roof overhangs to provide shade to the south facing walls exposed to the intense Californian sun.

- Clay plasters were used to provide straight edges on the outside of the building but more traditional curved finishes were left on the inside.

- Clay plasters used externally benefit from rain protection.

- Straw bales and earth plasters moderate temperature and humidity for correct storage of wine barrels.

- The under floor heating was turned off as it was difficult to control.

3.6 Straw bale showroom, Hopland, California

Straw bale showroom at Real Goods Trading Co, Hopland, Medocino County, California completed in 1996.

A little further north still and this award winning building, at 14 years old now, was looking a bit tired (but perhaps this was just because it was a dull day in February!).

Like Ridge Winery, the Real Goods showroom was an example of a straw bale building, which included many other ecological features in support of similar business ethics. It was interesting to see how straw bales were used in part of the building only.

3.7. Andrew Morrison, training straw bale builders

Andrew Morrison. Photo courtesy of his website www.strawbale.com

Andrew Morrison now concentrates on leading straw bale workshops after spending many years as a contractor. He kindly invited me to his home in Ashland, Oregon, where we chatted about his work for an hour or two. Andrew embraces modern technology in spreading straw bale knowledge – DVDs, Facebook page, blog, tele-seminars, You Tube and online forums. This allows him more time with his young family than working away on construction sites did.

Andrew rightly pointed out how natural building needs to be economically sustainable as well as environmentally sustainable. He tries to develop systems that are fast and effective to compete with conventional building methods.

3.8 Straw bale house, Cottage Grove, Oregon

Straw bale house built at Cottage Grove, Oregon in 1997 for dormitory accommodation.

Oregon State University monitored this building for 5 years, until 2002. Funding for research anywhere tends to be short term. More is needed to monitor the performance of straw bale buildings over a much longer time span.

Most straw bale builders are so proud of their straw bale walls that they leave a “truth” window to show an un-plastered section of straw. Size varies from a few inches to a few

metres – I saw a wide variety on my travels. The truth window in the new building at Aprovecho is in a timber wall rather than a straw wall but it was interesting because of its novel curved shape and because it shows the build up of the clay plaster layers – a technique we have adopted in a recent educational project we have worked on.

3.9 The Living Building Institute

Ecosense – home of Ann & Gord Baird – Victoria, British Columbia, Canada. Photo courtesy of The International Living Building Institute.

http://ilbi/lbc/certified

Inspirational Vice President Eden Brukman took an hour out of her busy schedule to chat to me over coffee in Portland, Oregon. The Living Building Challenge is the *"most advanced green building rating system in the world*". It tries to *"reconcile humanity's relationship with the natural world……. to create a future that is socially just, culturally rich and ecologically restorative"*. The deep-green standards set are very high and the first projects have only just been accredited under the scheme. The photo above is of a private straw bale residence in British Columbia. It is not one I visited but it recently achieved partial program certification and Kris Dick, who I was about to meet in Canada (see below), was part of the project team.

The Living Building Challenge should be compulsory reading for every person alive today. Everyone should be aware of how much better our buildings could be. The objectives may be difficult to achieve but if we don't know about them we can't be striving towards them.

The Challenge has 7 performance areas:

Site – encourages building on brown field sites, opportunity for growing food, habitat exchange and pedestrian orientated community

Water – 100% water use should be met by precipitation on site

Energy – 100% energy needs should be met by on-site renewable energy generation

Health – all occupied space should have access to fresh air, daylight and good air quality. The human attraction to nature should be nurtured.

Materials – red list materials are prohibited (eg asbestos, lead, PVC, creosote), but locally sourced products and services encouraged, sustainable resource extraction, fair labour practices, no waste.

Equity – accessible to all members of society, promote culture and interaction.

Beauty – include design features solely for human delight, celebrate culture – as the precursor to caring enough to preserve, conserve and serve the greater good.

It's a tough standard to meet and continually evolving. More information can be found at www.ilbi.org

3.10 The Lone Oak, Lincoln, Nebraska

The Lone Oak built in 1945 in Emerald, near Lincoln, Nebraska, originally as a restaurant with dance hall above.

I'm in Nebraska now, the home of straw bale building and in the very capable hands of Joyce Coppinger, editor of The Last Straw – the international journal of straw bale building.

No trip to the US would be complete without a stop off in Nebraska, home of straw bale building and of straw bale stalwart Joyce Coppinger, editor of the international journal, The Last Straw. Joyce was promoting the cause at the annual sustainable agriculture convention in town that weekend but still found time to show me around a few snow covered straw bale buildings in the area.

First was the Lone Oak, built in 1945 and still standing the test of time despite the use of non-breathing materials (cement!!!). The new owners are not concerned with its historical value or its upkeep and we viewed quickly from the safety of the car as they are not too keen on straw bale tourists!

The current owners have no interest or idea how to care for natural buildings - this could be the ultimate fate of any building.

3.11 Straw bale visitor centre, Spring Creek Prairie, Lincoln

A straw bale visitor centre – The Audubon Centre at Spring Creek Prairie near Lincoln, Nebraska built in 1996.

This is a wonderful building to showcase life on the prairie. Joyce was keen for me to learn from its mistakes too, all of which could result in moisture damage to the straw;

- Turned out corners (as in the centre of the above photo) not protected sufficiently by the roof overhang and showing signs of weathering.
- First course of bales placed too close to the floor.
- Poor detailing on walls where tin, higher up near the roof, joins the plaster lower down.

3.12 School, Roca, near Lincoln

Straw bale Montessori school at Roca, near Lincoln, Nebraska, built in 1995.

This school had a wonderful mural painted on the lime plaster. As we carefully walked around in the snow Joyce once again helped me learn from the mistakes, which could lead to moisture damage to the straw bale walls:

- Exposed electric boxes on one external wall made it look damp – a weak point in the external render – could they have been inside the building or in a separate structure?

- The gable ends needed overhang protection at single storey height (or a hipped roof).

3.13 Test centre at University of Manitoba, Canada

Straw bale test centre at the University of Manitoba, Canada.

My first stop in Canada was at the University of Manitoba where Professor Kris Dick runs the Department of Biosystems Engineering.

My first stop in Canada was at the University of Manitoba where Kris Dick runs the Department of Biosystems Engineering. His own company is also involved in the engineering design of many straw bale homes. This fascinating test centre, built with straw bales walls is home to many experiments with natural building materials and methods – an amazing facility.

Kris had much to tell. Of particular note was the fact that most compression can be achieved in a straw bale wall in 26 hours – after that there is very little settlement in the bales. Kris also explained how, unlike US builders, Canadian builders don't have to use mesh in the render applied to straw bale walls – the engineer takes responsibility for the design (as opposed to the strict codes enforced in the United States).

3.14 Straw bale home, Winnipeg, Manitoba

Denise & Bruno's 4-storey non-load bearing straw bale home near Winnipeg, Manitoba.

Professor Dick's company provided structural calculations and advice for this project.

Kris took me to see this lovely family home on the way to supper. For research purposes, Denise is taking regular readings from equipment Kris made to monitor the moisture levels in the straw.

The inclusion of a basement, common practice in Canada, raises the straw bales well above the snowline - a good design strategy in this climate. In the UK we would specify wide windowsills to protect the walls below but in Canada sills are not a good idea – the weight of the snow can be significant and thawing snow seeping in the wall would be a problem too.

Denise choose straw bale construction because it looks good, rather than for its insulating or environmental credentials. It certainly looked well.

3.15 Straw bale home near Steinbach, Manitoba

Paul & Naomi's 3-storey non-load bearing straw bale home near Steinbach, Manitoba.

Canadian Nuffield scholar, Wally Doerksen, took me to see this straw bale house in his neighbourhood.

Kris handed me over to Canadian Nuffield Scholar, Wally Doerksen who took me to see this straw bale home in his neighbourhood. Paul, Naomi and their friends did most of the building work themselves – they were also extremely good at finding reclaimed materials at bargain prices. The end result was a very reasonably priced house and the most fun and creative design I've ever seen.

Not long after completion, a fire broke out on the decking, very close to the external straw bale wall. The metal roof melted in the heat but straw bale wall remained intact. The local fire brigade were very impressed.

3.16 Straw bale home near Guelph, Ontario

Paul & Donna's non-load bearing straw bale home in progress near Guelph, Ontario.

Ben Polley and his team are the straw bale experts in the Guelph area. They were away at the time I visited but they very kindly put me in touch with many of their clients.

Paul and Donna are self-builders with the good fortune to be able to take their time as they can live in an old house on site until their straw bale home is complete. The photograph above shows how the bales at single storey height have a small roof to protect them - an important detail that Joyce Coppinger pointed out earlier in Nebraska.

It was great to see Paul and Donna's photographs of the process – especially where they had plastered the walls before the roof went on. I'd never seen that done before but it would probably be quite difficult in an unpredictable British summer

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3.17 Prefabricated straw bale house near Hillsburgh, Ontario

Modular straw bale house reassembled for the second time at Everdale Organic Farm near Hillsburgh, Ontario.

Thousands of people visiting the 2003 National Homes Show in Toronto saw this home. It was originally built in a warehouse, transported and erected at the exhibition. Afterwards it was dismantled, transported and re-erected at Everdale Organic Farm. It was in very good condition despite its unusual journey and still attracts many curious visitors like myself.

3.18 Student Accommodation, Cambridge, Ontario

The Grand House, Cambridge, Ontario built as student accommodation.

The Grand House was built by students for students. Piles and steel legs anchor it to a steep hillside overlooking the Grand River. It incorporates 14 bedrooms and communal space and is owned and run by a student housing co-operative.

One of the main concerns of the current occupants, who were involved with the construction, is how to ensure that future occupants know how to properly look after a building made with natural materials.

3.19 Testing straw bale panels at Queen's University, Kingston, Ontario

Testing straw bale panels at Queens University, Kingston, Ontario.

Photo courtesy of Assistant Professor Colin MacDougall.

Colin MacDougall, Assistant Professor, was my host for my visit to Queens. Load bearing, earthen rendered straw bale building techniques are becoming popular in Ontario. Natural builders may instinctively know that using mesh can lead to poor plaster-to-straw bonding or that straw bale walls with bales stacked flat are much stronger than those with bales stacked on edge but the research carried out here by Colin and his team confirms this.

