THE BARRIERS TO THE MAINSTREAMING OF LIME-HEMP: A SYSTEMIC APPROACH

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by

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ABSTRACT

Lime-hemp is a biocomposite made of the mix between the wooden core of the hemp stem and natural hydrated lime. Building with lime-hemp has environmental, economic, and social benefits. Among its features: high carbon sequestration; low toxicity, walls breathability, low embodied energy, good thermal performance, comparable costs to standard building materials and methods, hemp is a valuable new crop for farmers.

Ireland has recently seen a certain number of enthusiasts getting interested in the biocomposite. Few private dwellings have already been built and, following the rise of interest from abroad, more people are trying to look into its potential benefits. Lime-hemp is now in the delicate process of being accepted by the mainstream Irish construction sector.

The assessment of the barriers constraining the widespread take up of lime-hemp in the country is the aim of the present research. It is argued that an approach from a wide point of view is necessary to clearly distinguish all the different issues involved. Six categories of barriers have been identified (technical, commercial, knowledge, regulatory, psychological, and invisible) and a list of issues with their required level of attention (low, medium, high) has been produced.

Apparently the lime-hemp industry is emerging in Ireland. Both supply and demand are existent and about to be linked by the supply chain. The lack of Agrément certification on lime-hemp (regulatory barrier) together with an overall lack of awareness amongst the main stakeholders (knowledge barrier) resulted to be the major constraints.

It is concluded that the role of the Government is of utmost importance for speeding up the wide take up of lime-hemp in Ireland. It would be a win-win-win solution for the overall community, the economy, and the environment. Nonetheless, as long as a systemic perspective is not applied to face issues in general, it will be unlikely for public authorities to correctly perceive reality thus risking to avoid exploiting the opportunities that might arise.

DECLARATION

I certify that this thesis, which I now submit for examination for the award of M.Sc. in Sustainable Development, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for an award in any other Institute or University.

The work reported on in this thesis conforms to the principles and requirements of the Institute's guidelines for ethics in research.

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Signature _____ Date _____

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TABLE OF ABBREVIATIONS AND ACRONYMS

ADAS – Agricultural Development and Advisory Service (UK)

Al_2O_3 – Aluminia

BC – Before Christ

BRE – Building Research Establishment (UK)

$Ca(OH)_2$ – Calcium Hydroxide

$CaCO_3$ – Calcium Carbonate

CaO – Calcium Oxide

CE – Christian Era

cm – Centimetre

CO_2 – Carbon Dioxide

DEA – Drug Enforcement Administration (US)

DEHLG – Department of the Environment Heritage and Local Government (Ireland)

DTI – Department of Trade and Industry (UK)

EC – European Commission

EEC – European Economic Community

EPA – Environment Protection Agency (Ireland)

EU – European Union

Fe_2O_3 – Ferric Oxide

GNP – Gross National Product

ha – Hectare

HLCPA – Hemp Lime Construction Product Association (UK)

IAB – Irish Agrément Board

ICF – Irish Concrete Federation

IUCN – International Union for the Conservation of Nature and Natural Resources

kg – Kilogram

m – Meter

mm – Millimetre

n.e.b – Newly emerged barrier

N/mm2 – Newton per square millimetre

NHL – Natural Hydraulic Lime

RIAI – Royal Institute of Architects of Ireland

SiO_2 – Silica

t/ha – Tonnes per hectare

THC – Δ^9 Tetrahydrocannabinol

UK – United Kingdom

US – United States of America

USSR – Union of Soviet Socialist Republics

W/m^2K – thermal conductivity coefficient

WCED – World Commission on Environment and Development

WISE – Wales Institute for Sustainable Education

WWF – World Wildlife Fund

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CHAPTER ONE: INTRODUCTION

1.0 Introduction

At the dawn of the twenty-first century, the relationship between human society and capacity of the planet to support life is being challenged. The scientific debate is increasingly recognising the evidence that many natural equilibriums which have existed for thousands of years are on the brink of falling apart.

According to the results of the latest Living Planet Report (WWF, 2006), two indexes should be seen as an admonition on the current situation. The 'Living Planet Index' measures the trend in the Earth's biological diversity by tracking a population of more than one thousand vertebrates. It has dropped by 30% since 1970, suggesting that we are degrading the natural ecosystem at a rate unprecedented in human history. The second index, the 'Ecological Human Footprint', specifies the area of biologically productive land and water needed to provide ecological resources and services: food, fibre, timber, land on which to build, and land to absorb carbon dioxide released from burning fossil fuels. Since the late '80s, Earth's footprint has exceeded by 25% the Earth's available capacity to meet humanity's need. Human beings are exploiting the Earth's resources at a faster pace than their natural regeneration cycle.

When population growth, peak oil, global warming, water shortages, declining natural systems and increasing gap between the 'haves' and the 'haves not' are added to the big picture, it becomes very clear what Brown means when he declares (2006, p. 3) that "our global economy is outgrowing the capacity of the Earth to support it, moving our early twenty-first century civilization ever closer to decline and possible collapse".

Every single way in which we presently provide for human needs, starting from those basic, must be re-thought so that it respects the 'rules of the game'. It is becoming more and more apparent that only a systemic approach may be the key to solving humans environmental, social and economic issues. It is therefore important not to try and fix one single issue at a time but consider every human activity in its upstream sources instead of its downstream consequences.

1.1. Background

Housing and shelter in general is one of the basic human needs. Today, in global terms, developed countries use energy and resources to fuel their building industry that is wasteful and way beyond the ability of the planet to support such wasteful consumption. Mass materials like cement and concrete cause significant pollution; use a lot of energy and non-renewable resources.

It has been almost forty years now since some enthusiastic individuals started to observe and integrate indigenous and low impact construction techniques into modern design standards of comfort, health, safety and durability. Today a growing number of professionals and ordinary people are realizing that organic materials such as wood, wool and other fibres, and earth materials such as clay and lime, can benefit both human health and, at the same time, the environment.

Hemp, a crop that has been at the base of human activities for thousands of years providing food, shelter, oil, textile fibres, paper and hundreds of other uses, has been recently rediscovered. In the construction industry in particular, it is proving to be an ideal material when mixed with lime forming a biocomposite. Among the main interesting properties of lime-hemp there are high insulation, breathability, low toxicity, carbon sequestration and low embodied energy.

Europe is leading the way in the discovery of lime-hemp biocomposite as construction material and building method. In France lime-hemp construction is today common and has already been used in hundreds of new buildings. The UK has recently carried out research, both private and academic, in order to test the claimed benefits of lime-hemp and, after a few pilot projects, the ‘new’ construction material is now available on the market for those interested.

