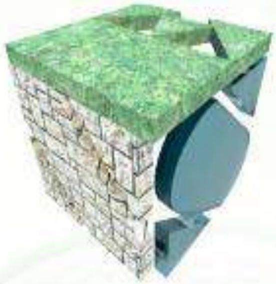
Training for Sustainable Building

NEES Training Manual

Training support material for the vocational training modules for the

Natural Energy Efficiency and Sustainability (NEES) Project



Where can I get more information on NEES?

If you wish to find out more about the NEES Project, please check our comprehensive Web Site, contact your NEES regional rerpesentative or the NEES Project Manager at the address below.

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Innovatively investing in Europe's Northern Periphery for a sustainable and prosperous future

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Contents

Introduction and overview of the NEES vocational training modules.

The NEES vocational training package consists of set of training modules that address the various aspects of Natural, Energy Efficient and Sustainable (NEES) building practices.

The package is made up of six modules; Module 1 General principles, Module 2 Construction Methods, Module 3 Envelope 1 Roofs and earth construction, Module 4 Envelope 2 Windows and insulation, Module 5 Accreditation and certification and Module 6 Energy and water usage.

The modules are designed to be stand alone and each module can be delivered individually or as part of the series. Each module consists of a PowerPoint slide presentation which contains notes and images.

Module 6 is designed as a support module and covers some of the fundamental building energy principles.

This manual contains additional training support material that can be used to aid delivery of the modules and a list of the headings from each module and the intended learning outcomes.

Section A: Principles of Sustainable Design.

Introduction

Sustainable development is essential to growing a strong competitive economy in which the cost of energy and services is of key importance to the cost of what we produce for consumption at home and abroad. By using our resources efficiently we will keep energy and utility costs down. This will help attract inward investment while protecting the environment from pollution and carbon emissions. A clean environment is important for good public health and creates the right conditions for leisure and tourism activities to flourish.

Sustainability involves taking responsibility for all our actions no matter how little an impact we make individually in the overall picture. By thinking about why we need to use energy we can find ways to use it more efficiently thereby reducing imported energy and fuels.

The guidance given in the manual is aspirational in nature and it should not be applied prescriptively but with intelligence on a project by project basis.

The following topics are covered in this manual:

1. Ensure sustainability through design
2. Mitigate the causes of climate change and adapt to the impacts
3. Promote equality and ethical standards
4. Encourage a sustainable culture and behavioural change through education
5. Sustainable development is rooted in place
6. Plan for sustainable neighbourhoods
7. Protect biodiversity
8. Integrate landscape and infrastructure
9. Encourage urban agriculture and urban forestry
10. Prioritise sustainable development in land use
11. Re-use vacant sites
12. Sustainable transport
13. Sustainable water use
14. Energy use reduction
15. Assess the sustainability of biomass and bio-fuels.
16. Renovate and re-use buildings
17. Protect the built heritage and encourage good design so that new buildings are valued and become the future heritage.

18. Make new buildings flexible in use
19. Put fabric first
20. Use passive solar design and shading
21. Prioritise indoor air quality
22. Reduce emissions from building fabric
23. Select sustainable building materials
24. Take account of embodied energy
25. Use renewable and natural low impact materials
26. Conserve and reuse materials.
27. Design for demolition and re-use
28. Take sustainable development as far as possible

Recommended generic principles for sustainable development

1. Ensuring sustainability through design

While some designers and developers may make token references to sustainability, very rarely are efforts made to push out the boundaries and to be truly innovative. This is often because there is an assumption that adopting a greener approach will inevitably be much more expensive, even though this need not be the case.

Rather than tying sustainable design to specific policies and rigid standards it is better by far to prioritise objectives and to adopt *generic* principles that can inform design strategies. The suggestions below may at times seem specific but they should be viewed not as rules, but as opportunities to adopt innovative approaches that would provide really positive benefits to the environment. Instead of adopting tick box measures, a design led approach weighs up all the options and goes for the most creative and holistic solution.

These suggestions draw on a wide range of sources and experience of sustainable design. It owes much to the concept of 'Living Building', initiated by the Cascadia Green Building Councils in the USA who believed that the US Green Building Council LEED standard did not go far enough (http://living-future.org/lbc). Assessments models such as BREEAM and LEED, while useful in raising awareness of sustainability issues, are too limited in their scope and often hamper a design led approach. Instead 'Living Building' advocates a step change to a more holistic approach to sustainability. While BREEAM or LEED remains a requirement for Government funded projects in some countries, it only ensures a minimum level of sustainability in the average project. Designers and their clients are encouraged to have the courage to divert from minimum standards when it is sensible to do so. It is hoped that the guidance given here will provide the justification for such an approach when dealing with innovative cutting edge designs.

2. Mitigate and reduce the causes of climate change and adapt to its effects

Set low, zero or carbon neutral objectives for development. Assess the risks of climate change such as temperature rise, drought and flooding in the design of buildings and places, and design accordingly. It pays to be sustainable.

3. Promote equality and ethical standards

A commitment to sustainability should involve both an equitable and ethical approach leading to a built environment that upholds the dignity of all members of society regardless of their physical abilities, their ethnic background or economic situation. This covers a range of issues, including accessibility, rights to natural systems regardless of property ownership, and protecting individuals from the negative impacts caused by adjacent properties. It also includes the sourcing of materials and the impacts of quarrying and manufacturing on local population and an adequate standard of protection for workforces.

An ethical and democratic approach should not seriously disadvantage or hurt others for individual benefit. An ethical approach in the planning system would not permit construction of buildings that may advantage their owners / occupants while seriously degrading others' enjoyment of the environment.

Protect the future of the planet: Our Common Future, also known as the Brundtland Report:
"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

"It is critical to remember that most projects in the built environment greatly outlive the original owner or developer – and society inherits the legacies of bad decisions and good decisions alike. Since the act of building is a considerable environmental impact shared by everyone, there is an inherent responsibility to ensure that any project provides some public good and does not degrade quality of life for others or for future generations. After all, a society that embraces all sectors of humanity and allows the dignity of equal access is a civilisation in the best position to make decisions that protect and restore the natural environment" Living Building Challenge.

4. Encourage a sustainable culture and behavioural change through education.

All sustainable buildings should embody an educational function. They should also act as a best practice road map for other projects, teaching people about the design decisions made and systems used. Examples of educational tools that some teams are currently planning include: websites with real-time utilities tracking; 3D interfaces that highlight systems and their functionality; display areas on-site that publicise the project's metering systems; and classes that will be taught on-site about the design and construction process. A commitment to include such facilities and provision should be made in each sustainable project whenever possible.

5. Sustainable development is rooted in place

As all elements of the built environment are rooted in place, all planning decisions should be informed by its eco region's characteristics. The demands of a project in terms of energy, resources, water and its impact on the environment should be as responsible as possible and related to the local context. Careful thought should be given to the need for the building or development and whether it performs a useful social or economic function. Sustainable buildings should be in sustainable places and linked to other places by sustainable transport options.

6. Plan for sustainable neighbourhoods

This includes projects involving multiple buildings and outdoor spaces in a continuous campus, neighbourhood, small towns or villages, and including university, college or corporate campuses; business or industrial districts. The creation of attractive and people friendly and accessible public spaces, public facilities are part of sustainable development.

For the last one hundred years we have been remaking our neighbourhoods, cities and towns to be car friendly rather than people friendly. The scale of civilisation has shifted away from places that work well for people -especially those who do not own a car. Human scale and humane places should aim to reintroduce building and infrastructure parameters and enforce scale relationships that simply work in creating positive, humane and human-centred spaces.

Access for people that are economically disadvantaged and access for those with physical disabilities is also an important part of sustainability policy. There is a disturbing trend among modern cities where sizeable portions of what used to be considered 'public space' is now gated or subject to private security surveillance. The privatisation of streets, bridges and other public spaces should be discouraged. These are examples of semi-public infrastructure that create a segregated and inequitable society: gated communities, segregated building-to-building connections, and private parks that destroy the vitality of street life and compromise a greater sense of community.

Disability access and an awareness of the needs of disadvantaged people such as those with dementia, the needs of elderly people and children are an important part of social sustainability.

All people should have equal access to fresh air, daylight, clean water and natural systems. These rights should never be diminished merely because of current property ownership. Public footpaths are in short supply in Northern Ireland and many have to drive before they can find somewhere to go for a safe walk. Rivers, lakes and sea front areas are sometimes claimed as part of private property, but sensible public access should be allowed. This can sometimes be the only outlet for individuals to find a direct connection to nature. All proposals should incorporate a positive benefit to public space.

It is also important to protect sites adjacent to projects: Proposed developments should not impede another project's ability to access daylight and sunlight or compromise air or water quality through their function. In more urban areas, there will inevitably be some shading of neighbouring properties depending on their density but this should be carefully controlled.

Archaeology and history and significance of places to people and communities should be respected.