3.20 Straw extension, Guelph, Ontario

Jeff & Bonnie's straw bale extension on their existing brick home in the suburbs of Guelph, Ontario.

This was my first visit where straw bales had been used in a dense urban location. Jeff and Bonnie had an eight-month battle with city planners opposed to the idea of using straw but eventually won through.

The straw bale walls on the ground floor extension are joined to existing brick house and blend in very well.

Every straw bale building I had seen up to now boasted curvaceous walls but Bonnie's preference was for perfectly straight edges and clean lines inside and out. Ben Polley and his team delivered exactly what the client wanted.

contd. on next page

3.21 Straw bale house nearing completion at Guelph

Martin's straw bale house nearing completion near Guelph, Ontario.

This was the most recent straw bale construction project for Ben Polley's crew. I stopped in on my way to the airport on my last day in Canada. Even though the quality of earlier buildings I'd seen was excellent, there was something very special about this house designed by architect Ingrid Cryns.

If there is enough work for a straw bale team to stay together, they hone their skills and methods on successive projects.

3.22 Big bale holiday home, Disentis, Switzerland

A holiday home in Disentis, Switzerland designed and built by Werner Schmidt with jumbo bales in 2001.

Werner was a wonderful host for a couple of days. He has a vibrant architectural practice in the Alps. The office is filled with models of straw bale buildings and very clever folding furniture, solar cookers and engines! A great place to work.

Werner Schmidt has a vibrant architectural practice at Trun in the Swiss Alps. His office is filled with models of his straw bale projects, an array of clever folding furniture, solar cookers and engines that he has worked on. A very inspiring place to work. Werner has

been building with straw for over 15 years. All his work uses big bales of straw, often in the floor and roof as well as the walls. A crane is installed on Werner's building sites. One project used bales in 3 load bearing storeys. He successfully calculated the expected bale compression in each storey.

The house pictured above needs very little heating because of the winter solar gain through the highly glazed south façade. This highlights how important it is to design according to the local climate – this amount of south facing glazing will not have the same benefits in a predominantly dull and grey English winter.

3.23 Holiday apartments, Lana, Italy

Three straw bale holiday apartments photographed during their construction in Lana, in the South Tyrol region of North East Italy.

Photo courtesy of Werner Schmidt and Margareta Schwarz who worked together on this project.

The apartments were completed a few years ago – we had the pleasure of renting one for a few days. www.esserhof.com

Werner worked with architect Margareta Schwarz on these very stylish holiday apartments in the South Tyrol region, also built with big bales. It was very hot when we stayed here in early July – we sat outside until late watching an electric storm overhead.

Although the rendered straw bale walls moderate the high temperatures, it was still very warm inside. Some clever form of passive ventilation would have been an added bonus perhaps.

3.24 Third storey extension near Meran, Italy

The roof was taken off the original 2-storey house near Meran, Italy and a 3rd storey was built on top with straw bales used for the walls and the dome shaped roof.

Architect Margareta Schwarz kindly showed me this project of hers and another inspiring eco renovation she worked on in Meran (non straw bale).

Margareta took me to see this unusual extension she worked on – the straw bales were added on top of an existing house. Margareta has a very special gift for combining natural materials with style and the best of modern conveniences. She had a special relationship with this client and another non straw bale eco renovation that she took me to see in Meran. They are obviously very pleased with her work.

3.25 Straw bale roof insulation, Vienna

Straw bales were used to insulate the roof of the home of architects Karen Allmer and Florian Macke near the centre of Vienna, Austria.

This photograph was taken on the decking as we were treated to lovely local bread and ham and chatted about straw bale building in Europe after our tour of this lovely home with a host of eco features.

Architects Karen Allmer and Florian Macke specified straw bales to insulate the roof when they built their new home hidden away in a courtyard in the centre of Vienna. Straw was cleverly used as natural insulation in this city location to create a contemporary home in the midst of more traditional buildings.

3.26 Yurt near Bratislava, Slovakia

Yanke's permaculture farm near Bratislava, Slovakia.

The photo says it all!

My guide for the day was Zuzana Kierulfova who works tirelessly with the Slovakian Straw Bale Association. Zuzana showed me many photographs of straw buildings in Slovakia but this was the only one within easy reach on that day (we had to save time to eat wonderful traditional Slovakian fare with Zuzana's parents!).

Architect Zuzana Kierulfova and her husband Bjorn have been involved in several straw bale projects. In the time available, the nearest place to visit was a local permaculture holding where straw bales had been used effectively to provide insulation for a yurt! Although a temporary measure it was quick, cheap and had been in place for a year or two.

3.27 Discussion

On my travels I was privileged to see first hand some of the huge variety of straw bale buildings around the world and some of the many equally valid methods of construction. So how can we develop and promote more straw bale building in the UK? I think the answer is: everything that I have seen and more – inexpensive, organic, self-built buildings for those who need or prefer them; professionally built, stylish or high-tech buildings for those that can afford them; perhaps prefabricated buildings to make urban or large straw bale buildings easier. Straw in bales, chopped in plaster or compressed into boards – whatever it takes to safely incorporate more straw in the built environment; just get on and do it – lead by example!

Travelling around can be a bit depressing sometimes. Thousands of people in airports and train stations, city skylines whizzing by, time to read books about how we have lost our connection with the natural world, corruption and unfairness, impending climate change, population growth, food and water shortages – the list goes on!

This is an agricultural scholarship. My emphasis is on growing building materials. Food and shelter are basic human necessities that most people in the developed world take for granted. Few understand how food is grown, let alone understand its nutritional

value. Probably even fewer understand how a building works, how to occupy it effectively or how to look after it properly. Food is processed in factories by multi-national companies and buildings are whacked up with no thought to the environment in which they are placed or the people who will occupy them. Profit is often the only driving force.

All this is rather overwhelming at times! And then you arrive at your next meeting, or strike up a conversation with someone along the way and faith is restored – another ordinary person doing his or her bit to make a difference.

I came across The Slow Movement several times. It is "*against time poverty, incivility and workaholicism*". The Slow Food website explains how the movement aims to *"link the pleasure of food with a commitment to community and the environment……..to encourage people to think more about food – where it comes from, what it tastes like, how to enjoy it……..promote local, small businesses…….fight against the globalisation of agricultural products".*

Food can be substituted by *building* to make statements similar to those above: Building can be a pleasure and it should be linked to community and environment. People should be encouraged to think more about the buildings in which they live and work, where the materials come from, how they work, and how to appreciate the space created. There is a need for local craftsmen to work for or alongside local people and because every region has its own materials and cultural and climatic considerations, globalisation of building products is wrong.

Perhaps I should initiate the Slow Building arm of the Slow Movement?!

There is a great willingness in the green building and straw bale networks to share information and help one another – very much like the Nuffield family. This kind of co-operation is needed in all spheres of life if we are to deal with the challenges we are facing.

My lasting memory of my Nuffield travels is an Amish horse and buggy making its way close to the verge with hazard warning lights flashing – a striking mix of traditional transport with a dose of modern health and safety regulation tacked on! I passed athe buggy on my way to Paul and Donna's straw bale house near Guelph, Canada. They told me how the local Amish community embrace the best technology the world has to offer in their workshops but still enjoy the simple, technology free, pleasures of life in their homes.

4. Energy and Carbon – an overview

The major challenges of the 21st century are energy shortages and the mitigation of climate change – we urgently need to reduce both carbon emissions and energy consumption through the use of renewable energy sources and greater energy efficiency.

The challenges are linked. The fossil fuels that have powered the developed nations over the last 150 years have released the greenhouse gases that are now thought to be the cause of climate change. Reducing the use of fossil fuels will reduce carbon emissions.

4.1 Energy

It is very difficult to assess world oil reserves accurately, to forecast their extraction rate and to predict future global demand. Many experts claim that oil production is peaking now, whilst more optimistic models point to a 2030 peak. At best we have less than 20 years before demand begins to exceed supply at which point market forces will inevitably result in large price rises for all forms of energy. In addition, the distribution of fossil fuels over huge distances from point of extraction to point of use will have many practical, political and environmental implications.

One thing is certain – we urgently need to find ways to use far less energy than we do now. I came across this quote in one of the books that travelled with me;

> "*Modern agriculture is the use of land to convert petroleum into food"*
> Professor Albert Bartlett, University of Colorado[2]

Few farmers in the industrialised countries could imagine growing without oil to power their machinery, to make their fertiliser and chemicals and to transport their farm inputs and outputs around the globe. However, agriculture is little different to any other industry in that respect, converting petroleum into all the things we *need* for modern life. Every sector will see massive change as it moves into the post oil era. Below is a brief look at the building materials and heating sectors, as background reading for the following chapter.

4.1.1 Energy embodied in building materials

The embodied energy of a material is typically the total energy required to produce it. That could include the energy needed for growing, recycling, extracting, processing and transport for example.

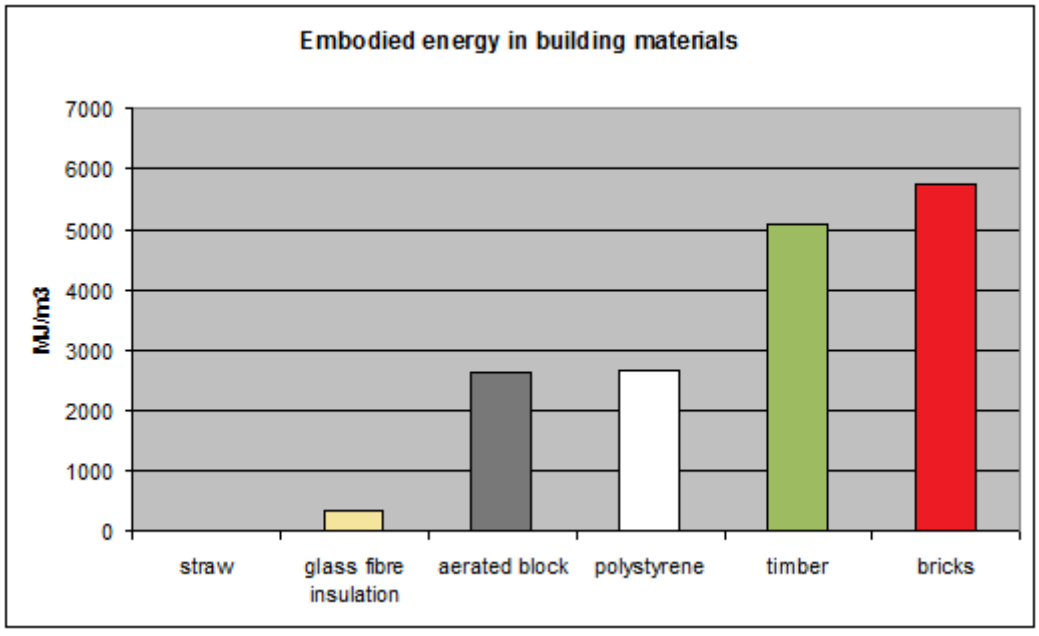
[2] As first read on p76 *Sustainable Energy – without the hot air* by David JC MacKay published by UIT Cambridge Ltd 2009 ISBN 978-0-9544529-3-3

About 10% of national energy consumption is used in the production and transport of construction products and materials.