Ireland has seen a certain number of ‘eco-enthusiasts’ getting involved in lime-hemp. Few private dwellings have already been built and, following the rise of interest from abroad, more people are trying to look into its potential benefits. Lime-hemp is now in the delicate process of being accepted by the mainstream Irish construction sector.

1.2 Objective

Like in every innovation, there is a certain set of barriers for the 'new' to be taken up and accepted by the 'status-quo'. In the case of lime-hemp the situation is made more difficult by the particular conservative attitude of the Irish construction industry. Moreover, being made up of a mix between an agricultural crop (hemp) and an earth derived material (lime), as well as involving many different kinds of issues, it requires an approach from a higher viewpoint to be completely understood.

The aim of the present work is therefore to explore and understand what the existent barriers to the mainstreaming of lime-hemp in Ireland are. Six main categories of barriers have been initially identified, namely technical, commercial, regulatory, knowledge, psychological and invisible. The approach, even if it could seem too broad, is indeed needed in order to completely understand the overall background where this sustainable construction material is placed. Only a similar comprehensive view would help the interested stakeholders to know where to act for facilitating the take up of lime-hemp in the Irish building reality.

1.3 Methodology

The methodology applied to the research work consists primarily in the use of in-depth interviews. Six key individuals were carefully selected in order to shed light on the various categories of identified barriers. It was believed that only persons with an established knowledge of lime-hemp and the issues directly linked to it would be able to provide useful insights.

In addition two sets of questionnaires were handed out to a sample of architects and consumers in order to primarily assess their awareness and perceptions about the biocomposite. The use of in-depth interviews would not have been appropriate for this purpose.

1.4. Conclusion

A complete list of barriers for each category (technical, commercial, regulatory, knowledge, psychological and invisible) has emerged. Each barrier has been given a priority level (low, medium, and high) according to the attention it requires. A certain number of interesting key findings surfaced from the research. The stakeholders with interests in the mainstreaming of lime-hemp would certainly find both the results and the discussion chapters valuable.

CHAPTER TWO: LITERATURE REVIEW

2.0. Introduction

The existing literature is reviewed in this chapter with the aim of providing a background for the following research. The chapter consist of six parts. The first part deals with the definition of sustainability, the second gives an overview of the relation between construction industry and sustainability, and the third introduces the concept of natural building. The fourth and fifth parts provide a background on hemp and lime as separate concepts. The last part deals with lime-hemp as a construction material and building method.

2.1. Sustainable development and sustainability principles

Sustainable development, sustainable life-styles, eco-sustainability, sustainability are today some of the most overused terms. Sustainable development, in the mainstream current, is defined in the report ‘Our Common Future’ by the Brundtland Commission (WCED, 1987) as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Another common definition describes sustainability as the commitment to improving the quality of human life while living within the carrying capacity of supporting ecosystems (IUCN et all, 1991).

These definitions provide an overall idea of what sustainability means. They could be misinterpreted and, being the concept extremely broad, they do not suggest any practical framework than can be usefully applied for reaching its aims. As a consequence few people really understand their actual meaning, what it takes to achieve sustainability and, most important, what are the effective strategies to plan for it.

2.1.1. ‘The Natural Step’ approach

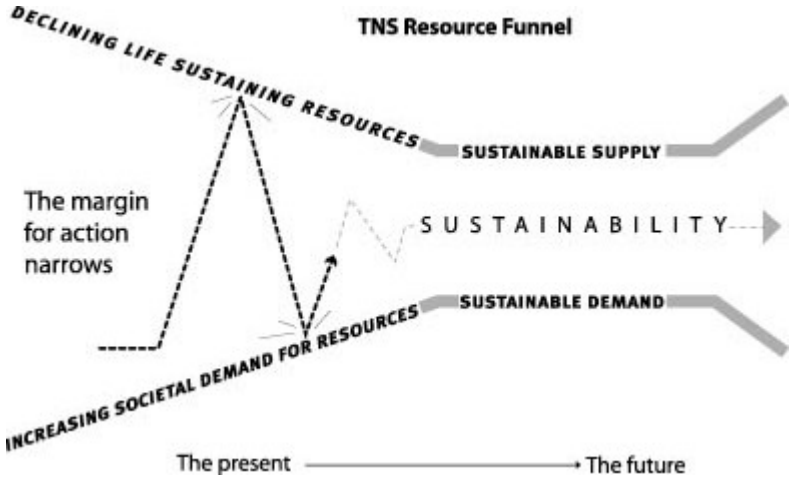
A comprehensive approach to sustainability comes from ‘The Natural Step’. The international no-profit organisation was born in Sweden in 1989 from a consensus process initiated by Karl-Henrik Robèrt, a major Swedish oncologist. At the time, he

noticed a significant rise in the leukaemia rates amongst children and he associated their cause with the increasing presence of toxins coming out of human production processes.

With the help of fifty scientists Robèrt wrote, for the first time in the history of science, a document describing the basic knowledge on the functions of the planet and on how human beings interact with it. The initial document passed through twenty-one revisions in a consensus process that lasted two years and, with the support of the Government and the King of Sweden, it was finally sent to all the Swedish households and schools. Today the process, still under continuous development, is supported by politicians and entrepreneurs. The Natural Step has offices in twelve countries around the world and has created a network of hundreds of scientists in tens of research centres. More than a hundred public local governments and more than seventy multinationals private organisations are using The Natural Step approach to sustainability (James and Lahti, 2004).

Instead of defining what sustainability is, The Natural Step tried to give a definition to the opposite, un-sustainability: that is the inability of a certain system (human society in the biosphere) to keep on carrying on its own functions. The current situation of societies on the planet could be metaphorically compared to the idea of a funnel (Figure 2.1), where its walls represent the decreasing resources on one side and the increasing overall demand on the other. As time passes, the windows of opportunity steadily reduce in size and so does the freedom of choices in the number of possible actions that can be performed. The cause of such situation can be identified in the systematic destruction and systematic decline of resources that allow human species to survive and that assure the existence of life on the planet: clean air, clean water, fertile soil are all declining. Simultaneously the demand of such resources from society is increasingly rising (Robèrt, 2002).

Figure 2.1 – The Natural Step representation of the Funnel



Source: http://www.naturalstep.ca/thefunnel.html

2.1.2. 'The Natural Step' principles

Out of the above mentioned scenario, a set of four principles can be extracted. Once again the starting point is the negation of the necessary conditions for a system to get destroyed. Considering that our planet is indeed a closed system with the exception of the energy entering from the sun, and remembering that according to the second law of the thermodynamic nothing disappears but everything dispels (Robèrt, 2002); it is possible to extrapolate four necessary and sufficient conditions for our society to continue supporting life.