7. Protect biodiversity

All development projects should make reference to nature as the ultimate measurement stick for performance. This involves assessing the overall impact of any development proposals in terms of its effect, not simply by saving energy, but on the planet and the biosphere as a whole. EU guidelines exist on how this can be measured and are based on carbon or ecological foot printing (EU foot printing guidelines). (BREEAM currently includes some standards to protect biodiversity)

[Ref. Ares (2012) 873782 -17/07/2012 Product Environmental Footprint (PEF) Guide Deliverable 2 and 4A of the Administrative Arrangement between DG Environment and the Joint Research Centre No N 070307/2009/552517,Including Amendment No 1 from December 2010 European Commission (EC) Joint Research Centre (JRC)Institute for Environment and Sustainability (IES)Authors: Simone Manfredi, Karen Allacker, and Kirana Chomkhamsri, Nathan Pelletier, Danielle Maia de Souza]

When faced with loss of habitats the 'Living Building Challenge' encourages habitat exchange. This requires that we acknowledge that by developing a site for our own use, we may have evicted other species from their home. As a way to protect thriving ecosystems from suffering the same demise, a commitment can be made to support and maintain land set aside to support natural biodiversity on site or elsewhere, though this may only be feasible in larger developments.

8. Integrate landscape and infrastructure.

Roads, bridges and other transport infrastructure should be carried out to sustainability standards and incorporate natural landscapes or green amenity space where possible. These will include open-air 'park-like' structures, restrooms, amphitheatres and nature trails to encourage healthy outdoor activities.

Landscape proposals may only include planting in such a way that supports the processes involved in plant community restoration by using native or naturalised species. Maintenance activities must allow the ecosystem to mature and change with time. Eventually, some stable type of community will form and can maintain itself. Proposals such as green roofs should only be included if planted with indigenous species and constructed with environmentally responsible materials. Green roofs make only limited contribution to biodiversity and the thermal performance of buildings, thus they should not be adopted for tokenistic reasons.

9. Encourage urban agriculture and urban forestry

All development even in urban areas should consider opportunities for agriculture. Suitable areas may be at ground level, on the roof or incorporated into vegetated walls. Planting does not all need to be of native or naturalised species. However, as much indigenous tree planting as possible should be encouraged. Urban tree planting should be encouraged.

10. Prioritise sustainable development in land use

There are different categories of land and these may be defined in different ways in planning policy documents:

- A Land that is set aside as a nature preserve or is defined as sensitive ecological habitat. Only in limited circumstances related to the preservation or interpretation of the landscape should this land be developed, for instance through the use of visitor centres and visitor facilities.
- B Land that has a primary function for agriculture currently restricts development to exist-

ing farm building clusters but there may be a case for new policies such as Low Impact Development as has been adopted in Wales.

(www.tlio.org/chapter7/Welsh%20Low%20Impact%20Report.pdf)

Such a policy allows small self-sufficient communities and smallholdings to be approved in order to regenerate declining rural populations. Such policies encourage people to develop intensive growing of food and management of woodland. Development of isolated new houses for commuters is not part of such a policy however.

C Low-density mixed-use development in rural villages and towns, which may also include businesses related to food and timber processing should use local materials and respond to the local character. They should be designed to be as self-sufficient as possible in terms of infrastructure.

D Medium-density mixed-use development found in larger villages, small towns or at the edge of larger cities should be designed to be as self-sufficient as possible in terms of infrastructure and to not encourage greater commuting by private car.

E Medium-to high-density mixed-use development found in small to mid-sized cities or in the first ‘ring’ of a larger city provide multiple opportunities for sustainable planning where energy sources and facilities can be shared. Unfortunately in normal practice, developments are considered only in isolation within the site boundary.

F High-to very high-density mixed use development found in large cities and metropolises can require massive external infrastructure to supply energy and deal with waste. While some argue that high density is the most sustainable approach, it is necessary to be aware of the large ecological footprint of cities. Sustainable solutions are not always within a project’s property boundary but this should not preclude making proposals for the greater good.

Development should also focus on re-establishing balance between nature and the built environment. Any tendency to decentralise our communities, increasing transportation impacts and pollution should be avoided.

Limits to Growth (Club of Rome 1972), restricts the placement of new projects to reduce the impacts of development on intact ecosystems such as wetlands, dunes, forests and prairies, and to eliminate encroachment on much needed agricultural land and flood plains

Projects should preferably only be built on grey-field or brownfield sites.

‘Limits to Growth’ also requires that site conditions be improved. Teams must survey the existing site conditions to determine the most appropriate solutions.

11. Re-use vacant sites

Make optimum use of land especially vacant sites before considering high-rise and high-density developments. Encourage use of vacant sites in the city by reinstating green belts.

12. Sustainable transport

Car free living should be an objective where possible. This involves providing the potential for a community to support a car free lifestyle based on the density and the mixture of occupancy types in an area. This is not the same as eliminating cars from the development. Rather, 'car free' is defined by the potential for a majority of people living in the neighbourhood to have a productive and rich lifestyle without need for a car. Provision for car-pooling and car sharing, electrical car charging points should be included.

Access to public transport should be facilitated and new routes negotiated with public transport providers. All proposals should set out the role of public transport connected to the development.

Cycle friendly design, safe and secure storage for cycles, shower facilities for cyclists and safe routes and access is also a vital part of design and development.

Most people are willing to walk 1 kilometre (just over 3/5 of a mile) to access amenities. Good unobstructed, safe and well lit pedestrian access and encouragement of useful local facilities should always be included.

13. Sustainable water use

All projects should treat water as a precious resource. Conventional practices are incredibly wasteful – both by design and in use: Sometimes water leaves the project before it is even used once. For example, more efficient taps could save gallons of water a year from going to the sewer. (*www.ech2o.co.uk)*

There are regulations which impede ecological solutions to water usage as water must be from potable sources because of local health regulations, but there are still many steps that can be taken to safeguard this precious resource. The supply of good quality water requires a great deal of energy and resource consumption even if there is a good rainfall. A public utility is usually the only supplier available to a building and the water delivered is generally used for everything – drinking, bathing, toilet flushing and irrigation. This process relies on large, centralised and energy-intensive systems to move water far distances, and once water passes through the pipes, it is reclassified – often as 'black or grey water' – which is then conveyed to a treatment facility many miles from its point of use. It is exceedingly wasteful to use drinking water to flush toilets or irrigate plants. Buildings can be water independent for some activities. Composting toilets and waterless urinals offer solutions that have many benefits in water reduction.

Once the need is minimised, water for occupant use can come from rainwater harvesting or closed loop systems that account for downstream ecosystem impacts. However such measures should only be adopted if appropriate and economical.

Current regulations make it very difficult to get permission for compost toilets and on site ecological treatment systems such as reed-beds but these policies should be reviewed as more proposals for sustainable buildings come forward. However care should be taken to ensure that any water systems are low embodied energy and do not make extra energy demands.

Low impact solutions like collecting rainwater for watering gardens and car washing are simple to implement.

It is also important to focus on the flow of water and drainage outside buildings. Storm water and building water discharge should be managed on-site where this is practicable. Sustainable urban drainage can be useful but should not be applied in a thoughtless way where it might not be appropriate.

14. Reduce energy usage

While the sustainability aim would normally be for Net-Zero Energy use in buildings, this is not always practical and appropriate. It is critical that all projects are designed to be super-efficient and eliminating energy demand. Between 60-80% reduction from the norm should always be possible and realistic in most buildings. Extreme claims to achieve Zero Energy use are rarely achieved and extreme measures that attempt to achieve this can cost far more in embodied energy than they ever save in use.

Reducing energy consumption and methods of making buildings energy efficient should always come before applying renewable energy technologies to create more energy. In some cases it may be appropriate – to put a wind turbine or a large photovoltaic array on an individual site or building, but a wind farm could easily feed the needs of an entire community and larger scale renewable energy systems may be more economical and sustainable.

The use of heat pumps and other technologies should not be assumed to be more efficient and only used if appropriate. Combined heat and power systems, for instance, only work if there is a heat demand that justifies using energy to create electricity.

Air conditioning and cooling systems should only be installed if absolutely essential and natural ventilation systems should always take priority over mechanical ventilation and air conditioning. Mechanical ventilation and heat recovery systems (MVHR) are frequently advocated as energy efficient but a good case must be made for this, as it is not always the best solution.

15. Assess the sustainability of biomass and bio-fuels.

Burning biomass is often seen as a green solution but should be considered very carefully. Using logs or willow coppice, if grown on site or nearby can be acceptable but importing wood pellets from great distances is not. Bio-fuel powered energy is often presented as sustainable but we need to acknowledge that bio-fuels are only a short-term transitional strategy for harvesting energy and are not really suitable for sustainable projects. The limited amount of usable land that is suitable for agriculture should not be used to feed machines, especially since the energy required to create bio-fuels is often comparable to the energy output.

16. Renovate and Re-Use Buildings

Most developed western countries have enough buildings and built resource to satisfy current needs. The case for new buildings should be made on social and environmental criteria, once the possibility of re-use of existing buildings has been exhausted. For instance there is still a case for new housing in areas where there is a housing shortage. Generally renovating existing buildings is more sustainable. Retaining existing built heritage and familiar buildings and places is also sustainable. Third party carbon profiling studies will generally show that retrofitting existing buildings has a lower CO2 impact than demolition (RICS/Sturgis Associates: Redefining Zero *https://consultations.rics.org/consult.ti/embodied_carbon/view?objectId=259 8228.* However, the retrofitting of existing buildings should be carried out carefully so as not to damage the fabric of the existing buildings. Sustainable renovation and retrofitting may not achieve extreme energy efficiency standards but, by retaining and re-using existing buildings and materials, the overall impact on the environment is much lower.

17. Protect the built heritage and encourage good designs so that new buildings are valued and become the future heritage.