Most conventional building materials such as bricks or cement have high-embodied energy because a great deal of energy is required for extraction from the ground and processing at very high temperatures. As only a small percentage of construction grade timber is grown in the UK, imported timber embodies the energy needed for transport over long distances.

Straw, on the other hand, has low embodied energy. A figure of 0.24 MJ/kg is obtained when the energy used to grow the crop is assigned to the grain (this being the primary reason for growing the crop). The graph below illustrates the embodied energy calculations from the University of Bath. It highlights how the energy involved in making straw bales barely registers on the scale when compared to the energy needed to make other building materials.

The figure for recycled steel is not included in the graph below because it is 13 times the figure for bricks and including it would make the graph too big for the page!



Graph showing the energy embodied in building materials, using figures originating from the Sustainable Energy Research Team (SERT) at the University of Bath and accessed on 24/11/2010 at http://www.greenspec.co.uk/embodied-energy.php

There are, as always with figures, different ways to calculate them. A Swiss company (www.ecoinvent.ch) working in Life Cycle Analysis uses more of a mass allocation between straw and grain (rather than the economic allocation above) and includes capital inputs such as the impact of making the tractor. The result of

their analysis[3] is 0.4 – 1 MJ/kg baled and stored with the lower figure being for organic straw, which is grown without manufactured nutrients. Although the Swiss figure is up to 4 times more than the figure used in the above graph, straw would still barely feature on the scale – and the figures for the other materials would also rise under the revised methodology.

4.1.2 Energy for heating and cooling

Over half of domestic delivered energy in the UK is currently used for space heating. There would be enormous energy savings from reduced heating (and cooling in summer) if homes and commercial buildings were built with better thermal performance in mind.

Over a third of agricultural direct energy use is for heating and better insulation could reduce this by 20%.[4]

4.2 Carbon

Since the Industrial Revolution, levels of carbon dioxide (CO^2) in the Earth's atmosphere have been rapidly rising as a result of burning fossil fuels. In 1750 atmospheric CO^2 was 280 parts per million (ppm) and in 2007 it had risen to 383 ppm. In 2007 the Inter-government Panel on Climate Change agreed that 450 ppm was the maximum safe level but some scientists now think that we should aim to return to a level of 350 ppm to prevent runaway climate change.

Annual greenhouse gas emissions in the UK are nearly 600 million tonnes CO^2 equivalent. We have set a target of 80% reduction by 2050[5]. Undoubtedly, kicking the fossil fuel habit is the most important change to make – by finding efficiencies and by finding alternative sources of energy. However, capturing and storing carbon (C) has a part to play too – in the UK we even have a Government department dedicated to it – the Office for Carbon Capture and Storage (CCS)[6].

The CCS website talks mainly of capturing CO^2 from large power stations to store offshore in exhausted gas fields – a multibillion £ industry with, it claims, a potential to store up to 10 Gt CO^2. However, the technology is uncertain, time-consuming, costly and

[3] From a personal communication with Andrew Norton, director, Renuables www.renuables.co.uk
[4] Warwick HRI, Final report to DEFRA AC0401: Direct energy use in agriculture: opportunities for reducing fossil fuel inputs. May 2007
[5] The Climate Change Act 2008
[6] http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/ccs/occs/occs.aspx accessed 2/12/2010

risky; power stations need to produce 25-40% more energy to capture and compress the CO^2 and there could be problems such as leakage or ocean acidification.

There is a simpler way. Plants do it every day - they use the sun's energy to absorb carbon dioxide from the atmosphere during photosynthesis, sequestering carbon in plant material. If we can store that plant material in structures, insulation or products, for example, we will be locking away the carbon that the plants have captured.

Plants also store carbon in their roots. The quantity varies according to plant species, growing conditions, time periods, soil type, agricultural practices etc. The root systems of perennials are much larger than those of annual crops. I have read that converting permanent pasture to arable cropping can emit 3500kg CO^2/ha[7] because grasses can establish a significant root system over time. Research continues into natural carbon storage below ground.

[7] Zero Carbon Britain – A New Energy Strategy – The Second Report of the Zero Carbon Britain Project. Downloaded from www.zerocarbonbritian.com 23/12/10

5. Energy and carbon – the effects of what we do with straw

According to DEFRA statistics, in June 2009 over 2 million hectares of cereal crops (wheat 79%, barley 17% and oats 4%) were planted in the UK. As straw yields can vary considerably (perhaps from as little as 2.5t/ha and up to 5t/ha) it is difficult to know with any certainty the annual UK straw resource but it is probably in the range of 5 to 10 million tonnes. For the purpose of this report, I am ignoring oilseeds and assuming a yield of 4 tonnes of cereal straw per hectare, giving a total annual straw yield of 8 million tonnes.

This straw can be simply left in the field or can be removed for a variety of uses. The main agricultural uses are bedding or dietary fibre for livestock. Some is used for mulching fruit and vegetables and growing mushrooms. The burning of straw in power stations is becoming more popular, encouraged by Government subsidy. There is also research into using straw to produce biobutanol for transport fuel and to make more energy dense pellets or briquettes by mild pyrolysis and densification.

This chapter concentrates on the carbon and energy consequences of incorporating straw, using it for animal bedding, burning it and then building with it or processing it in some way.

5.1 Incorporation in soil

Some farmers chop straw behind the combine because they value its benefits to the soil, others because they want to follow quickly with the following crop or because they don't have a profitable or dependable market for the straw.

Each tonne of winter wheat straw contains over 1 kg of phosphorous (P), and over 9 kg of potash (K) so when left in the field it is providing a small amount of nutrient value to the following crop, although most is removed with the grain (7 kg P and 5 kg K). Current estimates for the financial value of the P and K in the straw range from £15/ha upwards but world shortages of P are predicted in the next 20-30 years and this will impact on both price and availability.

The other benefits to the land of straw incorporation are harder to quantify but should not be underestimated; improved soil structure from the fibre in the straw, improved water retention, reduced run off and improved post harvest nitrogen (N) retention.

Energy

There is an energy cost of chopping the straw prior to incorporation but a bigger energy saving from not making, transporting and applying quite as much bagged P and K. There is also an energy saving from not baling, transporting, storing and dispensing the straw.

Carbon:

A reasonable estimate of the amount of C in a tonne of fresh straw is 400 kg but estimates of how much of this C is retained in the soil when straw is incorporated varies more widely – I've seen a variety of research papers quoting from 7.5% to 22% (the remainder being released back to the atmosphere as CO^2 as the straw decomposes). The range is understandable given variability in soil types, seasons, cereal varieties, agricultural practices and the complexity of soil science.

7.5% of 400kg x 4t per hectare leaves 120 kg C in each hectare of the field – or 352 kg C/ha at the upper end of the scale. As each 1 kg C forms 3.67kg CO^2 in the presence of air, straw incorporation can sequester from 440 kg CO^2 /ha/pa to 1,290 kg CO^2 /ha/pa or 0.88 million tonnes to 2.58 million tonnes CO^2 if all the straw on the entire acreage of wheat, barley and oats is incorporated back into the soil.

This carbon store is limited; if straw were incorporated into the soil every year, soil carbon equilibrium would be reached in 20-30 years[8]. It could also be temporary; soil disturbance increases carbon loss so length of storage will depend on future agricultural practices. More research is needed into soil carbon, both in and below the plough layer. Soil contains a myriad of organisms, many of which are unknown to science. Researchers are beginning to identify them and their role in the soil using DNA sequencing[9] but there is still a very long way to go.

5.2 Animal feed and bedding

I have seen estimates saying that currently half of the UK straw resource is used for feed or bedding. It is a popular bedding material with livestock farmers because there is usually a relatively local and inexpensive supply. It is absorbent and comfortable for the animals and they enjoy nibbling on it too. The resultant farmyard manure is a good fertiliser when put back on the field. When the manure is spread on the land the following year, nitrogen (N) is provided for the crop as well as the P, K and fibre described above. There is more of the scarcer P in manure too as P is excreted in animal urine and soaked up by the straw.

[8] Keith Goulding, Rothamsted, presentation b at Food Climate Research Network, soil carbon sequestration workshop at DEFRA headquarters 21/1/10 accessed at http://www.fcrn.org.uk/fcrnEvents/seminars/soilcarbon/pdfs/FCRN_SoilCarbon_summary.pdf on 21/12/10

[9] Press *release Journey to the Centre of the Earth: the first 23cm* http://www.rothamsted.ac.uk/Research/Centres/PressReleases.php?PRID=135 accessed 22/12/10

Energy

Energy is required for baling, leading, bedding down, mucking out and spreading on land but energy is saved in the extraction or manufacture of N, P and K plant nutrients.

There is a great deal of energy needed to make nitrogen fertiliser. In the first stage, nitrogen from the air and natural gas are reacted in the Haber-Bosch process at temperatures of 500^{o}C and 200 atmospheres of pressure.

A brief note about the nitrogen cycle

Prior to invention of the Haber-Bosch process, nitrogen fixation occurred only via a limited group of microorganisms and lightning. Fertiliser application has more than doubled the amount of reactive nitrogen in circulation on Earth. Man-made reactive N is linked to climate change, acid rain, ozone depletion, reduced water quality, human health and ecosystem health. There is an International Nitrogen Initiative set up to understand the multiple impacts and feedbacks of the changes in the N cycle and the interconnections with other cycles such as the carbon cycle. www.ini-europe.org

Carbon

Ultimate carbon storage will be similar to when the straw is directly incorporated as discussed above, although some reading seems to indicate a slightly higher amount, presumably because livestock also excrete carbon.