1. *In the sustainable society, nature is not subject to systematically increasing concentrations of substances extracted from the Earth's crust.*

Substances including heavy metals, such as cadmium, lead, mercury, minerals such as phosphorus, and fossil fuels are mined and brought into use by our society. These substances and their emissions, such as carbon dioxide and nitrogen oxide created by burning of fossil fuels, have been steadily accumulating both in human society and nature at levels far greater than their natural occurrences. These metals and minerals cannot break down any further and many of them are already known to be toxic.

2. *In the sustainable society, nature is not subject to systematically increasing concentration of substances produced by society.*

Human society also has been manufacturing synthetic substances, chemicals and other compounds that do not occur in nature, faster than these materials can be broken down. Many of these materials are persistent, meaning they do not break down easily or quickly, and they can spread far from their places of origin.

3. *In the sustainable society, nature is not subject to systematically increasing degradation by physical means.*

Human activity also is breaking down natural systems, land, water, forests, soil, ecosystems, by depletion and destruction faster than these natural systems can renew themselves.

4. *And, in the sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.*

If people around the world cannot meet their basic human needs, the first three system conditions will not be met. The control of 80% of the world's wealth and resources by 20% of the population is an unstable condition that can lead, if it is not already leading, to social unrest and conflict. This inequality will continually undermine achievements toward the first three conditions.

2.2. Construction industry & sustainability issues

The construction sector in western societies is all but sustainable. With the exception of a minuscule niche, the building activity violates every single sustainability principle mentioned above. The majority of raw materials and energy used are made of substances systematically extracted from the Earth's crust. Cement as the most used building material, and oil as the main energy source are the best examples. Nearly all the materials used in any kind of building are man made and unknown to the natural cycles: plastic, synthetic insulation, and finishes containing toxic chemicals are just a few of the numerous cases confirming the idea. Most of the new urban and sub-urban developments are built on green fields, therefore degrading nature by physical means

and hence avoiding fertile land to be used for food production as well as reducing biodiversity. Finally the provision of affordable housing, today often forgotten or left aside on new developments, further on reduces people's capacity to meet one of the most important basic needs.

2.2.1. Mass balance of the UK construction industry

The 'Construction Industry Mass Balance' study in the UK, has for the first time identified and quantified the natural resources used, as well as the wastes and emissions produced by the industry during 1998 (Smith et al., 2003). The study confirmed there is a lack of strategic understanding of the impact of the construction industry on natural resource and the environment. In adding 275 million tonnes to its stock, there was a total requirement for over 420 million tonnes of material resources, of which only 360 million tonnes were incorporated into construction products, the rest becoming waste.

Energy equivalent to just less than 8 million tonnes of oil were used in the manufacture of products and the transport of products and waste. The largest consumer of energy is product manufacture, followed by the transport of materials and products accounting for 50% and 20% of energy use respectively.

The total mass of all solid waste from the construction industry in 1998 was estimated to be over 150 million tonnes. 40% of these wastes were from product manufacture and 60% were from construction and demolition activity. Quarry wastes were by far the largest component of product manufacturing wastes accounting for nearly 97% of these.

Emissions to the air by the construction industry in 1998 totalled just over 30 million tonnes of which over 97% were carbon dioxide. If, however, some of the other emissions are calculated in terms of their global warming potential, this figure rises very dramatically to over 500 million tonnes of carbon dioxide equivalent (Smith, et al., 2003).

2.2.2. Irish construction industry

Unfortunately there has never been such a comprehensive overview on the overall impacts of the Irish construction industry. Nonetheless it is not difficult to guess there certainly are similarities with the British reality. Considering the massive weight of the construction industry in the overall Irish economy, its impact definitely requires the maximum attention.

According to the latest review of the Irish construction industry (DEHLG, 2007), the Irish economy has been relying heavily on the construction sector during the recent years and, in 2006, this accounted for € 35.5 billion equal to almost 24% of the GNP. The overall construction output has been steadily increasing for the past fourteen years up to 2006 when the number of new dwellings peaked at 88,219 units. Even if the volume is forecasted to decrease to 60,000 units per annum in 2008 and 2009, the overall impact of the industry will remain severe.

In Ireland, cement manufacture is currently the second largest industrial source of carbon dioxide and nitrogen oxide emissions, after the generation of electrical power from fossil fuels. Almost one tonne of carbon dioxide is generated in the manufacture of one tonne of Portland cement, along with 2kg of sulphur dioxide, 3.5kg of nitrogen oxide and 2kg of carbon oxide (Seymour, 2005). These are astonishing figures considering that the Irish construction industry uses 15 million cubic metres of concrete every year, yielding emissions of 5 million tonnes of carbon dioxide. Almost the entirety of these emissions, i.e. 90%, arises in the production of the cement used by the concrete industry (Kinsella, 2007).

Fortunately the recent years have seen the debate on the sustainability of the Irish construction sector steadily grow. Interest in sustainable construction, both from individuals and businesses in the private and the public sector has grown rapidly. Even if the ability of the industry to respond to this interest is under developed, association like *Easca* (Environmental and Sustainable Construction Association) and magazines like *Construct Ireland* are leading the way in promoting the viability of sustainable construction in Ireland.

2.2.3. Construction industry and 'green-washing' attitude

A preoccupying aspect of the construction industry's approach to sustainability lies in its cosmetic 'green-washing' attitude. Most of the literature on sustainable building is concerned with justifying the continuation of conventional construction methods (Woolley, 2004). Better energy efficiency, construction management, less wastage, and the inclusion of new technologies are coped with by suggesting only superficial changes

This kind of approach is backed up by a number of environmental assessment tools and standards that are designed as much to improve the image of the construction industry, as they are to ensure real sustainability (Woolley, 2004). The superficial changes that result from these kind of measures are usually justified on the basis that the construction industry is only willing to make light adaptations to the current state because it would take much longer to completely renovate. Doing a little is seen as better than doing nothing. Hence, the debate in wealthy northern countries is often only of resource efficiency, instead of resource depletion (DTI, 2004).

2.3. Natural Building

'Natural building' is a promising reaction to the mentioned 'green-washing' approach to sustainable construction. It consists in looking for alternative methods of construction which significantly reduce resource consumption, provide energy efficiency without causing pollution, damaging health and eco-systems. Natural building represents attempts, particularly in rich developed countries, to substitute a much lower impact technology for that which is currently used (Kennedy, J.K. et al., 2002 & Elizabeth and Adams, 2000). Its aim is to use materials and technologies which minimise the depletion of planetary resources and thus to reduce or eliminate dangerous and damaging materials such as cement and toxic chemicals.