Healthy cities are also like organisms – and they continue to grow and show their age. Nineteenth and early twentieth century mills and warehouses were not valued in the same way as they are now for their design quality when they were built. We value them now because they are old and solid and they use techniques that are now unaffordable; they have become valuable and beautiful because they have assumed a patina of age. It is important for the sustainability of culture and society that we continue to make buildings that will be old and valued in 100 years time. We have to build them so that they will be valuable enough to society and well enough built to last that long, that makes new buildings a lot more sustainable.

New buildings may have better thermal performance than older buildings but overall there are many aspects of older buildings that make continued use sustainable.

18. Make new buildings flexible in use

Always consider the whole life of buildings and how they can adapt to change of use.

19. Put fabric first

Fabric first should be the main aim in any project so that buildings are so thermally efficient that only minimal energy input is required. It is important to ensure that buildings are insulated in the most effective, healthy and environmentally friendly way. Assuming that the material with the best claimed thermal resistance should always be used can be a mistake. Lightweight buildings with lightweight insulation lack thermal mass and have been found to overheat and not perform as efficiently as predicted. Hygrothermal calculations should also be taken into account as thermal comfort is also related to humidity and the ability of materials to manage moisture in buildings.

20. Use passive solar design and shading

Solar gain can also contribute to thermal efficiency but must be handled carefully so that buildings do not overheat. Having large areas of south facing glazing can be counterproductive if buildings overheat. It is also important to ensure that thermal mass is used appropriately to provide passive heating or cooling. It is often assumed that concrete is the best material for this but the thermal lag time in concrete can mean that it doesn't function as effectively as other materials. Unfired earth walls, hempcrete and solid timber can be more effective and responsive as well as cheaper and having lower embodied energy.
Solar shading is frequently added to over glazed buildings, adding cost and embodied energy, whereas careful design can ensure there is good solar gain, daylighting without overheating. Frequently solar shading can be seen on north facing facades as it has been added for aesthetic reasons! More sophisticated and energy efficient glazing systems are becoming available and this can help make buildings more energy efficient. However it must not be assumed that the most expensive top of the range triple glazing systems should be used as the embodied energy they represent may never be saved during the life of a building.
Daylight measurements are required under the building regulations, but acceptable daylight factors based on the function of the space may vary from a sustainable point of view.

21. Prioritise indoor air quality

This is a greatly overlooked issue, particularly in the UK, but should be central to any sustainability approach. Not just because it protects the health of building occupants but because it acts as a touchstone to so many other issues such as design, construction methods and materials, ventilation and heating, and the quality of the environment and the experience of users.

People operate and maintain buildings in many different ways and thus any design should involve education of the users of the building so they fully understand the systems and materials used. Cars and most electrical and mechanical equipment come with a user's manual that is legible and understandable to the user so why should buildings not be the same?

Sensible operation of buildings can reduce moisture loads and risk of mould growth. Condensation and mould growth remains a significant problem in many buildings. Ventilation systems are very important to ensure good fresh air but also to guard against condensation, particularly as energy efficient buildings are much more air tight than in the past.

Currently the general population and even facility managers are largely unaware of air quality issues and systems may not be operated as efficiently and carefully as they should. Mechanical ventilation systems require filters that must be maintained. Legionnaires disease can break out because of inadequately maintained cooling systems.

A civilised environment allows for occupant control, particularly as it relates to sensory aspects such as air quality and thermal and visual comfort. Despite the view that to reduce energy consumption, windows should remain closed, it is better that there are operable windows to ensure access to fresh air, daylight and views. Each occupied space should have at least one window-wall, which is defined as an exterior wall containing at least 10% glazing area. Good daylight is important for occupant well-being and should be an essential part of any design unless particular functions should not have windows or require particular air handling such as operating theatres or for security reasons.

Where possible natural stack, and other natural ventilation systems should be used with low energy mechanical assistance if necessary. Mechanical systems should be focused on removing higher levels of moisture from wet rooms. It should not be assumed that MVHR systems are the only answer though they may be appropriate in some buildings.

Hygroscopic materials can now be used in buildings, which buffer moisture. These are often referred to as breathable building materials, but they are not providing fresh air ventilation or extract. Such materials can help to reduce humidity significantly. Non-hygroscopic, non-breathable materials can aggravate problems of dampness and condensation and increase the risk of mould growth.

Carefully consider the source of fresh air to keep toxins from entering the building and prevent the area inside from being contaminated. External air quality continues to be poor in many cities particularly during periods of still air and pollutants from vehicles and other sources can enter buildings and even be absorbed by some materials such as curtains and carpets.

22. Reduce emissions from building fabric

Many materials used in the construction of buildings can emit a range of pollutants that can accumulate in buildings. These are at the highest once a building has been completed but even though they can decrease over months or years, they can still remain a health problem. European standards for indoor air quality have been adopted in a number of European countries, though there is a varying level of enforcement. UK building regulations do not set standards for indoor air quality other than to set ventilation levels, however in order to adopt a sustainable approach designers and the developers of buildings should adopt exemplar indoor air quality levels and test the buildings to ensure that there is compliance. Levels of suspended particulates and total volatile organic compounds (TVOCs) could be measured prior to occupancy and again at least 9 months afterwards. This is a legal requirement in some European countries.

Levels of particulates and TVOCs will depend greatly on building products but also on furnishings, cleaning products and the items brought in by the building occupants themselves. It is important to make a concerted effort to understand the impacts of the products specified and installed and to avoid products that have the risk of emissions. Occupants should be encouraged in sustainable buildings not to introduce toxic and dangerous chemicals for cleaning and air freshening.

Principle areas of concern are fire retardant chemicals that are used in insulation as well as computer equipment, furniture and so on. These can contain endocrine disrupting chemicals that can have serious health problems particularly affecting the thyroid, hormonal and reproductive functions.
(http://www.who.int/ipcs/publications/endocrine_disruptors/endocrine_disru ptors/en/) While such chemicals may appear to be at a low enough level in buildings to be acceptable, they are found in high concentrations in the natural environment as a result of manufacturing and waste disposal, and can thus affect biodiversity. Other chemicals commonly used in building materials and insulations can be carcinogenic and also emit highly dangerous chemicals in fires. Glues and adhesives are a particular source and can be found in insulations and even timber products and products used to stick down flooring materials, tiles and sealants.

Sophisticated and sensitive detectors are now available to check for emissions in buildings and the relatively small cost of carrying out tests should be included in projects where there is a serious concern about indoor air quality. Respiratory problems, asthma and cancer are on the increase and we should ensure that buildings do not contribute to this. A sustainable approach should be to adopt the precautionary principle and try to avoid the use of materials that emit risky chemicals when suitable alternatives are available.

23. Select sustainable building materials

Material selection has the most far-reaching and broad impacts on design, construction, and occupancy. It deeply influences – and is influenced by other sustainability criteria. Material selection needs to be understood in terms of individual products selection but also the overall building structure and system chosen to construct the building. Key decisions as to whether to use masonry, steel or timber frame can have a big impact on the carbon footprint of a building.

As with indoor air quality the precautionary principle is the underlying theme that defines the selection of materials, and defines the suggested method for decision-making.

It poses that if an action or policy might cause severe or irreversible harm to the public or to the environment, in the absence of a scientific consensus that harm would not ensue, the burden of proof falls on those who would advocate taking the action. In layman's terms, it is the 'better safe than sorry' approach.

Many manufacturers and suppliers of materials engage in 'GREENWASH' making claims for their products that cannot always be checked. They may also make unsubstantiated claims about energy and insulation performance and almost always say their materials come from sustainable sources! While the introduction of the EU Construction Products Regulations will lead to many building products having a CE mark, this does not yet provide any assurance of environmental characteristics.

Thus in addition to the precautionary principle the designer, specifiers and builder should also exercise 'Buyer Beware' caution and check out claims that are made as far as possible. Relying on manufacturers' literature and web sites is **not enough** and independent sources of information should be preferred. Material certifications should be from third party assessors and consider all environmental impacts. British Board of Agrement certificates for instance provide an excellent guide to the performance of materials but do not deal with environmental issues.

Ideally organisations may wish to adopt a RED LIST of materials that should be avoided following the precautionary principle. This is included in the 'Living Building Challenge' standard. However this may raise some difficulties in terms of procurement policies and any such list should only be seen in terms of guidance. Such a list might include compounds that are carcinogenic, persistent organic pollutants, and reproductive toxicants as referred to above. Many of these substances are bio-accumulative, meaning that they build up in organisms and the broader environment, often reaching alarmingly high concentrations as they travel up the food chain. While concern tends to focus on food and drink, blood tests done by WWF (WWF Contamination) the results of WWF's Biomonitoring survey November 2003) showed worryingly high concentrations of dangerous chemicals in the blood of volunteers, that can only have come from building materials, not food.

The building industry is largely responsible for many dangerous materials and chemicals that are still in use today. For example, approximately three-quarters of all PVC is in building materials. Some of the other items on the list such as cadmium, lead, mercury and phthalates are also used as plasticisers and stabilisers for PVC. PVC is responsible for dioxin emissions and other pollution concerns but is still widely used.

It is not easy to exclude all dangerous materials due to current market limitations and cost pressures. However, when faced with imperfect solutions, project teams must communicate with manufacturers to check on product ingredients.