The debate rages on about the gaseous carbon emissions from the livestock themselves. I would urge you to read *Meat: The Benign Extravagance* by Simon Fairlie[10]. He can weigh up the evidence much more thoroughly and eloquently than I can.

There is also the issue of nitrous oxide emissions from all agricultural activity to consider and I await a balanced discussion from the International Nitrogen Initiative mentioned in the preceding paragraph.

5.3 Burning straw for energy

Straw can be burned for heat and/or power on a scale from domestic sized stove or boiler to power station. Assuming 4 tonnes of straw per hectare as I have been doing

[10] *Meat: A Benign Extravagance* by Simon Fairlie Permanent Publications 2010 ISBN 978 1 85623 055 1

throughout this report, the heat energy content of baled straw from 1 hectare would replace just over 2 tonnes of coal (where the heat energy of straw is 15 GJ/t and coal is 28 GJ/t).

Carbon

Four tonnes of straw has energy content equivalent to two tonnes of coal. The CO^2 emissions from burning 4t straw or 2t coal are more or less the same. The difference is that the straw absorbed its CO^2 from the atmosphere as it grew that year or the one before. Burning coal, however, releases CO^2 stored millions of years ago thereby increasing the current day levels of carbon in the Earth's atmosphere.

Burning 4 tonnes of straw instead of 2 tonnes of coal could save 4.8 tonnes of fossil fuel derived CO^2 (60 GJ of heat releases 80kg CO^2 per GJ) or 9.6 million tonnes CO^2 if *all* straw could be used to replace coal (still only 1.6% of the UK's annual emissions).

The saving would be identical if coal burning was replaced by renewable technologies such as wind or solar, allowing the straw to be used for carbon sequestration in one form or another.

Energy

The main additional energy requirement is that needed for transport – the power plant is likely to be further away than the livestock farm or the volumes greater. As straw is not a very dense material, many lorries are needed to carry it away. Disposal of the ash involves transport too.

Straw for heat on a small scale, in an efficient appliance, would seem a sensible use of local biomass. Successful use of straw for heat and electricity in specially built power stations depends on location. The most energy efficient plant is close to the straw source and close to a demand for both the heat *and* the power.

Co-firing straw with coal in an old power station can never be energy efficient when only 30% of the energy in the fuel, renewable or fossil, reaches the final consumer. Burning straw is currently made financially attractive to the energy companies due to Government intervention. In the short term it is better than the madness of importing other biomass such as palm kernels from half way round the world but in the longer term it is not a sustainable use of the energy or the carbon in the straw.

Straw has a high ash and silica content when burnt. Ash levels can be 4 or 5 times that for wood or coal and the straw ash tends to become viscid and forms clinker. Flue gases can be problematic too causing corrosion to steel boilers and tubes. Grey straw (left in

the field to be rained on, allowed to dry then baled) is better for the equipment but this process will not be popular with farmers anxious to get the crop off the field so they can prepare for the following crop. The straw can also be washed and dried at the power plant but it loses 8% of its calorific value in the process.[11]

The P and K are left in the ash after the straw has been burned so these nutrients can be returned to the soil but the original straw is much better than ash for improving soil quality.

A brief note about alternative biomass

If our 4t per hectare of straw is brought off the field at 15% moisture, the *dry* yield is 3.4 oven dried tonnes per hectare per year (odt/ha/yr). Willow grown as short rotation coppice can yield over *3 times* that quantity (10-12 odt/ha/yr) and miscanthus similar or more.

Currently a high proportion of willow and miscanthus is co-fired in coal power stations – useful for developing the market, but as discussed above for straw, this is the least efficient use of the energy in the crop.

The added advantage in an energy scarce future is that these specialist biomass crops are perennial – once established they can crop continually for 20-30 years and need no annual soil preparation or manufactured nitrogen.

With regard to soil carbon, it would seem reasonable to assume that more carbon could be accumulated in the soil with these crops – there is no cultivation for 20 years or more and a considerable root system develops over this time. As we learned earlier, a significant amount of carbon is locked up in the roots of plants.

The installation of biomass boilers has increased by 25% in the last two years[12]. They score easy points when qualifying for funding so that there is less incentive to invest in thermal efficiency. The proposed Renewable Heat Incentive will further encourage this trend. We should be aiming to use less of all types of fuel – to achieve as much fuel efficiency as possible, then select a renewable fuel. It is crazy to reward the burning of more fuel than is necessary.

[11] http://www.videncenter.dk/gule%20halm%20haefte/Gul_Engelsk/halm-UK02.pdf accessed 20/12/10
[12] *Biomass – a burning issue* by Nick Grant and Alan Clarke accessed 19/12/10 at http://www.aecb.net/new_releases/detail/?nId=10

5.4 Building with straw bales

Millions of new homes will be constructed in the UK before 2050. Currently, 10% of annual energy use is embodied in construction materials. The embodied energy in an average house is estimated at 100,000 kWh. Where feasible, replacing the high-energy bricks, blocks and steel that were discussed in section 2.412 above with home grown materials such as straw, hemp and timber would greatly reduce this figure.

In this report, when I talk about building with straw, I am meaning bales of it – in whatever shape or size needed. Another way to easily incorporate straw in buildings, however, is to chop it to mix in natural plasters such as clay or lime. Clay in particular, is a wonderfully low energy material, the use of which modern construction has lost the habit of employing. Its use is commonplace on the internal walls of straw bale buildings but it could be used in a thick layer with chopped straw to insulate the walls of the existing housing stock. Millions of existing buildings will need to be retrofitted with insulation to meet the 2050 CO^2 targets.

Energy

To build an average sized, 2-storey house with straw bale walls and an internal floor area of 100m^2, we would need approximately 7 tonnes of straw. At the straw yield of 4t/ha that we have been using, 4 homes could be built per 7 hectares or over 1.1million homes every year.

As a very conservative estimate, when building with natural materials, the embodied energy in the average new home could be halved from 100,000 kWh to 50,000 kWh. If we built with the straw bales from a single hectare we would save 28,571 kWh (50,000 x 4/7^{th}). If we assume that conventional building materials are mostly made in natural gas-fired factories, the consequential CO^2 saving would be over 5,100 kg CO^2 (or 8,200 kg CO^2 if the factories were coal fired).

If every year a mere 100 new brick and block homes were built with straw bales instead, it would save 5 million kWh (or nearly 900 tonnes CO^2 from the gas-fired power station). If those 100 super-insulated homes then used 10,000 kWh less energy for heating that would be a further 1 million kWh saved *every* year per 100 homes.

There are 5 energy saving advantages of a rendered straw bale wall that help to keep a building warm in winter and cool in summer:

1. Straw is an excellent insulating material – heat does not travel through it very quickly

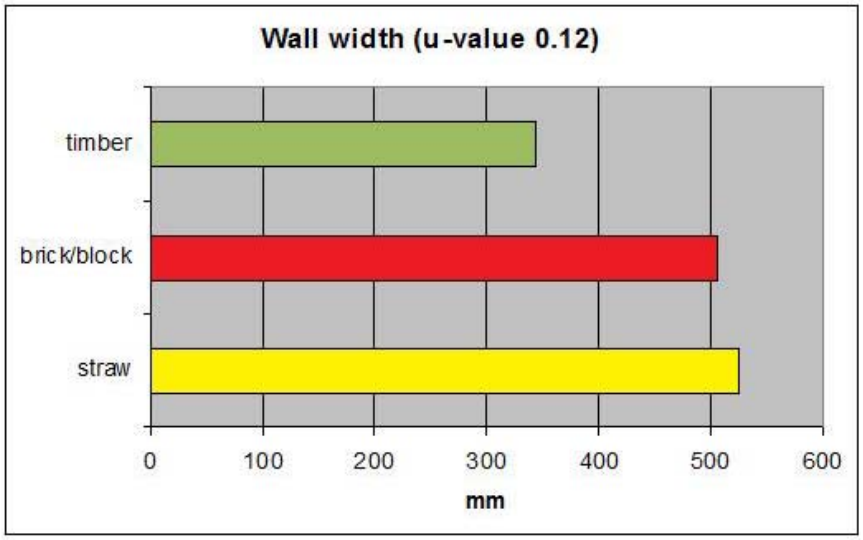
2. Straw walls are solid – there are no gaps in the insulation contributing to unseen heat loss (which is commonplace in standard construction methods)

3. As even a small bale is 450 – 500mm wide, there is a significant time lag for heat transfer due to the thickness of the bale

4. The lime and clay plasters combined with the bales help to make the building airtight – preventing unwanted heat loss through the cracks and gaps that are commonplace in conventional constructions

5. Clay plaster on the interior acts as a temperature and humidity regulator to maintain a constant internal environment

A straw bale wall built with a 475mm wide bale and 25mm plaster inside and out has a u-value of 0.123 W/m^{2}K. The graph below shows the width of a brick/block or timber frame wall that would be needed to match this insulation value.



Graph showing the width of a wall built to achieve a u-value of 0.123 W/m2K. The straw wall is rendered inside and out and the timber and brick constructions are insulated with glass fibre.

However, insulation value is not the only criteria. A timber wall this wide would have issues with air leakage and lack of thermal mass and a brick/block wall this wide would have issues with stability. Both would have problems with ensuring fully filled insulation, which is important to minimise heat loss by convection in the wall.

contd on next page

Carbon

In addition to the carbon savings resulting from the energy savings discussed above, the straw bale walls would act as a carbon sink – 1.47kg CO^2 is stored per kg of straw (assuming 400kg C in a tonne of straw as above, multiplied by 3.67). Therefore, when building with 4 tonnes of straw from 1 hectare, 5,880 kg CO^2 would be stored or 11.76 million tonnes CO^2 if *all* straw could be sequestered in buildings (still only 2% of the UK's current annual emissions).

Trees can capture 15t CO^2 per hectare per year[13] - nearly 3 times the amount captured in straw and so timber building products would seem a better carbon store. However, forest cover in the UK is one of the lowest percentages in Europe at 12% (3 million hectares)[14] and as construction grade timber can take 50 years to grow it will take too long to produce enough home grown material (not that we shouldn't be planting more). Straw is produced with the cereal crop every year.