This would play a key role in bringing construction in compliance with the four sustainability principles already mentioned. Natural building in fact, if managed in respect of those principles, could easily be taken as an example of sustainable development. Buildings are the most visible and tangible sign of economic development

anywhere in the world; ‘natural’ speaks for itself, indicating the use of materials and processes that are compatible with the functions of the natural world.

2.3.1. Past and present in Natural Building

Natural building began with the work of enthusiast individuals who spent decades in understanding indigenous and low impact construction techniques, and in integrating these historic concepts into modern design standards of comfort, health, safety and durability (Elizabeth and Adams, 2000). It is important when adopting this approach to develop forms of construction, which are as good as, if not better than conventional building (Wolley, 2004).

Traditional and vernacular architecture is a source of inspiration for natural building. For this reason many people still view some of these techniques as ‘turning the clock back’ (Wolley, 2006). Humans have evolved to live in contact with organic materials such as wood, wool and other fibres, and earth materials such as clay and lime. We can only benefit from them especially when employed to create shelter, which is where we spend most of our existence. Today’s natural building involves applying the knowledge and skills developed over the years, as well as by taking advantage of new technologies, thus leading to a better quality of life. It consists in the opposite of reducing existing standards or returning back to the past. Table 2.1 clearly compares the conventional and natural building approaches.

Table 2.1 – Comparison between conventional and natural building approach

CONVENTIONAL BUILDING	NATURAL BUILDING
Uses non-renewable resources and materials	Uses renewable materials which can be grown and provide cash to farmers
Uses a lot of energy in extraction - high embodied energy	Uses materials which need little energy to extract
Significant transportation costs	Should use local materials
Extraction is often damaging and causes social problems	Uses materials such as clay which is of low impact
Many metals and other polluting materials are extracted and refined in poor countries and shipped to rich	Materials are extracted and processed locally
Significant energy and chemicals are used to create energy efficient solutions	Generally little energy used
External air pollution caused by manufacturing processes	Virtually no external pollution
Internal pollution due to the use of toxic additives like solvents	Natural materials rarely cause health problems if handled properly and are not treated with toxic fire retardants, etc.
Waste manufacturing and installation is a normal part of processes	Little waste if care is taken
Damage to eco systems at end of life disposal	End of life can be recycled or returned to the earth and decompose naturally

Source: Woolley, 2004

It is believed, by many people and professionals, that using green materials or technology is much more expensive than those standard. Oppositely, as confirmed by Wolley (2004), the aim of the natural building movement is for such materials to be as economical, if not cheaper than conventional, to be of a high standard and have a very good life cycle performance.

Natural building is still at a pioneering stage and it still requires many more efforts to demonstrate that the methods and materials used are going to be problem free, will be durable and meet the regulations. There is indeed a need for scientific research and changes in official regulation and standards. Another interesting aspect of natural building is its ability to be more attractive, create more beautiful and harmonious buildings, and generally to make its occupants feel better.

In recent years there has been a growing interest in the relation between health and buildings. The emergence of the 'Sick Building Syndrome' and the increase in such health problems as allergies, medical hypersensitivity, and asthma have added urgency

to the debate (Harris & Borer, 2005). The natural building movement can only benefit from this and attract the attention of the public opinion.

Given the choice between a ‘cheap’ synthetic material, product or method of building and a natural one, people are generally aware that the natural option is better. There may be awareness of the scientific and environmental reasons but not always an understanding of the technical detail. Intuition leads to the natural alternative. Unfortunately the building industry is still very conservative and customers interested in using materials and methods often get plenty of hostile advices. Professionals themselves tend to stay away from building techniques that are not covered by a standard, an Agrément certificate, warranties and indemnity insurance (Wolley, 2006).

2.4. Hemp

The present work tries to analyse the barriers to the mainstreaming of lime-hemp, a particular building material and construction method that can definitely be classified among the ‘natural building’ category. It is therefore necessary to provide the reader with an overview on what its core components are as well as their own singular properties.

2.4.1. Introduction

‘Hemp’ refers primarily to *Cannabis sativa* L., Cannabaceae family, although the term has been applied to dozens of species representing at least 22 genera, often prominent fibre crops (Small and Marcus, 2002). There are many pseudonyms for hemp, throughout history and in different languages. Hemp is a term that has also been used casually to describe other fibre plants such as Manila hemp and Sunn hemp. This can and has lead to confusion both within and outside the academic community (Young, 2005).

Cannabis sativa is a multi-purpose plant that has been domesticated for bast fibre in the stem, a multi-purpose fixed oil in the seeds, and an intoxicating resin secreted by epidermal glands. The common names hemp and marijuana have been applied loosely to all three forms, although historically hemp has been used primarily for the fibre

cultigen and its fibre preparations, and marijuana for the drug cultigen and its drug preparations. The current hemp industry is making great efforts to point out that "hemp is not marijuana."

Italicized, *Cannabis* refers to the biological name of the plant *Cannabis sativa* L., since only one species of this genus is commonly recognized. Non-italicized, 'cannabis' is a generic abstraction, widely used as a noun and adjective, and commonly – often loosely – used both for cannabis plants and/or any or all of the intoxicant preparations made from them (Small and Marcus, 2002).

2.4.2. History of hemp in the world

Archaeological evidence from a relic found in Taiwan places cultivation of hemp as early as 10000 BC (Robinson, 1996). Hemp was harvested by the Chinese 8500 years ago (Schultes and Hofmann, 1980). For most of its history, *Cannabis sativa* was most valued as a fibre source, considerably less so as an intoxicant, and only to a limited extent as an oilseed crop. Hemp is one of the oldest sources of textile fibre, with existing remains of hempen cloth trailing back six millennia. Hemp grown for fibre was introduced to western Asia and Egypt, and subsequently to Europe somewhere between 1000 and 2000 BC.

Cultivation in Europe became widespread after 500 CE. As with other Asian commodities like spices, hemp came to Europe along traditional trade routes. One of the oldest examples of hemp textiles in Europe was found around 400 BC in Germany (Roulac, 1997). At this time hemp was cultivated in central Europe and was spreading. The Spanish Moors introduced Europe to the art of hemp papermaking by building the first European paper mill in 1150 CE (Roulac, 1997). The next 500 years in Europe were a period where paper making was perfected and utilized hemp as the main source of raw material. Renaissance paintings were painted on hemp cannabis, hence the term canvas, and hemp oil based paints were often used (Gibson, 2006).