24. Take account of embodied energy

Apart from the dangers of toxic chemicals, sustainable construction must also take account of the depletion of natural resources and the energy used to manufacture building materials and construct buildings. Many materials used in Western European countries are sourced from all over the world and clock up many miles in transportation. Non-renewable resources are extracted from mines and quarries but information about environmental damage caused by this is rarely available. Materials frequently described as sustainable, turn out on closer inspection to come from sources where little care is taken to avoid pollution. Local people protesting about the dangerous chemicals dumped into local watercourses, for instance, have shut down photovoltaic cell factories in China.

Even materials that are claimed to be from recycled sources can be misrepresented. The Advertising Standards Authority has issued numerous judgments against building materials manufacturer for making false or misleading claims about recycled content and the environmental benefits of products. The credentials of recycling can be checked with organisations such as WRAP, http://www.wrap.org.uk

The energy used to manufacture materials represents a significant contribution to CO2 emissions. Portland cement, for instance is estimated to be responsible for 6-8% of the total CO2 emissions in the world, though there are lower impact cementitious products available based on recycled materials.

Measuring the environmental impact of materials through Life Cycle Assessments requires the measurement of embodied energy.

The United Nations Environment Programme (UNEP) has published several reports that demonstrated that a significant proportion of a building's carbon impact occurs prior to occupancy. (Buildings: Investing in energy and resource efficiency 2011) As projects are built for greater operational efficiencies, the percentage of impact is even greater. This is significant, especially when considering that many buildings are constructed to last 75-100 years. It is possible to curb some of the carbon impacts by making better and different decisions about material procurement and assembly. The Embodied Carbon Footprint Imperative means that this major contribution of greenhouse gases needs to be accounted for. Recent research done in London and Finland has identified the "Carbon Spike" problem and demonstrates that the energy used to create new buildings or event renovate existing ones will never be recovered by the resulting energy in use savings *[Heinonen et al, Sustainability 2011 3, 1170-1189].*

Reducing energy used today would be a more significant contribution to reducing CO2 emissions than energy saved in 25 years time, so reducing embodied energy must be taken as seriously as energy efficiency.

For a project to be carbon "neutral", it is important to first reduce emission potential by examining design and construction methods. Project teams may wish to calculate the project's overall carbon footprint and demonstrate how they intend to reduce or offset the emissions. Such carbon profiling can be independently assessed by a 3rd party, and a number of consultants now provide carbon counting services. For instance recent work by Sturgis Associates in London for WWF managed to reduce the predicted carbon footprint of the new WWF HQ building by 40%, simply by sensible analysis of the carbon footprint. No extra costs for the building were created by this process that was made at the design stage. Offsetting emissions by paying money to carbon offsetting organisations is a way of avoiding the problem and the issue is much better dealt with through design. Many so-called carbon neutral products are basing this claim on paying offsets.

Acceptable carbon offset projects are hard to find and many products described by companies as carbon neutral may be brought into question. However it is possible today to use renewable materials that lock up CO2 in the building fabric and this can thus be offset against other higher energy elements.

25. Use renewable and natural low impact materials

Timber is the main renewable material in common usage in the UK. Only the timber industry has a formalised standard, created by the Forest Stewardship Council (FSC) that provides evidence of sustainable management of forests and sources of timber. FSC is an independent certification system but some timber producing areas have been unwilling to pay for the certification. The timber industry has set up its own system known as PEFC (Programme for Endorsment of Forestry Certification), which is accepted as equivalent to FSC by UK Government departments.

Wood, for building structure and many wood products can be FSC certified, from salvaged sources or harvested onsite. It is important to check FSC claims and ensure that suppliers have full 'chain of custody'. Using locally sourced timber may be an alternative and this may not be FSC certified so it is up to the project team to check that the forests are being properly managed and new timber is being planted.

A wide range of environmentally sound products, made from a wide range of materials including timber, are independently certified by "Natureplus" which only approves materials with minimal fossil fuel input and minimal toxic chemicals. While the Natureplus standard is a useful guide it represents only a tiny proportion of materials currently available. *[www.Natureplus.org/en]*

Many companies now offer EPDs (Environmental Performance Declarations) though these are only voluntary under EU construction products regulations CE labels. EPDs do not offer any guarantee of environmental performance, as the requirements under the Construction Products Directive under health, environment and resource impact have not been fully implemented. However EU changes have led to the BRE Green Guide to Specification, being questioned.

It may be useful to set appropriate sourcing distances for materials and also apply limits to the location of the primary design team, but this will need to be checked against any UK or EU procurement rules that may or may not allow this. The mode of transport should be considered, as this will affect embodied energy figures. Product density and function will affect embodied energy. Heavy materials that typically are used as structural components should have the tightest radius and can usually be sourced locally. This encourages place- based and climate appropriate solutions for a building's shell or an Infrastructure project's most commonly used material.

Salvaged products can be used in buildings and this has enormous environmental benefits. Aggregates can be crushed on site from demolition and timber and steel can also be found locally.

However it may be necessary in the short term to go further afield to obtain the best environmental materials. Wood fibreboards and insulation, for instance could easily be made in the UK or Ireland, but all the products currently in use come from Germany, Austria and Switzerland.

Transparency is a vital element of a sustainable marketplace but some manufacturers publish product ingredients while others keep this information secret. Designers should advise manufacturers that such information is very useful when they are making specification choices and without it products may not be selected. Again this should be checked against any UK or EU procurement rules that may or may not allow this.

26. Conserve and reuse materials.

It is necessary to set stringent levels for material recycling and salvage to deter unnecessary contributions to landfills and to reduce the creation of landfill gases. Gases such as methane, carbon dioxide, hydrogen and volatile organic compounds (VOCs) are created from the waste on site and its degradation over time. Considerable progress has been made in the UK as a result of the work of WRAP.

27. Design for demolition and re-use

Diversion percentages are based on existing infrastructure that is available for various industry sectors. Although project teams are expected to make every effort to avoid landfill deposits, there is a temporary exception for meeting this level of diversion in jurisdictions where municipalities do not have systems in place to collect all listed construction materials.

In 2003, the US EPA estimated that 170 million tons of building related waste was generated from construction, renovation, and demolition -equal to 3.2 pounds per person per day. It is important not only to reduce or eliminate material waste, but also to redefine it as a wasted opportunity. In the UK there are plans to halve waste going to landfill *(2011 Signatory report WRAP).*

To minimise wasted materials, project teams must consider impacts during the design, construction, operation, and end-of-life phases of a development by developing a Material Conservation Management Plan, or Waste Management Plan. These are normally required for public sector funded projects and advice about this should be available from Government bodies. If material is conserved it is not waste so there will be no conflict with waste management policies. In it, teams are encouraged to consider appropriate durability of products. For example, is it necessary to manufacture and install a countertop that could outlive the building, the occupants and even their future generations? Another focus area is the potential for adaptable reuse of a development. How can the project be flexible enough to respond to the needs of the future without getting demolished?

28. Take sustainable development as far as possible

Decisions should be steered by 'restorative principles' instead of minimum solutions required by regulations and standards. Design should aim to be transformative from conventional practice to be a demonstration of best practice based on our current knowledge. Projects should act as an inspiration to others to strive for even lower impact solutions.

Projects should try to go beyond standards such as BREEAM and LEED if they wish to adopt more ambitious environmental impact reductions and CO_2 emissions. Adopting a more holistic approach can push at boundaries.

Certification of buildings and projects should be based on actual performance instead of predicted outcomes. Computer assessment tools are useful for design but will not explain how a building actually performs. Projects should be fully operational for at least twelve consecutive months prior to any certification. Finance should be set aside to ensure that proper post occupancy evaluation and monitoring is carried out.

Section B: Defining and Identifying renewable and non-renewable materials

Low impact materials

In order to understand why natural and renewable materials are beneficial in mainstream building construction it is necessary to explain what these materials consist of and to compare them with more conventional products. These notes focus largely on timber frame construction, insulation and board and panel materials. From these materials it is possible to construct most buildings that are required by society, even multi storey buildings. Environmental issues related to steel and concrete are not discussed in any detail here.

Natural and renewable materials can be made from biological sources such as hemp, flax, wood, straw, sheep's wool and so on. They can also be combined with benign or low impact materials like lime and earth into composites. However, some natural materials also include synthetic additives that are intended to improve performance. Many building problems can be solved using these materials, opening the possibility of significant benefits in terms of less pollution, less energy used, better and healthier buildings. A key issue here is the reasons for selecting such materials and also the reasons given for not selecting them. There is a great deal of prejudice against natural or unusual materials and when beginning a conversation with 90% of people they immediately say that such materials are "more expensive." However there are many ordinary people, professionals and builders who overcome these prejudices and have been willing to give natural and renewable materials a chance.

Synthetic Materials

Most construction materials used today involve a great deal of energy and much environmental damage to produce. They must be quarried, processed, subject to heat or treated with a range of chemicals. Very often they are derived directly or indirectly from petrochemical sources and polluting emissions are frequently a by-product of the manufacturing process. In this manual these materials will be referred to as synthetic materials. The word *synthetic* is used to contrast with the word *natural* but as with so many things in the English language there are problems of definition. Mineral wool insulation, for instance, is often referred to as a *natural* product as it is made from natural rock. However the process of melting the rock and then binding it with chemical glues is far from natural and can safely be referred to as synthetic. On the other hand many natural insulation materials such as sheep's wool or hemp may also have glues and binders and other chemicals added to them to make them perform better. There are also a growing body of materials made from recycled materials such as glass and plastic that many regard as environmentally acceptable. These recycled materials are even referred to as renewable but frequently they require significant amounts of heat and chemical processes to convert them. An environmental judgement, based on scientific evidence and independent certification, has to be made about the impact of these processes before deciding whether such materials are acceptable.