5.5 Processing straw

Straw board

Straw can be pressed to form boards that can be used in buildings. The Stramit Technology Group use wheat straw in a patented process of heat and pressure to fuse straw using its internal resins to form strong boards 35-60mm thick which are then bonded with recycled paper to provide a tough surface[15].

According to the Stramit website, a straw board factory requires 10,000 tonnes of straw annually to produce 500,000m^2 of board. That is one factory per 2,500 hectares on the yield assumptions used in this report. A UK factory is envisaged in 2011.[16]

The density of a good building bale is 100-120 kg/m^3. As the density of the standard straw board is 380 kg/m^3, the carbon storage of these boards is three times more than the bales. However, the energy embodied in the boards is much higher than in the simple bale because of the processing and transport involved. The boards also save less energy in use because with all the air squeezed out,

[13] P246 *Sustainable Energy – without the hot air* by David JC MacKay published by UIT Cambridge Ltd 2009 ISBN 978-0-9544529-3-3

[14] http://www.forestry.gov.uk/website/forstats2008.nsf/LUContents/4B2ADD4323421111280257361003D32C5 accessed 2/12/2010

[15] www.stramit.co.uk accessed 17/12/10

[16] From a personal communication with John Mosesson, Stramit Technology Group 20/12/10

they are much less insulating; a bale of 475mm width is equivalent to a width of over 800mm of straw board in terms of insulation.

Straw boards, however, increase the range of options for using straw in construction. They can be used instead of plywood or gypsum plasterboard in partitions, ceilings, linings, doors etc and have greater carbon, energy and environmental benefits than the products they are replacing.

There is an interesting new project that could help to develop the market for straw board. Bill Dunster OBE, a British architect well known for his zero carbon design, is working on a new low cost energy efficient home using a timber frame fitted with cassettes made with Stramit board and filled with recycled newspaper[17]. A prototype was exhibited at Ecobuild in London in March 2011.

Straw blocks

At the Buildwell 2010 conference in San Francisco, two young men were exhibiting their "STAK" blocks; compressed, interlocking rice straw blocks for building use[18]. The advantages they provide over bales of straw is that they are perfectly straight, standardised and tested but as for the boards above there is an energy and carbon cost in their manufacture.

In my view, their design has a major problem with convective heat loss but that could be easily remedied.

Biodegradable packaging

Straw can also be used to make biodegradable packaging. Again there is an energy use in the process but when replacing packaging made from fossil fuel feedstock there should be a net carbon saving.

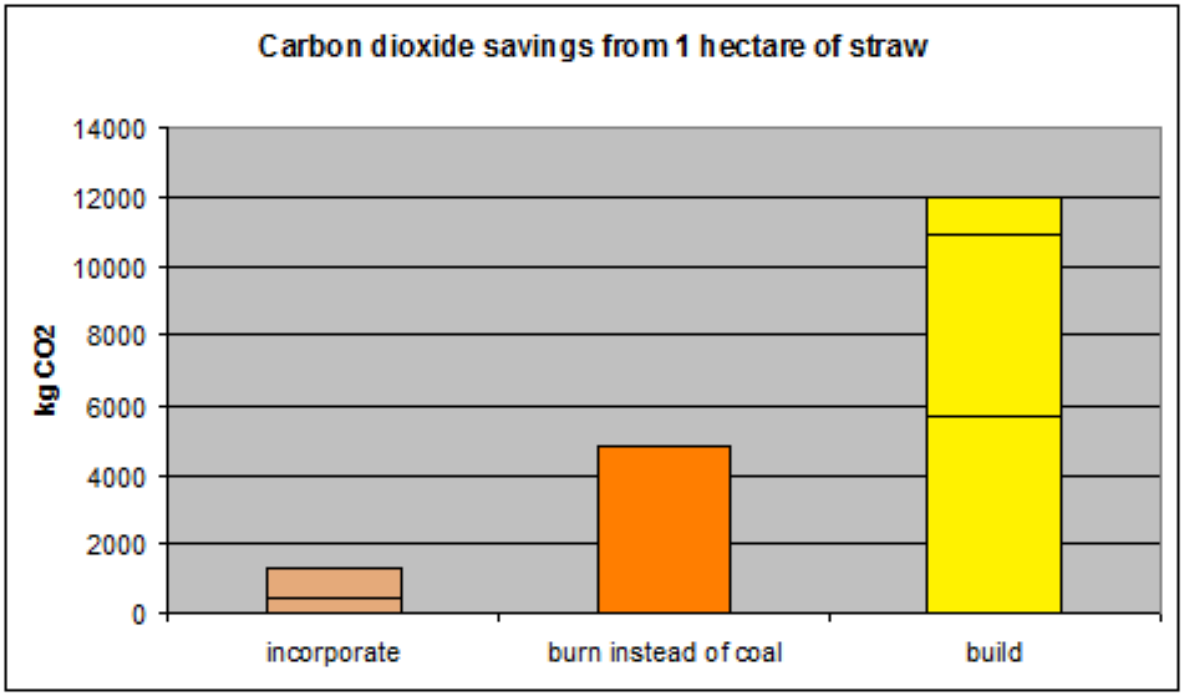
5.6 Summary of the main carbon impacts

The table on the next page summarises the carbon effect of the main uses of straw examined in the earlier sections of this chapter.

A graphical representation of the same data follows.

[17] www.stramitzed.co.uk accessed 17/12/10
[18] www.oryzatech.com accessed 17/12/10

Use of straw	Carbon effect	Carbon quantification
Incorporate	Carbon stored in the soil	440 – 1,290 kg CO^2/ha/pa
Burn	*Old* carbon saved by not burning coal	4,800 kg CO^2/ha/pa
Build	*Old* carbon saved by not making conventional building materials (with gas) *Old* carbon saved by reduced heating (with gas) Carbon stored in building fabric	5,100 kg CO^2/ha/pa 1,020 kg CO^2/ha/pa (every year!) 5,880 kg CO^2/ha/pa



A graph to illustrate the carbon dioxide effect of how we use the straw from 1 hectare of cereals according to the figures examined in chapter 3 and summarised in the table above.

In summary:

- The left hand column shows that there is some carbon sequestration when straw is returned to the soil (but there are other very important benefits to soil health to consider too)

- The central column shows the CO^2 kept buried in the ground by not burning coal. The column would be smaller if the straw was substituted for gas and it

would practically disappear if we had sufficiently developed wind or solar energy resources for example or if we made energy efficiencies and did not need as much electricity generation

- The largest, right hand column highlights the triple carbon saving benefit of using straw for building – the bottom section is the carbon stored in the wall for the life of the building, the middle section is the carbon saved by not making conventional building materials and the top section is the carbon saved by the reduced heating demand of a straw bale building in year one (and this bit recurs every year!)

That small section on top of the yellow, *build* column is significant. The heating energy saved by super-insulating a building with straw would wipe out the middle, *burning* column in less than 5 years. Or to quote from a recent report on the burning of biomass " *The only sure source of energy in an uncertain future is what Amory Lovins called Negawatts – that is 'energy conserved or not required thanks to radical efficiency measures*' "[19].

Whilst the figures presented and assumptions made are simplified, I have tried to err on the side of caution. However, it seems there is enough of a difference to safely conclude that building is by far the best way to use straw if the goal is reduction of CO^2 in the atmosphere.

Of course, balance and moderation is required as in every thing. I do not advocate that all straw should be used in the built environment. It is a very important material for soil conditioning, either directly or via livestock. However, Government subsidy would definitely be better directed towards encouraging more building with straw rather than burning it as is currently the case.

5.7 Other straw issues

There isn't time or space to do these issues justice but it is important, I feel, to mention them briefly:

Financial implications – currently a rendered straw bale wall is cheaper than a brick and block one but, as a wall is only a small part of the build cost, the saving makes little difference to the total material cost. As energy costs rise, however, bales should become even cheaper by comparison to manufactured materials.

[19] *Biomass – a burning issue* by Nick Grant and Alan Clarke accessed 19/12/10 at http://www.aecb.net/new_releases/detail/?nId=10

It is probably easier to learn straw bale building skills than bricklaying skills so using your own labour could save cost too. Most importantly, there will be significant financial savings resulting from reduced heating and cooling costs over the life of the building.

Builders could afford to pay more for good quality building bales to reflect the time needed to make them at the busiest time of year and to store them properly until needed.

Carbon pricing – a carbon-based economy may be the only way to drive the reductions needed but before carbon trading can commence the fundamentals of accounting, monitoring, auditing, verification, registration and ownership must be agreed. [20]

Organic yields – currently 60% less at an average of 5t/ha grain compared to 8.25t/ha for conventional crops but less research and development is focused on organic (so it could be better in future). Presumably tonnage per unit of fossil fuel energy expended will be higher for organic?

Perennial wheat – increasing the root system below ground and no till – great for maintaining soil carbon though early studies indicate a problem with yields reducing over time[21]. There are also trials planting wheat with clover to reduce the amount of manufactured nitrogen needed.

Long straw wheat – new and old varieties that produce longer straw - more for building and good for out-competing weeds, thereby reducing the need for herbicides.

Phytoliths *(plant stones)* – microscopic spherical shells of silicon formed on the roots of some plants (including wheat) that can lock away carbon.

Biochar – a charcoal created by the pyrolysis of straw or other biomass which is said to increase soil fertility and soil carbon. However, could pyrolysis generate persistent organic pollutants that could cause health issues both at the production plant and in the field?

Burying timber as a carbon sink – could apply to straw board too – but why dig huge holes to bury it when there is plenty of scope for above ground use?[22]

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[20] Jennifer Hawkins 2009 Nuffield Scholar – *Carbon – The New Diamond for Australian Agriculture* http://www.nuffieldinternational.org/rep_pdf/1289383356Jennifer_Hawkins_Final.pdf
[21] www.thelandinstitute.org accessed 21/12/10
[22] http://www.cbmjournal.com/content/3/1/1 accessed 21/12/10

6. Conclusions

Straw is a valuable resource!