The crop was first brought to South America in 1545, in Chile, and to North America in Port Royal, Acadia in 1606 (Small and Marcus, 2002). The 16th to 18th centuries saw hemp and flax dominate fibre crops in Asia, Europe and North America. At this point in

time, hemp was used, almost universally, for ship sails and ropes. It was a highly valuable and necessary material for the shipping/trading industry colonizing the new world, as well as for military purposes (Roulac, 1997). Until the beginning of the 19th century, hemp was the leading cordage fibre. Up to the middle of the 19th century, hemp rivalled flax as the chief textile fibre of vegetable origin, and indeed was described as "the king of fibre-bearing plants; the standard by which all other fibres are measured" (Boyce, 1900). By the 20th century advances in technology, such as the steam and petroleum fuelled engines, made the largest demand for hemp in shipping decline. Hemp remained a labour intensive crop, due in large part to the dew retting procedure and lack of a mechanized method for harvesting (Roulac, 1997). Hemp became unable to compete economically with cotton, due to the invention of the cotton gin (Roulac, 1997) until which point in time, hemp had been the most common textile fibre.

In 1937, the American Government passed the Marihuana Tax Act which outlawed and criminalized marijuana, the variety of *Cannabis sativa*, which is high in the psychoactive ingredient Δ9-tetrahydrocannabinol (THC) (Roulac, 1997). Hemp was associated with marijuana and its cultivation eventually fell under the US Drug Enforcement Administration (DEA) (Roulac, 1997). It was technically not illegal to grow hemp under the new tax act but it did require a license from the DEA and the red tape surrounding its cultivation became so cumbersome that most farmers stopped growing it (Roulac, 1997). Canada quickly followed the American lead and outlawed *Cannabis sativa* in its 1938 Opium and Narcotics Control Act (Blade *et al*., 1999). According to Wool and Khot (2001), the US DEA stopped granting hemp licenses in 1958. Many European and colonial nations also made hemp cultivation illegal after World War II (Merfield, 1999).

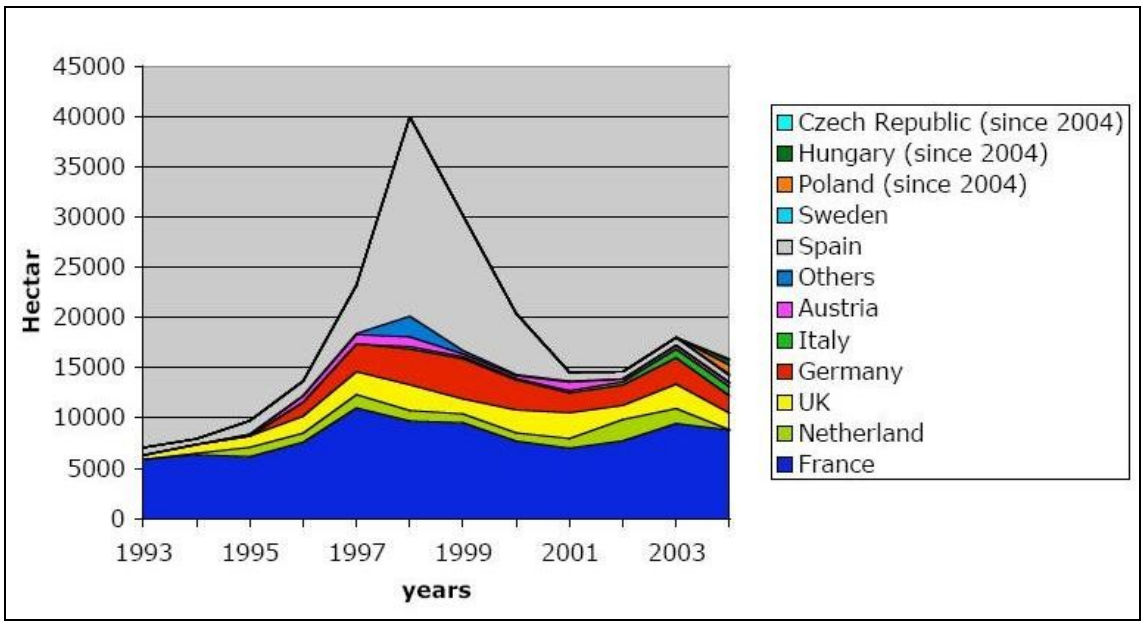
In more recent history, the prohibition surrounding hemp cultivation has been lifted in all developed nations with the exception of the USA. It remains, however, a ban on the consumption of hemp food products in New Zealand and Australia. Two major reasons are behind the elimination of hemp prohibition in developed countries. The first is environmentally driven, fuelled by unsustainable agricultural practices, non-renewable resource use and depletion resulting in a renewed interest in renewable resources. The second reason lies in agricultural demand. Food crop prices in Europe have been falling

along with subsidies due to an over production of food (Harris, 2002; Ranalli & Venturi, 2004). The need for alternate sources of fibre is also becoming apparent (Roulac, 1997; Ranalli & Venturi, 2004). As well the demand for natural products has grown in developed countries alongside ecological agriculture initiatives. This cumulates in farmers searching for viable alternative crops that can be used in combination with crops for rotational purposes.

2.4.3. Increased interest for hemp in the EU

In 1970 the European Community adopted a regulation for the organization of the flax and hemp markets due in part to an over production of food in the Community and an underproduction of flax and hemp (Council Regulation (EEC) 1308, 1970). However, due to national prohibition legislation, hemp cultivation in Europe was limited almost exclusively to France during the ‘80s and 90’s. With the renewed interest in hemp and an increase in its cultivation, the European hemp industry saw its volume raise threefold since the early 1990’s (Karus, 2005). At the same time the EU hemp production subsidies began to decrease (Karus, 2005). In order to have access to these subsidies farmers had to abide to certain restrictions, which changed over time as the industry grew and the political climate changed. The most recent and relevant conditions are that the hemp cultivar used must come from certified seed from the EU’s approved list containing less then 0.2% by weight of THC and harvest must occur at the end of the flowering period (Council Regulation (EC) 953, 2006). France, Britain and the Netherlands are involved in an EU supported hemp breeding program aimed at completely eliminate the THC content from industrial hemp varieties (Matthews, 1999).

Figure 2.2 – Areas under hemp cultivation in the EU between 1993 and 2004



Source: Karus, 2005

Figure 2.2 shows the threefold increase in the cultivation of hemp in Europe. In 2004, the cultivated area in the EU amounted to approx. 16,000 ha. The high volume of hemp production in France is explained by the fact that its cultivation was never prohibited in the country and it is therefore long established.