Limitations of synthetic and recycled materials

The key difference between natural and synthetic materials is the added concept of renewability. Once a load of rock has been melted into mineral wool insulation it cannot be returned to the earth or grown again, it cannot therefore be renewed, also, its carbon emissions from manufacturing cannot be recovered though manufacturers of such products often say they are renewable or sustainable.

There is a little doubt that stone based insulations can be useful products, particularly because of their fire safety characteristics, though some natural renewable products also have good fire performance. The aim here is not to suggest they should never be used, however the specifier is confronted with a simple choice when considering the use of renewable or synthetic products and needs to question some of the sustainability claims for such products. For instance a stone wool manufacturer state on their web site that their product is 97% recyclable. Stating that something is recyclable does not mean that it is actually recycled.

Stating that rock wool is one of the most sustainable products available is based on a definition of sustainability that is not accepted by all. In order to be sustainable, based on the Bruntland definition, non-renewable materials that also use a great deal of fossil fuel energy for manufacture should be excluded. It should also be largely free of added chemicals and able to be disposed of safely.

Rock wool products do not meet this standard. There may be an argument for the use of high embodied energy or petrochemical based products used in small quantities, like aluminium or plastics, when nothing else will do the job. This is a social policy decision, but sadly if a manufacturer says their product is the most sustainable, the average specifier may believe it without exercising their own judgment or applying social policy criteria.

It is possible that stone wool products can be recycled if the building that it is in is carefully dismantled, so that the insulation can be taken out and re-used, but this rarely happens in practice. More commonly, synthetic insulations can end up as semi-toxic waste in landfill. Mineral wool does not decay back to a natural material. Also the off-cuts and general mess on building sites can lead to a significant amount of insulation material going to waste and land fill.

Most of the manufacturers of synthetic insulation materials make claims about the role of recycled content in their materials to claim a good environmental performance. They state that they can recycle all recovered material in their factory but never give figures, so it is not too difficult to establish that these claims may be misleading. There are a few synthetic products that are largely made from recycled materials but it is often hard to distinguish these from other products where perhaps only a tiny proportion of the material is from recycled sources.

A manufacturer of sheep's wool insulation claimed on its web site in 2011, that mineral fibre insulation was not recycled and that manufacturers of these products were wrong to claim that this was the case.

"Landfill is not a sustainable option………..
Sheep's wool is biodegradable and therefore can be composted into the ground to enrich the soil and remain part of the earth's natural cycle. Sheep's wool insulation can be recycled or incinerated to produce additional energy, whereas man-made mineral fibre materials currently have no practical recycling system in place and can only be properly disposed of into landfill sites."

(www.**blackmountaininsulation.com**/Wool%20Brochure%20)

A complaint was made about this to the Advertising Standards Authority (ASA) by the *Mineral Wool Insulation Manufacturers Association* (MIMA) but the ASA found in favour of Black Mountain, as MIMA did not provide any solid evidence of recycling.

"The Mineral Wool Insulation Manufacturers Association (MIMA) challenged whether the claim was misleading and could be substantiated, because they understood that mineral wool insulation could be recycled."
"We noted that the MMMF (Man Made Mineral Fibre) manufacturers website MIMA referred to, stated that the manufacturer encouraged the return of their product for recycling where it was in the form of construction off-cuts or reclaimed from refurbishment or demolition work. However, we considered that that statement did not in itself constitute evidence that that particular manufacturer recycled significant quantities of end of life MMMF, nor that there was a generally used system in place for the recycling of significant quantities of end of life MMMF.
We concluded ……….. that there was not a generally used system in place for recycling significant quantities of end of life MMMF"

(http://www.asa.org.uk/ASA-action/Adjudications/2011/5/Black-Mountain-Insulation-Ltd/TF_ADJ_50476.aspx) Viewed 10.11.11)

While site management practices have improved significantly in recent years and waste is separated into different skips to assist recycling, off-cuts rarely end up being recycled.. Despite the existence of WRAP in the UK, (Waste and Resources Action Programme) which was established in 2000, promoting recycling in construction, no robust standards for measuring recycled content have been established. Environmental management standards, which are often quoted, are largely paper tick box exercises.

"The principal limitations to recycling insulation materials is the difficulty of processing the material, particularly in the case of fibre glass and polyurethane foam insulation. For example although the recycling of fibreglass is technically feasible, the practical issues are significant i.e. noxious emissions are produced

*from the organic binder when remelting the fibres. It has also been identified that the lack of sufficient recycling facilities and associated infrastructure are limiting the recycling potential of insulation, although **these criticisms are refuted by the manufacturers.** ”*

(http://www.wrap.org.uk/construction/construction_materials/insulation/insultation_limits.html)

A glass based mineral wool product, produced by Knauf, called ECOSE is marketed as more environmentally friendly than conventional glass fibre. The product is coloured brown rather than the normal yellow or pink as this was thought to make it more environmentally attractive.

“The natural brown colour represents a level of sustainability and handling never achieved:

- *Manufactured from naturally occurring and/or recycled raw materials, and bonded using a bio-based technology free from formaldehyde, phenols, acrylics and with no artificial colours, bleach or dyes added*
- *Contributes to improved indoor air quality compared to our conventional mineral wool*
- *Reduces impact on environment through lower embodied energy*
- *Reduces pollutant manufacturing emissions and workplace exposures*
- *Improving the overall sustainability of buildings in which they are incorporated”*

(http://www.knaufinsulation.co.uk/sustainability/ecose%C2%AE_technology.aspx#ixzz1hjJMcRyr viewed 27.12.11)

What is interesting about Knauf’s marketing is that they admit in the above statement, that their own conventional “mineral wool” may have problems in terms of indoor air quality and is an environmentally less attractive product. They sell a product called “earthwool” which gives the impression to poorly informed people from its name that this is a natural product. They had a product called Earthwool Carbon Zero, that was withdrawn, possibly because the term carbon zero could have been seen as misleading

*www.knaufinsulation.co.uk/.../Datasheet-**Earthwool**-**CarbonZero**.pdf)*

While the product may be based on glass cullet (recycled glass) their normal literature states what the formaldehyde free binder is made of. Formaldehyde is a known carcinogen but it is still found in many building products including some kinds of glass-based insulation. The Health and Safety data sheet was not available on the Knauf web site but it was available on one of their stockists sites. It states that the materials used vitreous fibre (mmvf), alkali and alkaline earth (CaO + MgO + NaO + K2O). Thermo set, inert polymer bonding agent derived from plant starches.

COSHH Earthwool Glass Issue Safety Data Sheet KI_DP_101 – UK (en) Date: 06/05/2010)

The insulation materials that are made from recycled sources such as glass *can* be about 60% 80% based on recycled materials. (though not all are) Environmental analysis of such products has to consider both the source of the material, especially what is not from recycled sources and then the amount of energy and added chemicals that are used. Some recycled products have achieved "Natureplus" certification and are regarded as relatively environmentally benign. *http://www.foamglas.co.uk/building/products/environmental_statement/)*

Deciding whether to use materials based on renewable or recycled materials is complex and subjective. Some natural insulation materials may also include recycled material such as waste wool or recycled wood fibre, but it is important to take into account all the other factors listed in the table when considering material choice.

Resource Consumption

There is little doubt that it is environmentally beneficial to used recycled resources such as waste glass. When we go to the bottle bank we want to believe that this material is going to be used for something and not end up in landfill. However using rock and stone is a different case. The cement and concrete industry sometimes argue that, as the planet is made of rock, so there is plenty to go round! This rather ignores the disruption caused by digging big holes in the ground with massive excavators and explosions, often in environmentally beautiful or sensitive areas! For instance one multi national cement company, Lafarge (originally Redland), wanted to demolish an entire mountain on a Scottish island, creating a "super quarry" *(Harris Super quarry) (http://www.alastairmcintosh.com/articles/2004-ecos-lafarge.htm).* There have been countless environmental campaigns against quarries and while rock may not be regarded as a scarce resource, control of extraction is a key environmental criterion. *(https://earthfirst.org.uk/actionreports/content/rossport-round viewed 24.10.11)*

Rockwool go one stage further than saying there is an unlimited supply of stone by arguing that, as their raw material is volcanic stone, it is almost a renewable material because of regular volcanic eruptions! Rockwool say that "*thanks to volcanic activity 38,000 tonnes of new diabase material is created every year more than they use*," though they don't use this new volcanic material stating that their source is 200 million years old stone in "Ireland." *(http://www.rockwool.co.uk/homeowner/why+stone+wool-c7-)* Rockwool is manufactured (at the time of writing) in Bridgend South Wales from basalt stone quarried at Tully Quarry Ballymena in Northern Ireland and shipped from Belfast to South Wales. This basalt is about 60 million (not 200 million) years old and certainly not as a result of recent volcanic activity.