• Incorporating straw into the soil – either by chopping behind the combine or, preferably, by returning it as farmyard manure – has huge benefits to soil health and structure

• Building with straw bales has triple environmental benefits –

1. Energy use and carbon emissions are greatly reduced by making fewer bricks, blocks, cement and conventional insulation products – the production of these is very energy intensive whereas baling straw is not. Straw bales have very low "embodied energy"

2. Energy use and carbon emissions are reduced because much less heating and cooling is required over the life of a well designed, super-insulated straw bale building

3. Carbon (in the plant material) is locked away in the walls for the life of the building – a straw bale building is not zero carbon – it is carbon negative

• In most cases, burning straw as fuel is not a good idea – *much* better for the environment to incorporate or build with it

• Investment in research, development and training is crucial. Knowledge must be shared

• We should encourage a greater knowledge and appreciation of *all* buildings and their link with environment and community

Straw bale construction could be a part of the solution to impending fuel shortages and rising levels of carbon in the atmosphere – it saves energy and carbon both in building and in use and it provides a carbon sink.

Although the carbon storage potential is only a small percentage of current UK emissions, the proportion will rise as emissions reduce. Using straw to replace energy greedy non-renewable building materials and using it to create super-insulated, thermally efficient buildings has the potential to save significant amounts of energy and carbon.

7. Recommendations

Practical steps should include;

• **Insulate more** – to minimise the amount of energy needed – preferably with a renewable material such as straw.

• **Increase awareness** - currently Government subsidies are encouraging the burning of straw in large power stations and where this reduces fossil fuel use it may be a useful *short-term* measure. However, straw can and should be put to better use, whether it is in soil or in buildings and Government should be made aware of this.

Farmers are well placed to increase awareness by building with straw grown on their own farms for housing, offices, storage, holiday lodges etc.

• **More research and development** - Government support should be directed at research into natural building materials and methods. Some projects should be guaranteed long term funding because it is long-term analysis that is lacking globally. UK farmers are among the best cereal growers in the world and UK universities should be at the forefront of straw bale research.

The research should inform the next two recommendations - maintaining quality, but not stifling innovation through restrictive regulation.

• **Official recognition** - building regulations and environmental codes must be updated to give credit for the use of renewable materials in the fabric of the building, acknowledging that straw and other locally grown materials provide environmental benefits in the original construction of the building as well as in the reduced energy requirement for that building over its entire lifetime. Official recognition in this way will raise the profile of building with straw – get people thinking “renewable materials”.

In the long-term renewable materials such as straw, hemp, timber or products therefrom should be automatically specified with use of non-renewables having to be justified (such as underground, where natural materials may not perform satisfactorily).

• **Training** many more people how to build with straw, clay, lime and other natural materials is vital. At a time when youth unemployment is at an all-time high, providing young people with natural building skills could not only provide them with an income but also a valuable understanding of materials and buildings and their relationship with nature.

Perhaps there could be a chance for them to build their own affordable housing in the future, particularly in rural areas? One of the great advantages of growing building material is that is easy for each new generation to grow its own.

- **Make quality bales** - construction grade bales should be made, stored and priced accordingly. If they are going to be used more widely, good quality bales must be readily available. If the price properly reflects the effort that goes into baling them dry, baling them densely and storing them safe from moisture and vermin, then farmers, contractors or merchants will be more interested in serving the developing market for them.

8. What's next?

8.1 For farming

An 80% reduction in carbon emissions represents a huge change from how we live today. As we reduce our dependence on fossil fuels we will increase our dependence on land - food, energy and "stuff" (clothes, buildings, vehicles, packaging etc) can all be grown – but it must happen without reducing the land available for biodiversity and without compromising the production capabilities of future generations. It's a very daunting task but also exciting and challenging. I have come across so many people over the past two years who are thinking differently and working smarter with a better future in mind. I am very encouraged by this.

I am convinced that best long-term solutions will come from observing and working with nature.

8.2 For me

We have already started to incorporate some of the practical straw bale tips and techniques that I have learned on my travels. We will continue to develop our natural building techniques and share them with others. I will work continually to promote the benefits of building with straw – aiming to emulate the inspiring people I met during my Nuffield Scholarship.

I hope that this report will be useful to begin convincing Government departments that burning is definitely not the best thing to do with straw.

I will make time to think and learn. This is the most important outcome from my Nuffield Scholarship – a realisation that I still have an awful lot to learn. I have many more unanswered questions now than I had at the outset! Carbon cycles, nitrogen cycles, energy balances and sustainable agriculture for example. In time, I aim to write a short essay in response to each of my questions. I hope they will stimulate a debate from which I will learn even more.

I stumbled across sustainable agriculture several times as I travelled around. My eyes were opened and I wanted to delve straight in to this huge and fascinating subject area. I had to rein back and concentrate on my core subject; otherwise this report would never be finished! I have provided some information and links in Appendix B – just in case they are useful to others interested in this subject.

9. Thanks and Acknowledgments

I thought that my Nuffield Scholarship would help me discover more ways to successfully build with straw and it has, without a doubt. However, the people I have met and the things I have seen and heard on my travels have made me think about so much more. Their work is truly inspirational. Governments may not be doing as much as they should to stem carbon flows or to prepare for climate change or peak oil crises but there are many, many individuals and communities around the world trying to make a difference. It has been my real pleasure to meet some of them. My heart felt thanks to everyone I have met on my journey at home and abroad and special thanks to Nuffield, and in particular The Yorkshire Agricultural Society, for making all this possible.

I would like to thank my family – Richard, Sam and Joe – for their patience, understanding and support as I have travelled around, had my head stuck in a book or been glued to my computer screen in the name of research or writing up.

Kate and Martha Grubb – my wonderful travel companions through Europe who made the trip so special.

Nuffield – what an amazing group of people - at home and abroad! They are so kind, knowledgeable, helpful and supportive. I'd particularly like to thank my hosts in Canada; Wally and Ruth Doersken near Steinbach, Manitoba; Karen Daynard near Guelph, Ontario (and her lovely parents, Terry and Dot) and Ann Gordon and her husband Cam. Thank you all so much for your kind hospitality.

"Baleheads" everywhere – many being contributors to The Global Straw Bale Network and the European Straw Bale Network – thank you for sharing your thoughts and experience - long may this good work continue!

Carol Atkinson

Barmby Grange
Eastrington
Goole
East Yorkshire
DN14 7QN
01430 410662
07930 212804
carolatkn@aol.com
www.homegrownhome.co.uk

Appendix A

Straw bale itinerary in date order

1. **Belgium** *(18th – 23rd August 2009)*

    • European Straw Bale Gathering hosted by Casa Calida near Riemst. www.casacalida.be
    A series of workshops, lectures and discussion groups involving many of Europe's straw bale experts.

2. **United States of America** *(24th January 2010 – 8th February 2010)*

    • Buildwell conference, San Francisco www.ecobuildnetwork.org

    This conference brought together high profile speakers from around the world who are working hard to make a difference in the built environment. Academics, professionals, inventors, builders, regulators and entrepreneurs met to discuss materials, energy, habitat, toxicity, rules and business opportunity. I presented a poster about our unique straw bale "caravan" and wrote a summary report of the conference for ARC, Hull. Copies of both are available on my website.

    • Tim Owen Kennedy – Vital Systems www.vitalsystems.net

    Established 13 years ago, Vital Systems is the largest natural building company in Northern California. Their website claims that they have collaborated with the leading innovators in the ecological building community but that is far too modest – Tim himself is obviously a very well respected leader and innovator in the field. After the conference, Tim kindly took me north of San Francisco to see an amazing half million-dollar straw bale home that he was just completing for a client.

    • James Stark and Penny Livingstone co-manage a 17-acre certified organic farm, Commonweal Garden, at Bolinas, California on the edge of Point Reyes National Park. www.regenerativedesign.org. They have straw bale and cob bedrooms to accommodate volunteers and students working on the farm. The separate compost toilet and solar shower facilities work fine in the Californian climate!

    • Ridge Winery at Lytton Springs, Sonoma County, California www.ridgewine.com . Ground conditions would not allow traditional underground wine cellars in this location so straw bale walls were a must for this organic certified vineyard committed to sustainable practices. When completed in 2004, at 18,000 square feet (1670m^2) this was the largest commercial straw bale building in the US. Tim Owen Kennedy (above) worked as the straw bale sub contractor on this project. It is built with rice straw in a timber frame with clay plaster inside and out. The high ceilings (7 metres) allow warm air to rise above people and wine. Read more on the design strategy at www.ridgewine.com/acrobat/strawbbwebvert2page.pdf . The moisture levels in the straw bale walls were monitired by John Straube at Waterloo University, Canada. His report can be read at http://www.ecobuildnetwork.org/what-we-do/straw-bale-test-program . Ridge wine - highly recommended!

• Real Goods Trading Company/Solar Living Institute, Hopland, Mendocino County, California www.realgoodssolar.com / www.solarliving.org . Again, use of straw bale walls supported the business ethics of Real Goods who sell energy conservation and self-sufficiency products. Fantastic choice of eco books on sale in the 5,000 square foot showroom! The building, completed in 1996, resembles a curved bird wing with stepping roofs where clerestory windows capture the seasonal angles of the sun so that additional light and heating is virtually unnecessary. The building features solar powered evaporative coolers that flush the building with cool night air and hemp awnings provide shade in summer. The architect, Sim Van der Ryn, addressed the Buildwell conference (see above). www.vanderryn.com

• Andrew Morrison, Ashland, Oregon www.strawbale.com and other sites - an experienced straw bale builder mainly concentrating now on training workshops, DVDs and online products.

• Aprovecho – a non-profit research and education centre on a 40-acre rural campus at Cottage Grove, Oregon www.aprovecho.net , which built a straw bale house for dormitory accommodation in 1997. The building manager on site told me how Oregon State University monitored the moisture levels in the walls for the first 5 years but not since. The new community building on site was being constructed with timber felled from the surrounding forest.

• Eden Brukman, Vice President, International Living Building Institute www.ilbi.org . Eden is based at the offices of the Cascadia Green Building Council www.cascadiagbc.org in the Eco Trust building in Portland, Oregon and is responsible for development and international deployment of the Living Building Challenge.

• Joyce Coppinger, Lincoln, Nebraska www.thelaststaw.org . Joyce has been running her own straw bale training and consultancy business, ReBuild Associates, since 1997 and is the editor of the international journal The Last Straw. Straw bale building originated here, on the vast plains of Nebraska, in the late 1800's.