Apart from the peak in Spain in the years 1997-1999, the areas under hemp cultivation have remained relatively constant in recent years. The peak is no such in fact: hemp cultivation in Spain primarily was a matter of subsidy swindle. The straw was harvested and processed to merely a small extent in reality, the subsidy funds have been subsequently paid back to Brussels (Karus, 2005). Before the collapse of the USSR, the areas under hemp cultivation in Eastern Europe alone had amounted to almost 100,000 ha; the cultivation in Romania, Hungary, Bulgaria, Poland and the Czech Republic was of special importance. Not much of that is left nowadays. With the incorporation of new member countries in 2004, three new hemp cultivation countries entered the EU: Poland, Hungary and the Czech Republic with an overall production of about 1,500 ha. In the other Eastern European (non-EU) countries, the total area under cultivation today amounts to less than 3,000 ha (Karus, 2005).

2.4.4. History of hemp in Ireland

Hemp was grown in Ireland during the 18th century, but no commercial enterprise was ever established (Neenan, 1969). Some hemp was grown during the 1938-45 period for bird seed. The first scientific evaluation of hemp took place from 1960-66, using the varieties 'Fibrimon' 21, 24 and 56. Stem yields of 10 t/ha and fibre yields of 2.5 t/ha were achieved. The quality of yarns and twines produced were shown to be slightly inferior to British Standard specifications. It was concluded that, at the prices then prevailing, hemp could not be regarded as an economic source of raw material for paper manufacture (Neenan, 1969).

As with most European countries, the search for alternative non-food crops has been underway in Ireland since the late 1980's. The high yields and long list of possible industrial uses for hemp prompted a limited re-examination of the crop in Ireland starting in 1995 (Crowley J. & Rice B., 1998). Two objectives were set in this re-evaluation: (a) to establish the yield potential of the low-THC varieties and (b) to identify possible domestic end-users. With no paper industry in Ireland, two optional uses for the whole unprocessed stem were considered: burning to generate energy, and fibre board manufacture.

From 1996 to 1998 Teagasc, the Irish Agriculture and Food Development Authority, grew *Cannabis sativa* in order to verify the above mentioned objectives. The report concluded that hemp can produce high yields of stem material, (10-14 t/ha) for processing. The crop can be produced on any arable mineral soil and without the aid of agrochemicals. Sowing in early to mid-April ensures maximum yields, and seed rate can be reduced significantly, where fibre quality is not a priority. The report also stated that the development of harvesting and storage techniques were required before commercial development could take place (Crowley, 2001).

2.4.5. Botany

Cannabis Sativa is an annual herbaceous plant and it is wind pollinated. It is normally dioecious, meaning that it has distinct male (staminate) and female (pistillate) plants.

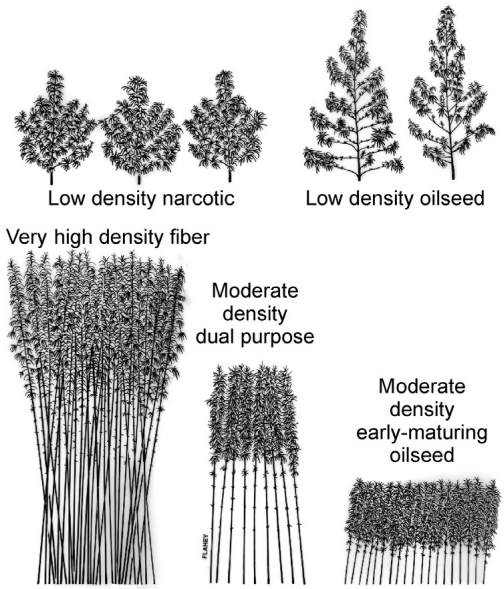
Female plants have generally a higher economic value and they take slightly longer to mature because of the extended flowering cycle (Bocsa & Karus, 1998).

The root is a laterally branched taproot, generally 30–60 cm deep, up to 2.5 m in loose soils, very near the surface and more branched in wet soils (Small & Marcus, 2002). Bocsa & Karus (1998) confirm that the root can reach a depth of 2-3 m as long as it is not obstructed by the water table or by a hard layer of soil. The extensive root systems are key to the ability of hemp crops to exploit deep supplies of nutrients and water.

The stems are vertical, furrowed, and usually branched, with a woody interior, and may be hollow in the internodes (Small & Marcus, 2002). Although the stem is often woody, the species is frequently referred to as a herb. Plants vary enormously in height depending on genetic constitution and environment, but are typically 1–5 m. Commercially, since it contains the bast fibre, the stem is the most important part of the plant, and much care is given both to its growth and knowledge of its structure (Gibson, 2006).

There is great variation in *Cannabis sativa*, because of disruptive domestication for fibre, oilseed, and narcotic resin, and there are features that tend to distinguish these three cultivars from each other. Moreover, density of cultivation is used to accentuate certain architectural features like height and branching. Figure 2.3 illustrates the different appearances of the basic categories of *Cannabis* in typical field configurations.

Figure 2.3 - Typical architecture of categories of cultivated Cannabis sativa



Source: Small and Marcus, 2002

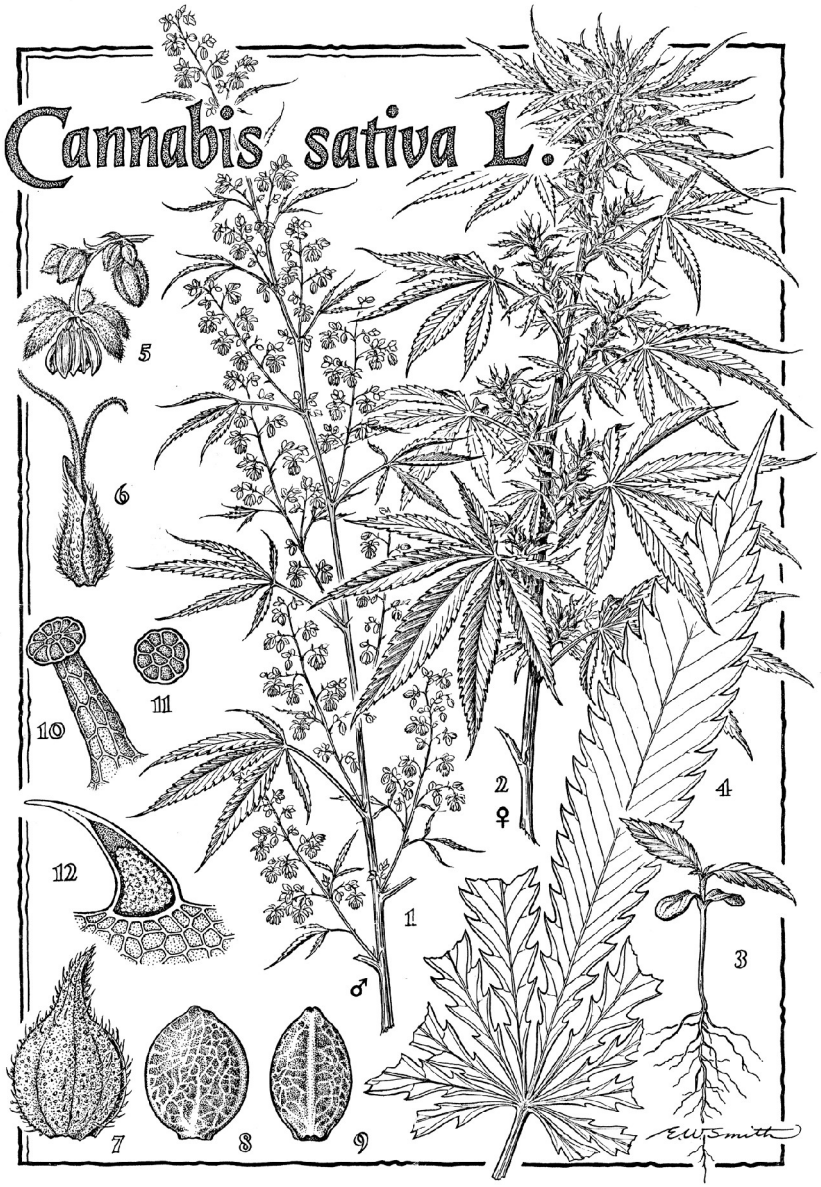
Mediavilla *et al.* (1998) divided the life cycle of hemp into four main growth stages. The first stage consists in germination and emergence. The second, also called vegetative stage, is when most of the plants growth takes place. The third stage is when flowering and seed formation occur. The fourth stage is senescence and is recognised by the dropping of leaves and drying out of the stem.