Quarrying aggregates in Northern Ireland have been a financially attractive option as the Northern Ireland Government waived the EU aggregates levy, thus reducing the price of the material. At present quarries in the province pay 40p per tonne under the Levy exemption, whereas UK mainland producers

have to pay £2.00 per tonne. A legal judgement in 2010 declared that the waiver of this levy was illegal but the matter still hasn't been resolved.
http://www.mqr.info/news/baa-defeats-uk-government-in-eu-court)

The bedrock of the Tully Quarry area is basalt and chalk. The basalt pillars, not far away, form the famous world heritage site of the Giants Causeway.
The issue of resource consumption is a critical factor when sourcing environmentally friendly materials. Very often designers and specifiers are unaware of the source of materials, as their main pre-occupation is with getting the building built.
Bioregional and WWF argue for local sourcing of materials in their "One Planet Living" standard.
"*Using sustainable and healthy products, such as those with low embodied energy, sourced locally, made from renewable or waste resources"*
(http://www.oneplanetliving.org/index.html)

But this can be interpreted as the nearest supplier rather than the actual source of the materials.
One firm of Architects in Cardiff said that they use Rockwool which is a local material from South Wales and thus environmentally acceptable, as it is manufactured in South Wales, but this ignores the fact that the rock has come from Northern Ireland! For this reason local sourcing of materials may not be a very useful environmental criterion unless you can be certain that the raw material source and processing is genuinely local. Standards like "One Planet Living" lack a scientific rigour, as they do not require a full carbon footprint and analysis of embodied energy, so it allows developers and builders to pretend they are being green by making vague assertions about "local sourcing."
If we are serious about safeguarding the planet for future generations we should try to limit the use of non-renewable materials. This is one of the strongest reasons for using bio-based, natural and renewable materials.

Renewable materials – Insulation

Insulation materials made from hemp and sheep's wool are renewable because the hemp can be grown again and the sheep sheared again next year. As most of the natural and renewable materials are quite new to the industry, there is little evidence of the extent of recycling so far, but some natural materials can include recycled material. The issue becomes a little more complicated with wood based products as timber, while being a renewable material, cannot be replaced on an annual basis, as trees take a lot longer to grow. Also some wood fibre products are made from wood waste but this is not so much recycling as using a by-product of another wood processing activity.

In some products, wood fibre and wood chipboards may be made from virgin timber, but with other products they can be made from recovered wood. Often products are made from mixed sources.

Natural and renewable natural materials have a number of advantages over synthetic products such as those discussed above, even if they are made from recycled materials. This is because natural renewable materials generally have a much lower embodied energy; they are significantly better in terms of health and indoor air quality as they are rarely made with any toxic materials.

Similarly they have a much lower pollution risk during manufacture and when disposed of at the end of life. Perhaps most significant of all is the characteristic of plant based materials as having absorbed CO2 during growth which is known as carbon sequestration. (Sheep's wool does not have this advantage as sheep can also be blamed for methane emissions, though this is not as serious as from cattle!)

It is quite possible that some embodied energy databases will show higher levels for some natural products and much lower levels for some synthetic products. This is because very few databases draw on information from original research, but instead reproduce claims made by manufacturers.

For instance the highly respect and much used ICE database from Bath University *(http://www.bath.ac.uk/mech-eng/sert/embodied/)* shows on its summary page Fibreglass/Glasswool at 28 MJ/kg, Mineral Wool at 16.6 MJ/kg and Flax at 39.5 MJ/kg. Anyone looking superficially at this would draw the conclusion that natural insulations have a higher embodied energy than synthetics. First of all this is strange as there are almost no flax insulation products on the market (the only one readily available is a mix of flax and hemp) and yet the ICE database does not list other more common natural products. It is a little hard to understand why a product that involves melting solid rock at over 1500 degrees centigrade uses less energy than a crop based product like flax. In some cases rock wool products are heated using waste incineration, so possibly avoiding a high score for using fossil fuels, but without being able to interrogate the build up of figures in embodied energy databases it is important to remain sceptical about what is published.

Perhaps most significant however, is the very different performance of natural materials when compared with synthetic products. Ironically this is the one criteria most quickly discounted by those hostile to natural materials, as there is a strange assumption that synthetic products will inevitably be more robust and effective. Experience and a growing amount of scientific evidence shows that natural materials can be more robust, long lasting and effective and these issues will be explored in more detail later. Most significant of these is that of dealing with moisture.

You can carry out a simple test at home to investigate this Take a square of sheep's wool or hemp fibre insulation and an identical square of your choice of glass or rock based insulation and soak it in a basin of water. The natural insulation will dry out and recover much more quickly. It should even regain its full "loft" and thus its insulation performance. You will find that some synthetic products will not recover at all and remain a soggy mess. A further factor related to this is that of **breathability and vapour permeability**. A crucial issue in well-insulated buildings is the risk of humidity and condensation. Natural insulations are able to "breathe" and vapour can pass through the material. Rock and glass products can also be regarded as breathable though some of classified as semi-permeable. Other synthetic insulation boards made from polyurethane, polystyrene etc. have very limited ability to breathe and handle moisture.

Finally, natural materials also possess thermal mass and the importance of heat storage and the decrement factor" is also discussed later. The ability to store heat can make a significant difference to improved insulation and thermal performance. Natural materials will vary in this respect quite significantly but all are much better in this respect than synthetic materials which possess almost no heat storage capacity. The following table summarises these issues

Characteristics of Renewable Materials compared with synthetics

Property	Natural Renewable	Synthetic
Energy used in manufacture (Embodied energy)	Usually low but energy is used in processing	Can be high involving melting
Added chemicals	Glues are added but are claimed to be low impact	Some products involve toxic glues, formaldehyde etc.
Robustness	Some natural insulations claim to be highly robust	Some synthetic products are very robust, others can fall apart quite quickly
Ability to handle moisture	Some natural insulations are able to handle moisture very well but some can degrade very quickly if not able to dry out	Most synthetic insulations are unable to absorb moisture but some still fall apart as a result of wetting, others are unaffected
Moisture buffering	Many natural insulations can help to regulate humidity	Most synthetic insulations do not have this ability
Breathability	Most natural materials are breathable and moisture permeable	Some synthetic materials are breathable but most are not
Indoor air quality	Most natural insulations claim to lead to good IAQ, some products like sheep's wool, even absorb formaldehyde	Either neutral or negative on IAQ
Recycling	Limited knowledge of recycling so far but some include recycled and waste materials	Some products are based on recycled resources but very little evidence of the finished product being recycled
End of life disposal and pollution	Natural materials can decay back into the earth	Synthetic materials can be classified as toxic waste
Ozone depletion	No negative effect	Many synthetic products even from recycled sources use chemical blowing agents though some products like forma glass do not
Thermal mass	Most natural materials contain thermal mass, some a great deal which improves thermal performance	Most synthetic materials do not contribute to thermal mass
Durability	Most natural materials are much more durable than is assumed and can survive wetting	Many synthetic materials re not as durable as is assumed though some are much more than others
Acoustic performance	Most natural materials have a superior ability to absorb sound	Some synthetic materials have good sound absorbency but most do not

Renewable Materials

The following natural **renewable materials** are examined. Hemp and Hemp concrete, Flax, Straw and Straw composite boards, Cork, Wood and Bamboo

Hemp and Hemp 'concrete'

Hemp fibre is used to make insulation quilts and boards. Sometimes it is mixed with flax or wood fibre. Hemp is a plant similar to Marijuana or Cannabis but with a minimal drug content. Hemp is widely grown throughout Europe, and many other parts of the world and, it is claimed, has over a 1000 uses. Apart from oil and seed for food production, hemp is used for clothing, automobile interiors and a wide range of bio plastic composites. Hemp is relatively easy to grow but often needs permission from the authorities because of concern about illegal drugs. Hemp is a very strong and tough plant and cannot easily be processed. The fibre has to be stripped from the straw (or shiv). While the fibre is used in insulation, the shiv (the woody core or straw) can be mixed with a lime binder to create a solid but lightweight insulating concrete.

It is quite common to be asked …'why not use' wood chips or miscanthus or jute or any other plant fibre that people can think of. Such questions usually indicate that the questioner has a prejudice against hemp because of its cannabis connection. Experiments using other alternatives have not been very successful as the plant fibres lack the strength and moisture coping capacity of hemp

A wide range of hemp insulation products are available from companies throughout Europe, France, Germany and Poland being the main sources. The growing, processing and manufacturing of hemp for industry is now big business and materials for construction for hemp are only a small part of the market. The European Industrial hemp Association (EIHA) (http://www.eiha-conference.org/) features hemp seed as an anti-ageing dietary supplement to soaps, foods, medical treatments as well as polymer composites, particle boards and shiv for building, car interiors. There is even talk of hemp fibre composites for the interiors of passenger aeroplanes.

As the shiv, the left over straw, once fibre has been extracted, is almost a waste by-product, its use in building construction as hemp concrete, is very important. Mixing the shiv with a lime binder creates an insulating, breathable solid wall system (see Modules 3 and 4). Its remarkable performance throws up a range of challenges for building physicists and scientists. Hemp can be grown in some Northern Periphery areas.

Hemp concrete is a solid but insulating masonry material that is made by mixing hemp shiv with a lime binder. Currently hemp is not grown and processed to any extent in Northern Periphery countries but this may change in the near future. Suitable lime binders for use with hemp come from a variety of sources but are not currently manufactured in Northern Periphery areas though this may change in the near future. There are numerous examples of hemp concrete buildings in NPP countries however.