As there was a good covering of snow on the ground and more forecast, Joyce and I didn't venture far in search of straw bale buildings in the Lincoln area. We visited three;

The Lone Oak was built in 1945 in Emerald, near Lincoln. It was originally a restaurant with a dance hall above. It is now in a state of neglect and the present owners are not very receptive to straw bale enthusiasts popping by so we viewed from the safety of the car for a few minutes only!

The Audubon Centre at Spring Creek Prairie is a large single storey visitor centre. It was built in 1996 using baled prairie grasses in a timber frame and lime render. www.springcreekprairie.audubon.org

Prairie Hill is a Montessori school at Roca, Nebraska. The non-load bearing straw bale building was constructed in 1995. www.prairiehill.com

3. Canada *(8th February to 18th February 2010)*

• Professor Kris Dick, Department of Biosystems Engineering, University of Manitoba. The University looked glorious in the sunshine, with a thick covering of snow underfoot. A wonderful place for an eco green building geek like me! Kris had a huge test centre (with straw bale walls) in which to carry out experiments. It was fascinating to see the work done and work in progress. His knowledge was extensive and his enthusiasm to learn more not dampened by his many years' experience. His own company, Building Alternatives Inc has been involved in the engineering design of numerous straw bale buildings in Canada. www.buildalt.com

• Kris took me to see a family home not far from the University that he had worked on (and was collecting performance data on). Denise and Bruno's 4-storey non-load bearing straw bale house near Winnipeg looked a picture in the deep snow. The basement rose out of the ground about one metre. This allowed for windows to provide natural light into the basement and raised the straw bales well above the snow line. Being the first family home I had visited, I was struck by the lack of curtains – possibly a British tradition I was thinking – but very good at keeping heat in when it is minus 20 outside! The window reveals were angled well back too. They looked good but I wouldn't do it because it reduces the insulation value. I asked Denise why they chose straw bale. "Because it looks nice" was the reply. Fair enough, energy is cheap and plentiful in Canada – and it does look amazing!

• Wally Doerksen, a Canadian Nuffield Scholar, collected me from Kris. While in the wonderful care of Wally and his wife Ruth, Wally took me to see Paul & Naomi's 3-storey straw bale house near Steinbach. Built in 1998/99 this was an exciting family home with lots of secret dens and platforms, captain steps and wooden shutters so that you could look from the bedrooms into the living space – a great home for children! Paul had read in an old book about boat building that small rooms could be made to feel larger if you could see out of 3 sides and so there were 3 views out of every bedroom – some cleverly achieved by opening doors or shutters. Paul and Naomi chose straw for ecological and financial reasons. They were both very practical, doing a lot of the work themselves and with friends. They were also exceptionally good at finding reclaimed bargains such as timber, insulation and doors. http://preimer.srss.ca

• Paul and Donna Psutka had been building their straw bale home at Winterbourne near Guelph for two and a half years when I visited. They estimated that it would take them a further year and a half to complete. The basement housed some of the bedrooms, rainwater harvesting and the heat pumps for the under floor heating. The living space had a large cathedral ceiling and interesting clay plaster detail. All doors had transom windows above to facilitate cross ventilation. Paul and Donna showed me their photographs – I'd never before seen a straw bale wall built and plastered before the roof went on.

• At Everdale Organic Farm and Learning Centre there is a straw bale house that was originally built in a Guelph warehouse by a team of over 200 volunteers led by Ben

Polley. It was reassembled at the 2003 National Homes Show in Toronto and then reassembled at Everdale after the exhibition. www.homealive.ca Again, the straw bale walls are only one of a number of eco features.

In the grounds of Everdale there also straw bale dormitories to house students/volunteers and a new straw bale office. www.everdale.org

• The Grand House in Cambridge Ontario is a housing co-operative for students of the architecture school. Laura was my knowledgeable host. The Grand House is built on steel legs because of the steeply sloping site. Two of the straw walls were lime plastered inside and out and two were clay plastered. The volunteers had to make their own clay plaster and paint, as none was commercially available to them. www.grandhouse.org

• Colin MacDougall, Assistant Professor, Structural Engineering, Queens University, Kingston, Ontario. Biomaterials for construction, especially straw bale construction, is one of Colin's research areas. On my tour of the facilities at Queen's, there was mainly research into hemp construction ongoing. Colin has been working with Chris Magwood, a leading straw bale expert in the area, to test the compressive strength of straw bale walls and earthen plasters. colin@civil.queensu.ca

• Jeff & Bonnie have built a single-storey straw bale extension on the back of their 100 year old brick house. It has a green roof so uses a timber frame and the lime rendered bales are stacked on edge. Bonnie has a preference for square edges so that is the finish that Ben Polley's team delivered – very stylish.

• Martin's house near Hillsburgh, Ontario was nearing completion when I visited. It was designed by architect Ingrid Cryns www.somaearth.com and built by Ben Polley and his team www.harvesthomes.ca or www.evolvebuilders.ca . It was an amazing house built in woodland. Beautiful stripped tree trunks from the site were a feature in every room. The stove in the centre of the house was incorporated in a massive clay chimney, which acted as a thermal store. Some of the windowsills were finished in colourful mosaics of broken tiles and marbles.

4. Switzerland (29th June – 1st July 2010)

• I left Howden just before 7am by Hull Trains to London, then Eurostar to Paris and a change for Zurich, arriving there about 11pm – an amazing distance travelled in one day without leaving the ground. The next day's train journey was equally amazing – spectacular views of the Swiss Alps as we made our way to Trun to meet Werner Schmidt, an architect and builder with straw bale. All Werner's projects use big bales (2400x1200x700mm), often in roof and floor as well as in the walls. There are lots of great photos on his website www.atelierwernerschmidt.ch and other big bale buildings around the world at www.grossbotte.com

Werner's interest in super-insulation began about 25 years ago but it was another 9 years before he came across the idea of using straw. He experimented on a building of

his own then started doing 2 sets of plans for all clients – one conventional and one straw. Eventually one client opted for the straw option and now many more are doing so.

Werner took me to see Haus Braun, Disentis, the first straw bale house in Switzerland, completed in 2001. It had 1.2m load bearing straw bale walls to 3 sides and the south side was fully glazed. Although winter temperatures fall very low in Switzerland, they have a great deal of winter sunshine that warms the house for free. The roof overhang at 2.5m keeps the snow off the walls in winter and keeps the summer sun away from the south glazed façade.

I chatted to Werner about straw. He told me of a local man who was growing old varieties of wheat because the very long straw was very good at out competing weeds so that the crop could be grown without herbicides.

5. Northern Italy (1st July – 3rd July)

• A sweltering, but very scenic bus and train journey took us through the irrigated meadows of Switzerland to the irrigated apple orchards and vineyards of North East Italy. Our destination was award winning straw bale apartments in Lana, near Meran in the South Tyrol region. Architect Margareta Schwarz worked with Werner Schmidt (above) to design and build holiday apartments, each in a sort of hairpin shape, three in a row. The bedroom was in the curve at the back and separated from the kitchen/living area by a glass shower module. They are very comfortable and stylish apartments. The website has lots of pictures of the construction and the completed accommodation. www.esserhof.com

• Margareta also took me to see her work at Casa Mair. Originally it was a 2-storey house but now it has a third storey on top built with small straw bales, including a dome shape straw bale roof. An amazing family home that I can't begin to describe effectively enough. Margareta is definitely my favourite architect. She combines natural materials and principals with style, clever design and attention to detail. She could convince the world to build with straw! Her website is www.archschwarz.com .

6. Austria (3rd July – 8th July)

• Architects Karen Allmer and Florian Macke (www.allmermacke.at) used straw bales to insulate the roof of their home in the very centre of Vienna. This small, cleverly designed family home was hidden away in a courtyard though large doors that once opened to admit coach and horses. There was lots of natural light and natural materials, great balcony and connection to the outdoors, internal walls doubled up as storage, staircases of metal grid that allowed heat to circulate around the home and the shower was finished with Tadelakt, a lime based waterproofing technique I first came across at the 1st International Hemp Conference in Ireland. www.atelierbiocreation.com

7. Slovakia (8th July – 12th July)

- Architect Zuzana Kierulfova and her husband Bjorn specialise in passive housing and eco building materials. Zuzana is heavily involved with the Slovakian straw bale and sustainable development group. There are lots of pictures of straw bale buildings on their website www.ozartur.sk but not on the English pages. To see them go to "eko info" then "slama v sk". Zuzana took me to see a straw bale insulated yurt on a nearby permaculture holding.

Work on a straw bale dome was about to begin close to Zuzana's house, led by German straw bale expert, Professor Gernot Minke. Zuzana has kept a great diary of this build at www.minke-strawbaledome.blogspot.com

Appendix B

Unplanned itinerary – sustainable agriculture in date order

As my straw bale tour progressed, it was interesting how I kept on stumbling across sustainable food production and land use issues. In date order, I have provided brief details and links to my discoveries for those interested in these subjects.

1. United States of America *(24th January 2010 – 8th February 2010)*

• **Agricultural and Land Based Training Association (ALBA)** is a small farmers education program based in the Salinas Valley, California. www.albafarmers.org –" creating economic opportunity for small farmers while promoting ecological land management and healthy local foods". After classroom study the students are allocated 1 acre each to actually grow their own organic vegetables. Successful students can have a larger land allocation in their second year. The students learn everything from growing to marketing. ALBA has established many links with local restaurants. This struck me as a really great way to get more people from diverse backgrounds involved with sustainable food production. By chance their education centre was built with straw bales!

• **Tom Tomich,** founding director Agricultural Sustainability Institute, UC Davis, University of California www.asi.ucdavis.edu . Tom explained that "agro ecology" is the term we now use for what we used to think of as organic – the latter term being hijacked by growers merely using substitute chemicals. He believes in a whole system approach - effects being cumulative. Holistic was a term I was going to encounter many times on my travels – from both the agricultural and construction fraternities. Professor Tomich believes any change in agriculture will have to be from the bottom up – governments are unreliable, presently food safety dominates ecology and lawyers rather than scientists are driving change. Another common belief I was to encounter.

• **Village Homes,** Davis www.villagehomesdavis.org. A 70-acre housing development built from 1975 onwards comprising 225 homes, 20 apartments and 23 acres of green space. Designed with a sense of community and conservation – orientated to optimise solar gain, narrow streets and limited parking to minimise car use, well thought out pedestrian and cycle routes, common areas, edible landscaping, natural drainage etc. A really lovely place to visit and obviously a popular place to live; the smallest homes now sell for $300,000, which goes against the original aim of affordable housing. This highlights the importance of getting the legal form of such developments right in the first place – the wealthy have a habit of taking over successful projects.