The first stage of germination and emergence can take place in about one week for hemp cultivars sown outdoors in early spring provided the right conditions are present (Clarke, 1999). During the second or vegetative stage the plants can reach heights of up to 5 m in 4-6 months under optimal conditions (Clarke, 1999). During the longest days of summer with favourable conditions the plant can grow up to 10 cm/day (Clarke, 1999). However, for temperate climates average heights are around 2-3 m. The stem can be from 4 to 20 mm in diameter (Lewin & Pearce, 1998).

The beginning of the third growth stage is indicated by the leaves changing from opposing to alternate position along the stem, and the emersion of the sexual organs (Mediavilla *et al.*, 1998). Figure 2.4 shows an illustration of *Cannabis sativa* L. differentiating the male and female attributes. The female flowers are fertilized from wind blown male pollen and the female plants develop seed which matures after 3 to 6 weeks (Clarke, 1999).

Figure 2.4 - Cannabis sativa L.

1. Flowering branch of male plant. 2. Flowering branch of female plant. 3. Seedling. 4. Leaflet. 5. Cluster of male flowers. 6. Female flower, enclosed by perigonal bract. 7. Mature fruit enclosed in perigonal bract. 8. Seed (achene), showing wide face. 9. Seed, showing narrow face. 10. Stalked secretory gland. 11.Top of sessile secretory gland. 12. Long section of cystolith hair (note calcium carbonate concretion at base)



Source: Small and Marcus, 2002

The fourth and last growth stage occurs at different times depending on the sex and if fertilization has occurred. The male plants begin senescence after the pollen is shed. Whereas the female plants mature for another 3 - 6 weeks if fertilized or 5 months if unfertilized before senescence begins. During this last stage, the leaves fall off first, then the stem starts to dry. Frost in some temperate areas can initiate bast fibre separation from the core (Mediavilla *et al*., 1998).

Modern industrial hemp cultivation, through European breeding programs, have selected monoecious cultivars to contain a higher ratio of female than male flowers on the same plant (Blade *et al*., 1999). The aim is to reduce the sexual dimorphism of the crop in order to optimize the growth and production of the economically valuable female plants. The female plants produce the seed which matures after the male plants have already entered the fourth growth stage or senescence leading to a loss of male fibre.

2.4.6. Agronomy

Industrial hemp can be grown on a wide variety of soil types, but it does best on loose, well-drained loam soils with high fertility and abundant organic matter (Van der Werf, 1991; Girouard *et al*., 1998). It is extremely sensitive to flooding and compaction as well as heavy soils. Good soil drainage is therefore important to maximize hemp production. Sandy soils will grow good hemp only when adequate irrigation and fertilization are provided, but doing so generally makes production not profitable (Small & Marcus, 2002).

Hemp is well adapted to temperate zones and it will grow under a wide range of environmental conditions. The temperature range for optimal growth is between 19° and 25°C, while precipitation between 500 and 700mm, with 250 and 300mm necessary during the vegetative period (Bocsa & Karus, 1998). According to Wynn (1998) hemp grows best when mean daily temperatures range from 14 to 27°C but can stand colder or warmer conditions. When mature, hemp can endure temperatures down to -6°C, but younger plants are too sensitive for these conditions (Van der Werf, 1991).

Hemp is one of the most tolerant crops to dry conditions but it is also a crop that has a good response to irrigation, particularly important when producing seeds. 30 to 80 mm of efficient water supply is sufficient in most cases to ensure a good yield in grain (Bocsa & Karus, 1998). Hemp resists well to drought because its root system can draw water from very deep with the soil profile. Hemp crops intended for straw production are not irrigated as the soil covers water requirements.

Sowing takes generally place in spring. It can vary between March and May depending on the location and the climatic conditions (Gibson, 2006). The optimum soil temperature is 10°C for early growth, but hemp can be seeded at a minimum of 6°C. Depth is an important factor to be considered, germination will be better if the seeds are well and evenly buried 3-5 cm in the ground (Small & Marcus, 2002). Seeding densities depend on the final purpose of the crop. When hemp is sown for fibre use, the density is high and this will lead to strong and tall plants. The density is lower when planted for seeds. The development of the plant is therefore different: it will develop more branches and therefore the seed yield will be higher than the fibre.

Generally, after germination hemp is a crop that requires very little care and it is even used to eliminate weeds and other pests from fields; centuries of observations confirm this (Gibson, 2006). Due to hemp's early growth and the density of the crop, strong weed suppression is virtually guaranteed (Bocsa & Karus, 1998). The harvest of the crop takes place after three or four months from sowing. Fibre hemp is ready before seed hemp, which will be only the female plants. In some instances, crops have been harvested for both, with the male plants cut first; or, when monoecious varieties are sown, all the plants reaped together (Gibson, 2006).