Flax

Flax is sometimes confused with hemp but is quite different. Flax is used to make linen clothing and is also a food crop (linseed also known as flax seed.) Flax is not as tough as hemp but it can also be used for insulation, though it is often commonly mixed with hemp. Flax boards and other composite products are available but not as common as hemp products. Flax can be grown in some Northern Periphery areas.

Straw, Strawbale and Straw composite boards

The shiv or straw from hemp and flax is referred to above, but generally straw is normally regarded as the waste material from wheat, barley, oats, rice and other cereal crops. Straw can be baled into oblong bales in the field and these can be used in strawbale building. This is often referred to in the UK as hay bales but it makes little sense to use hay for this purpose as it is a food material and may decay more rapidly than straw. Strawbale building can be found all over the world, but particularly in the USA and throughout Europe. (http://www.strawbale-net.eu/.)
Strawbale has largely been seen as a form of construction for self-builders but there are a growing number of buildings built by mainstream building contractors. A strawbale house in France (the Feuillette House) has stood for 90 Years.
(https://sites.google.com/a/compaillons.eu/feuillette-house/)
There numerous organisations promoting and studying strawbales and straw as a building materials (http://www.ecobuildnetwork.org/) (http://thelaststraw.org/)
(http://sustainablesources.com/mailman/listinfo.cgi/gsbn) and considerable knowledge and scientific data is now available. Strawbale building has been incorporated into building codes in some parts of the USA though there seems to be a constant struggle against prejudice about straw. (http://strawbale.sustainablesources.com/) (http://www.dcat.net/resources/index.php)
While the idea of strawbale building has spread widely it seems largely restricted to self-build enthusiasts. It remains a largely fringe activity in Northern Periphery areas through there are many examples in Ireland, Denmark and Scotland, In an effort to produce a more highly engineered strawbale project, the “Modcell” off site system has been developed and is being used for one of the case study projects. This has attracted research funding and a test building has been constructed at Bath University (http://www.bath.ac.uk/features/balehaus/)
Cereal straw can also be combined, as with hemp and wood fibre into boards and panels. Strawboard was very common in the 60s and 70s and was widely used but gained a bad reputation as it was frequently used in situations where it got wet, and could not dry out resulting it rot. De-

spite this many buildings that incorporated "stramit" boards still exist today and in recent years, the manufacture of strawboards has returned. The straw is compressed with heat and bound together by the natural internal resins without added glues. Stramit is essentially a Swedish invention, Stramit is the Swedish word for straw and is manufactured near Gothenberg in Southern Sweden.

Cork

Cork board and insulation is one of the most natural of products, stripped from the *cork* oak (Quercus Suber L) tree in countries like Portugal it can be used for excellent thermal and acoustic insulation. Cork insulation is made with granules of cork that are steam treated so that they bond together using natural resins in the cork. It is used as an alternative to stone wool in some proprietary external insulation systems, even those using other materials that are not particularly environmentally sound. Cork is usually more expensive than stone wool and has become less common in recent years as other renewable and low impact materials have become available. However it is a material with excellent properties and is always worth considering where other materials are not suitable. Cork is imported into Northern Periphery areas and there are also lime and granulated cork render products.

Wood:

Timber is the most familiar renewable material. Responsible forestry should ensure that any timber felled is replaced with replanting …but trees take many years to grow. Forest Stewardship Council (FSC) certification provides some guarantee that responsible forestry practices are being followed but there is a great deal of confusion about FSC certification. Timber sold for building construction is usually referred to as FSC certified but this usually means for an FSC source. Timber suppliers, joinery and timber frame companies, contractors should all have what is known as Chain of Custody certification. Very few have this. PEFC is another certification standard referred to as equivalent to FSC but PEFC is run by the timber industry whereas FSC is independent.
If timber is to be regarded as a renewable material it should be FSC certified and preferably locally sourced. Architects like to use cedar cladding for instance, one of the case studies in this book has used this material. Most supply companies can offer cedar "with FSC" if the client wants it but there is a lot of cedar that is not certified. Cladding using locally sourced FSC Larch or Douglas Fir is generally viewed as more environmentally acceptable.
Because timber is a precious and should be used sparingly. Far too many buildings contain large

amounts of timber that are unnecessary, for instance, large sections for floors and roofs. Composite timber products such as I-beams are much more economical and use poorer quality timber. As demands for greater insulation thickness are made, additional timber is used to create a deeper frame, again wasting timber.

Wood fibre

Wood fibre is the generic term for a wide range of products which include rigid boards, semi-rigid boards and insulation batts. Most people in the construction industry will be familiar with a wide range of composite wood panel products such as MDF, chipboard, wafer board and plywood. These products, while made of wood, depend heavily on formaldehyde and iso-cyanate glues. The negative environmental and health impacts of these glues take such timber products into the realm of synthetic products. Most wood fibre products, on the other hand, should be environmentally benign and are often compressed and glued together with the natural resins in the wood. It is important to distinguish between environmentally friendly wood fibre products and those made with synthetic additives.

There are a wide range of wood fibre products from relatively stiff boards to floppy insulation batts. This range of products can meet many building needs from roof sarking boards, boards that can be rendered and used in external renovation, laid on floors for acoustic separation and as sheathing boards in timber frame construction and so on. In lightweight timber frame construction, wood fibre products have the additional benefit of providing some thermal mass to the build up One manufacturer of wood fibre products claims to use an “ecological glue” made from a modified starch having previously used PVA (Polyvinyl Acetate) . The incoming softwood chips are treated using a thermo mechanical process and the fibre is mixed with water and then dried. No added chemicals are involved other than natural substances such as paraffin and natural starch to improve water resistance. As opposed to most synthetic fibre insulation materials, they contain no carcinogenic formaldehyde. Some companies rely on natural lignin in the wood for bonding though a small amount of bitumen (2%) can be added. Latex for waterproofing is also added to roofing products to provide rain protection during construction. The fibres are pressed using heat from burning wood waste in a plants in the factories.

Wood fibre products could be made in Northern Periphery areas where there is ample resource in terms of virgin and waste wood if there was sufficient investment in building factories.

Solid timber

An interesting new development is the use of cross-laminated solid timber panels (CLT) that are prefabricated and can provide structure for a building. Insulation still needs to be added but this is regarded by some as a valuable use of timber as poorer timber can be used and glued together. Solid wood panels are made in the Northern Periphery area (Northern Sweden).

Because of the concerns about glues an Austrian company Brettstapel has developed a glue free solid timber panel that is held together with dowels.

Conventional timber framing simply uses treated timber studs usually with a sheathing board for racking resistant made of chipboard or some other timber composite board. Timber structurally insulated panels are available but these generally use petrochemical based insulation materials

Low Impact and recycled Materials

Earth

Unfired earth is an important material that can be used in low impact construction. Earth is not a renewable material, as once dug up from the ground it does not grow again! However earth can be returned to the ground without environmental damage in most cases. Unfired earth can be used in rammed earth walls and cob walls (where it is mixed with a small amount of straw) and unfired earth bricks. Unfired earth products and construction methods have a very low embodied energy unless the earth is transported from some distance. Sub soil earth can often be excavated on site as part of normal earth moving for foundations. Earth can also be mixed with hemp and other plant based materials to create blocks etc.

Main forms of Earth construction

Light clay straw/Clay skip
Cob
Rammed Earth
Earth blocks/adobe
Earth plasters

Earth based paints Books on earth construction such as Minke (2000) and Morton (2008) There is also a UK Earth building association, (EBUK). Earth building can be useful as a form of thermal mass in a building, it can also enhance the appearance as earth walls can be beautiful. Earth is also hy-groscopic and can absorb moisture

Lime

Building lime is also an important part of natural and low impact building. Lime can use as much energy to produce as cement and quarrying and burning can contribute to carbon emissions much like cement which is also made from limestone. On the other hand it has many beneficial effects that cement does not have, and lime, once in place in a building, absorbs CO_2 from the atmosphere in a process known as carbonation. As the lime carbonates it gains strength , but it still remains breathable and flexible in walls unlike cement and concrete. Lime has natural waterproofing and biocidal preservative properties so, when used with timber and natural materials it can help to preserve them. If it is necessary to have a breathable wall then lime renders and plasters will assist with the breathability.

Lime has been used for centuries and old lime kilns can be seen in many parts of the UK and other parts of the world. Today there are a wide variety of limes available and it is important to use the correct one for the job, Lime has been kept alive because of the need to use the correct lime in historic building conservation but it has also become much more popular in modern new building and renovation. Lime also provides the basis for many new render systems and insulating plasters. Other lime mixes have been used with hemp though not always successfully as the wrong lime has been used in some cases.
(Holmes S. and Wingate M. Building with Lime ITDG 2002) but there is still a need for a comprehensive book on lime in new building construction.