• **James Stark and Penny Livingstone** co-manage a 17-acre certified organic farm, Commonweal Garden, at Bolinas, California on the edge of Point Reyes National Park. www.regenerativedesign.org. It just happened to be open house on the day I was in the area and I joined James Stark on his tour of the farm. He highlighted how permaculture principles can be applied to create sustainable and regenerative home and community

environments. Permaculture, leadership and nature awareness courses are hosted on the farm as well as a course titled "Earth Café" where gardening, culinary and nutritional subjects are weaved together. This struck me as a great idea although perhaps it should be a life long course!

As the tour progressed questions from the gathered prompted James to mention an award winning packaging from www.lifeboxcompany.com where native tree seed and mycorrhizal fungi are embedded in the cardboard box so that the packaging has a second purpose – growing new trees and fungus. He also discussed the nutritional benefits of mushrooms. I never realised that they were 20% protein (dry weight) and contained a wide range of essential amino acids and vitamins. www.fungi.com

• **Aprovecho** – a non-profit research and education centre on a 40-acre rural campus at Cottage Grove, Oregon www.aprovecho.net providing live working examples of appropriate technology, sustainable forestry, organic agriculture and permaculture. I noticed while browsing the net that Oregon State University runs a permaculture program – the first I'd encountered at a University suggesting that this subject is becoming less of a fringe idea. Also of note, the Aprovecho Research Centre has also developed an award-winning, highly efficient, rocket stove which uses half as much fuel compared to an open fire or unimproved stove.

• **Farmers' markets** are thriving in Portland. I picked up a copy of *ediblePortland* in the Eco trust building as I waited for my meeting with Eden Brukman www.edibleportland.com . It was quite a hike to 21st Avenue to the Peoples Co-op farmers market that afternoon but a good way to see the city. The magazine also had a full page listing of csa farms – Community Supported Agriculture – I'd not heard the term before but they were obviously popular in this part of the world. Farmers form a direct relationship with eaters who purchase a "harvest share" and receive a weekly supply of fresh produce throughout the growing season, giving the farmers a reliable market. Bit like our vegetable box schemes, I suppose. www.portlandcsa.org

• Eden also put me in touch with **Marc Boucher-Colbert**, an urban farmer, renowned in Portland for establishing the roof top garden at Rocket Restaurant, 1111 E.Burnside. Salads, herbs, fruit and vegetables are grown in a variety of raised bed systems on top of a 4-storey building for use in the kitchen below. http://www.cityfarmer.info/2008/05/28/rooftop-vegetable-gardener-at-rocket-rooftop-garden-takes-us-on-a-tour/ . Urban agriculture was a new concept to me too but it's easy to see the advantages; reduced food miles, fresh produce, new habitat, green in the city. Marc told me that some African and Asian cities produce 50-80% of the food needed by the city.

• Next stop, **Lincoln, Nebraska.** The weekend I was in town, my straw bale contact there, Joyce Coppinger, just happened to have a booth at the annual conference of the Nebraska Sustainable Agriculture Society. Great speakers, interesting exhibitors, the best food since leaving home and a Blue Grass band! www.healthyfarms.org .

The first lecture was "sustainable agriculture as the key ingredient for rural economic development" delivered by Kevin Fulton, a farmer with a 2,800 acre organic grass-fed

beef operation in Sherman County. I hurriedly scribbled down quite a few of his quotes; " What do we call the mass exodus of people and animals from the land? – Progress!!!", "Is it better to have a neighbour or your neighbours land?", "naivety is a virtue because it allows you to explore all the options", "industrial agriculture has helped over consumption, it hasn't relieved famine", "as well as £/acre we need to consider protein, nutrients and carbon stored per acre"

Ralph Tate gave a lecture entitled "The Life beneath our feet" in which he talked about the soil food web. There are 90 identified elements present in soil. A teaspoonful contains billions of bacteria, yards of fungal threads, thousands of protozoa and dozens of nematodes. Most of the microbial biomass is in the top 50mm of soil. Scientists understand very little about soil and so cannot possibly understand the full effects of artificial fertilisers or genetically modified organisms.

Dr John Ikerd talked of how the health of a people depends on the health of their soil and how the nutrient density of food in the US is decreasing. Industrial farming means more food but fewer nutrients leading to an over fed but undernourished nation. Farmers must have time and money to *love* the land – but they can only love *so* much – need more farmers and to repopulate rural areas. We need to reconnect with each other and reconnect with the land.

This conference was the first time I was to come across "mob grazing" where cattle are moved to fresh pasture every day. The calculated number of cattle and acreage mean that everything is grazed – including the thistles (which are very nutritious apparently). That section of pasture then re-grows for a month or more before the cattle return. This simulates what happened in the wild as herds moved over the range. It encourages more species of plant, which provide a wide range of nutrients for the cattle and increased biodiversity.

2. Canada *(8th February to 18th February 2010)*

• **Wally Doerksen** took me to see the Mennonite Heritage Village near Steinbach. The 40-acre site has a village street in the pattern reminiscent of Mennonite villages in Southern Manitoba at the turn of the century. There is also a visitor centre that tells the story of the Russian Mennonites, their faith and culture. This is Wally's heritage. As well as showing me the Village, Wally and Ruth also took me to eat traditional Mennonite fare in a café in town and we had a look around the Mennonite Thrift Shop (like our Charity shops but much, much bigger and nicer – there was even several shelves full of pre owned jam jars).

Although the snow was deep at the Visitor Centre, we could just see "The Semlin" – a tiny house of sod, soil, grass and timber – the only materials the first immigrants in 1874 had to build shelter. www.mennoniteheritagevillage.com

• On the first day of my stay with Canadian Nuffield Scholar Karen Daynard I attended a **Sustainable Agriculture Conference** organised by Farm Credit Canada. The first talk was about carbon pricing initiatives. The second, by Robert W Sandford was entitled "*Water*

for Life- Redefining Agricultural Sustainability in the Context of Water Use". He discussed a looming peak water crisis and how it could be delayed. The next speaker, John Paul, talked of how organic matter can be used to produce energy but asked whether recycling nutrients was more important – nutrient use efficiency is lacking in many agricultural enterprises. The final speaker was Tim Haig. He worked for a company developing a method of using algae to produce bio diesel. He said "If you can make money by burning something, there will always be something better you can do with it". He talked about the unintended consequences of biomass policy.

• Terry Daynard kindly showed me round the **Bioproducts Innovation Research Centre** at the University of Guelph. www.bioproductsatguelph.ca We saw a number of plant fibres being made into composite materials to replace petrochemical based products. Terry explained how bio plastics degrade at different rates; food packaging must compost rapidly but plastic car parts need to last much longer. Collaborative groups between farmers, researchers and the end users are being set up.

• Wally Seccombe, founding member and current chair of **Everdale organic farm** and learning centre www.everdale.org kindly showed me around the 50-acre working farm near Hillsburgh, Ontario. Community Supported Agriculture began there in 1998 and now 160 households come to the farm weekly to use their point allocation to select their share of fresh produce. Wally believes Everdale's flexible approach to harvest share is successful – members choose the produce they prefer and can transfer their points to friends or family if they are away. I like the strap line on the website which reads "know your food, know your farmer".

There is also an educational program at Everdale, delivering an organic farming certificate and an interesting course called "Farmers Growing Farmers".

As I left Everdale, Wally and I were discussing composting toilets. Wally observed that recycling was all about separating waste streams. Nature had gone to a lot of trouble to separate our own waste streams into liquid and solid but the first thing we humans do is mix them back up again! I was reminded of this recently listening to Jeremy Vine on BBC Radio 2. His guest was Sally Magnusson was author of *Life of Pee – The story of how urine got everywhere.*

3. Slovakia (11th July 2010)

• **Yanke's permaculture farm** near Senec, Bratislava is designed so two people can work it. Vegetables are grown in circles. Planting, weeding and watering is all done from a metal arm pivoted in the centre of each circle. He had very interesting plug plants in coils too – they opened out to yield with ease a tiny seedling to be planted out.

Appendix C

Straw Bale Building – FAQ's from our website: www.homegrownhome.co.uk

What is the fire risk with a straw bale building?

A bale of straw is often compared to a telephone directory. Loose straw or a single page of the directory will easily burn. However, it is very difficult to set fire to the dense bale or the whole directory as there is a limited supply oxygen to fuel the fire. Add to that 25 mm of clay or lime render and you have a wall assembly that will easily withstand more than two hours in a fire test – when only half an hour is required by regulation. The many fire tests carried out around the world on straw bale wall assemblies confirm this.

Are rats and mice a problem in a straw bale building?

Some straw bale advocates say that rodents will not live in straw because the food (the grain) was removed at harvest, but I don't think that this is true. As any farmer will tell you, a straw stack is a very popular home for rats and mice. However, there is a big difference between a farmer's straw stack and a straw bale building; in a well designed and constructed building the straw is completely sealed on all sides to prevent rodent entry and the bales are dense and carefully stacked together with no gaps whatsoever.

There is a further advantage if the bales are under compression as in a load bearing building – the bales are so tightly pressed together that the rats and mice would be unlikely to be comfortable there.

Our building bales for the cottage were riddled with mice in the over winter store. Out of 700 bales we struggled to find 300 that had not been chewed through. However, it was very reassuring to find that one part of the stack where some large, heavy big round bales where placed on the top there were no mice taking up residence!

Can rain damage a straw bale building?

Moisture is the main enemy of all natural building materials, as prolonged exposure to water would result in decay. However, with appropriate design, attention to detail in construction and timely repair in use straw bales, timber and hemp can all last a very long time.

Design techniques include a large roof overhang or porch, a breathable render, a ventilated rain screen on exposed sides and raised foundations or wall base. These simple measures were widely used in the past when all buildings were made from natural materials.

How long should a straw bale building last?

Straw bale buildings are relatively new in the UK but we have been using straw in cob buildings and in plaster for centuries. As described above, if it is kept dry it can last forever. The straw bale house in France built in 1921 is the oldest European example but there are several houses in the USA which are over one hundred years old.