Information about lime mortars in new build can be found in an NHBC publication Yates and Ferguson 2008

Cellulose – Recycled newsprint and paper

Cellulose insulation is usually made of 80% post-consumer recycled newsprint though some products use other kinds of paper. The cellulose fibre is chemically treated with borate compounds (approximately 20% by weight, though this may vary between products) to resist fire, insects and mould. It is claimed that insulating a 150 square metre house with cellulose will recycle as much newspaper as an individual will consume in 40 years. If all new homes were insulated with cellulose this would remove millions of tonnes of newsprint from waste streams each year that might otherwise end up in land fill. Cellulose insulation has an embodied energy 8 to 10 times less than synthetic fibre insulations it is claimed by manufacturers.
As cellulose fibers are tightly packed, effectively choking wall cavities of combustion air, preventing the spread of fire through framing cavities, cellulose is claimed to be more highly fire resistant than synthetic insulations. This also helps with air tightness.
Cellulose is also claimed to be hygroscopic, breathable and able to buffer humidity however if it gets wet through undetected leaks it can sag within framing cavities. Cellulose will not insulate well if it gets wet. There were also concerns about slumping of the insulation in early days, but manufacturers claim they have solved this problem with products available today
Concerns have been expressed by some environmental organization about the high level of borates in some cellulose products and a debate continues about whether these are harmful to humans. Some products claim to be borate free but still contain 10% or more “additives”. These chemicals used to protect cellulose from fire can also make it potentially corrosive in wet environments and can cause metal fixings, plumbing pipes and electrical wires to corrode if left in contact with wet, treated cellulose insulation for extended periods of time but there are few reports

of problems. Some cellulose products may contain ammonium phosphates rather than borates but this has led to problems where wet walls have led to a release of ammonium gas. *(http://ec.europa.eu/enterprise/tris/pisa/app/search/index.cfm?fuseaction=pisa_notif_oveview&iYear=2013&inum=259&lang=EN&sNLang=EN&CFID=8647679&CFTOKEN=d3b96de2f5aad604-4FD5A13F-9A80-F75F-4336007786012DAA)*

Some countries such as France have banned the use of ammonium salts in cellulose insulation. Sodium phosphate is also used. The Canadian Government has introduced hazardous product regulations for cellulose manufacture but cellulose is still widely used in Canada.

Cellulose is blown into cavities or lofts by specialist contractors. The job is dusty and wearing a mask is required. Borate salts can cause severe eye irritation. Generally the cellulose is dampened and is sticky so that it adheres to timber frames etc. Moisture levels should not be above 30%.

Arguments used against the use of bio based natural materials

Hemp, for instance is equated with bio-fuels and it is suggested that food production will be adversely affected if agriculture is turned over to making insulation. This argument is easily dismissed as hemp is in itself a food crop and is also invaluable when used in rotation with cereal and potato crops, cleaning up the ground. In any case even if all houses in the UK were built from hemp it would only require a relatively small area of land to grow the hemp. Another criticism of hemp is the distance it travels. As there is only one main processing plant in the UK, in Suffolk, hemp does travel quite a distance though smaller processing plants are emerging, in Yorkshire, for instance. The localism criticism is also levelled at wool as some companies have been accused of importing wool from China and New Zealand (in reality a great deal of European wool is exported to China!) Because of the practices of the UK Wool Marketing Board it is hard for sheep's wool insulation manufacturers to say exactly though most of it would be relatively local where their wool comes from. Wool also has to be treated with various chemicals for fire safety and to ward off pests, so this also attracts adverse comments.

The most familiar renewable material is wood and wood based, wood fibre and wood waste products are prominent among the field of natural and renewable materials. However it takes 60 years or so to grow a decent tree, so there is a significant difference between wood as renewable and hemp which is harvested every year. UK government support for biomass heating is also putting at risk all woodland if it is to be chopped down for burning. Some have suggested that to meet UK biomass targets would involve clear felling all UK forest over the next 20 years.

Thus the debate between using synthetic or natural building materials is not a clear black and white issue, as in most things there are shades of grey, however despite economic recession and a slow down in building construction, the production and use of natural and renewable materials has increased over the past ten years. This is because architects, their clients, contractors and developers can see the advantages. Very few professionals are willing to spend their time wading through complex life cycle analyses or environmental assessment reports; they make an intuitive choice that a natural and renewable material is better for the environment than synthetic ones. In this manual we hope to explore this simple choice in greater depth and illustrate with a range of mainstream construction projects where natural and renewable materials have been used.

Despite the apparent simplicity and good sense of reducing the consumption of synthetic materials in order to use less energy, petrochemicals and toxic chemicals, this common sense is sadly not apparent to many people in the construction industry, particularly many of those, discussed below, who campaign for greater energy efficiency.

Cost

There are also many people and organisations that assume that natural and renewable materials must be more expensive and dismiss them out of hand, often without seeking quotations. If synthetic petrochemical products were to pay the real environmental costs of their production then natural and renewable materials would always win on cost grounds. Sadly natural and renewable construction materials are seen as part of a niche market and many companies exploit the fact that some are willing to pay more, however if the consumption of natural and renewable materials grows to the volumes of synthetic material, the unit cost will most certainly reduce.

Assessment and labelling of natural materials

Natural materials are seen as having many environmental benefits over synthetic materials. Changes in green building standards and European regulations are suggesting that many materials may be less acceptable. Progress in regulation has been slow. For instance CFC and HCFC blowing agents were commonplace for synthetic petrochemical based foam insulations but these have been banned due to their green house effect. Substitute blowing agents such as pentane and other chemicals also have environmental risks.

The Living Building Institute in the USA has “Red List” of materials that cannot be used to meet their standards and changes in EU construction product regulations may restrict the use of some products. Various organisations and publications have been drawing attention to the problems of conventional materials for many years and this has had an impact on the market even where there has not been any regulation.

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The NEES training materials consist of the following:

This training manual on the principles of sustainable design and defining and identifying renewable materials and;

6 Vocational Training modules.

Module 1 General Principles of holistic design

Module 2 Housing Construction Methods and principles

Module 3 House Envelope 1 Roofs and Earth construction

Module 4 House Envelope 2 Windows and natural Insulation

Module 5 Certification and accreditation

Module 6 Energy and Water usage

Module 1: General Principles of holistic building and construction design.

1.0 Introduction

1.1 **NEES principles and criteria**

1.2 **Sustainable Materials Principles**

1.3 **Embodied Energy**

1.4 **Carbon Footprint**

1.5 **Natural Materials**

1.6 **Health Issues**

1.7 **Life cycle disposal and durability**

1.8 **Performance and energy efficiency issues**

Module 1 learning outcomes

After completion of this module the learner will be (able to):

1. List and describe the principles of holistic building design.
2. Appreciate the role and importance of embodied energy and carbon in relation to the specification of building products and materials.
3. Familiar with the characteristics of natural and renewable material and their role in construction

Module 2: Housing Construction Methods and principles.

2.0 **Introduction**

2.1 **Conventional Construction**

2.2 **Thermal performance principles**

2.3 **Airtightness**

2.4 **Foundations**

2.5 **Timber frame construction**

2.6 **Engineered timber products**

2.7 **Solid Timber Construction**

2.8 **Hemp-Lime Hempcrete**

Module 2 learning outcomes

After completion of this module the learner will be (able to):

1. Aware of the importance of thermal performance of materials and detailing in relation to low energy buildings.
2. Familiar with a range of low impact construction principles.
3. Familiar with a range of natural and renewable construction materials and their application in the built environment.

Module 3: House envelope 1 Roofs and Earth construction.

3.1 **Green Roofs**

3.2 **Earth Construction**

3.3 **Retrofit Methods and Material**

Module 3 learning outcomes

After completion of this module the learner will be (able to):

1. Familiar with the principles and application of green roofs
2. Familiar with range of low impact construction techniques and materials includ-ing, cob and earth, strawbale and timber frame building techniques.
3. Aware of the principles of retrofit techniques and the technical challenges asso-ciated with low energy retrofitting.
4. Understand the concept of breathability in relation to building materials.

Module 4: House envelope 2 Windows and Natural Insulation

4.1 **Windows**

4.2 **Passive Solar Design**

4.3 **Insulation types**

4.4 **Cellulose**

4.5 **Sheeps Wool**

4.6 **Hemp**

4.7 **Wood Fibre Insulation**

4.8 **IBO Catalogue Data**

4.9 **Comparative case study**

4.10 **Insulation products**

Module 4 learning outcomes

After completion of this module the learner will be (able to):

1. Familiar with the concept of passive solar design.
2. List and describe the properties of a range of natural insulation materials
3. Aware of a range of innovative low impact insulation materials.

Module 5: Certification and accreditation.

5.0 Introduction

5.1 CE marking

5.2 Construction Products Directive (CPD)

5.3 Agrément Certification

5.4 Carbon Offsetting

5.5 Natureplus Certification

5.6 REACH

5.7 COSHH

5.8 Environmental Product Declarations (EPDs)

5.9 Life Cycle Assessment LCA

5.10 ASBP

5.11 LEED

5.12 Living Building Challenge

5.13 Cellulose case study

Module 5 learning outcomes

After completion of this module the learner will be (able to):

1. Familiar with certification and accreditation as it applies to construction products.
2. Understand the role and importance of certification and accreditation in relation to the specification of low impact products and materials for construction projects.

Module 6: Energy and Water Usage

6.0 **Introduction**

6.1 **Energy usage and definitions**

6.2 **Building heat loss**

6.3 **Low energy lighting**

6.4 **Renewable Energy options**

6.5 **Energy Efficient appliances**

6.6 **Water usage and treatment**

Module 6 learning outcomes.

After completion of this module the learner will be (able to):

1. Familiar with the principles of power and energy measurement.
2. Understand the basic principles of building heat loss.
3. Familiar with a range of building energy usage reduction strategies
4. Aware of ways to reduce water usage in buildings.