2.4.7. Multiple Uses

Cannabis sativa is extremely unusual in the diversity of products for which it is or can be cultivated. Popular Mechanics magazine (1938) touted hemp as "the new billion dollar crop," stating that it "can be used to produce more than 25,000 products, ranging from dynamite to Cellophane." It was Jack Herer in his book 'The Emperor Wears No Clothes' (1995) who first re-inspired the western world with the idea that the hemp crop was far under utilised in the industrial age. Even if he was once seen as extreme political activist, now his statements are not only becoming acknowledged, but are truly being realised as hemp begins to touch mainstream industry (Gibson, 2006). Table 2.2 shows the main uses of any single part of the plant.

Table 2.2 – Multiplicity of uses for hemp

SEEDS	LONG FIBRES	WOODY STEM CORE	FEMALE FLOWER	WHOLE PLANT
Confectionary, baked goods	Plastic-moulded products	Animal bedding	Medicinal cannabinoids	Alcohol
Salad oil	Specialty papers	Thermal insulation	Essential oil (for flavour & perfume)	Fuel (biomass & biofuel)
Body care "cosmetics"	Construction fibreboard	Construction (hempcrete, fibreboard, plaster board)	Insect repellent	Silage
Animal food (whole seeds for birds, press-cake for mammalian livestock)	Biodegradable landscape matting & plant culture products			
Gamma-linolenic acid dietary supplements	Coarse textiles (carpets, upholstery)			
Specialty industrial oils	Fine textiles			

Source: Small and Marcus, 2002

2.4.8. Current hemp cultivation in Ireland

Hemp cultivation in Ireland was never commercially grown in the past. As mentioned when reviewing the history of the crop in the country, some hemp was grown during the 1938-45 period for bird seed and scientific evaluations were carried out during the ‘60s and in the late ‘90s. Thanks to the recent renewed interested in the crop, also the Irish farmers very recently started to become interested to the multiple possibilities that hemp offers.

In the spring 2007 issue, an article appeared on the Irish Farmers Journal (Doyle, 2007a) stated that hemp contracts were offered in the mid-Leinster region. The crop, to be used primarily in the construction industry for a range of end uses, was offered a contract price of € 150 per tonne if delivered in medium square bales to Edenderry, Co. Offaly. The price was said to guarantee a level of margin previously associated with sugar beet (Doyle, 2007a).

Due to some delays from the Irish authorities in providing the necessary authorisations for seeding the crop, only three farmers were able to grow hemp during 2007 on a total

area of 15 ha (Tong, 2007, pers. comm.). The success of the harvesting demonstration organised in October has been advertised in the same journal (Doyle, 2007b). If the yield and economics of the crop respect the expectations, hemp will be likely to attract an increasing number of farmers in the incoming years.

2.5. Lime in construction

Building lime has been used as a binder for building work for thousands of years, due to its unique setting properties and the exceptional smoothness which it offers when it is worked. Its versatility is shown by the wide variety of uses to which it is put. Structural elements for which lime mixes may be used, in appropriate designs, include foundations, walls, floors vaults and roofs. Lime is also used for many finishes including paints, plasters, renders, and decorative work such as cornices and hand-modelled stucco.

2.5.1. The lime cycle

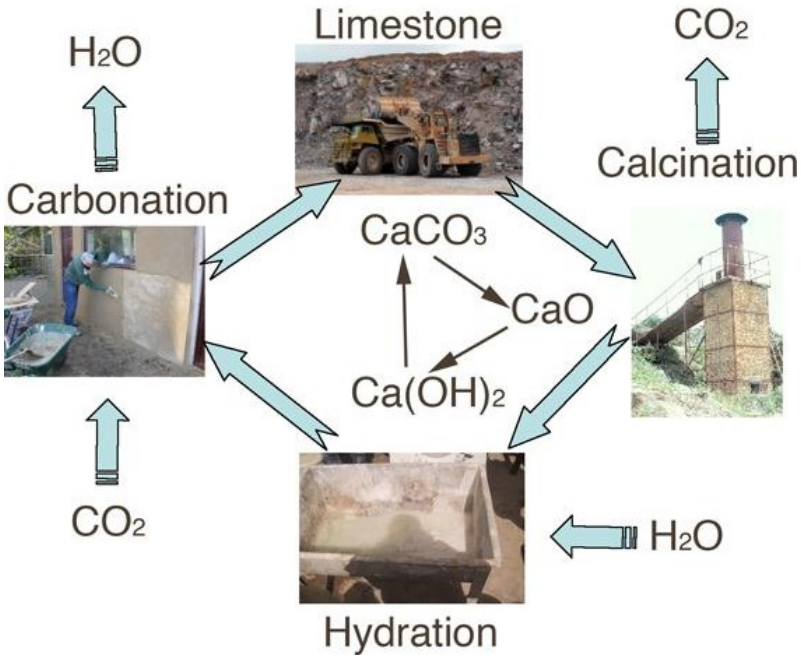
Lime does not exist in nature and therefore it must be manufactured. In the manufacturing process the material passes through several stages, as showed by Figure 2.5 below.

a) The raw material is *calcium carbonate* [$CaCO_3$] which is usually quarried as limestone, but may also be found as chalk, coral rocks or shells.
b) When this is heated at around 900~1100°C in a kiln it undergoes a chemical reaction, giving off *carbon dioxide* [CO_2] gas and forming *calcium oxide* [CaO]. This is commonly known as quicklime or lump-lime.
c) When quicklime is combined with water it changes to *calcium hydroxide* [$Ca(OH)_2$], commonly known as slaked lime, hydrated lime or often just ‘lime’.
d) Lime, when used for building purposes, slowly absorbs *carbon dioxide* [CO_2] from the air to form *calcium carbonate* [$CaCO_3$].

The whole process is often seen as a cycle because the final element is chemically the same as the raw material. In practice the carbonated lime which is finally achieved may

be very different physically from the limestone or other original material (Holmes and Wingate, 2002).

Figure 2.5 – The Lime Cycle



Source: Holmes and Wingate, 2002

During the 'slaking' process, i.e. when quicklime is combined with water, a great amount of heat gets generated. If the exact quantity of water is provided, the heat makes it completely evaporate, thus leaving a dry powder called dry hydrate of lime, usually known as hydrated lime. It can be used to improve the properties of cement-sand mixes, but it is unlikely to produce mortars or plasters which will carbonate well enough to give consistently good results. If a considerable excess of water is provided during the slaking, then lime is run to a free-flowing milk of lime, usually contained in a pit in the ground. The suspended solids settle out to form a cohesive mass called lime putty. Above this, a saturated solution of lime called lime water. It takes at least one month for lime putty to fully mature so that it can be successfully used for plasterworks (Holmes and Wingate, 2002).

2.5.2. Types of lime

Limes are generally classified by the way they set (Dorrian, 2004). Limes may set, either by a slow combination with carbon dioxide gas in a process called *carbonation*, or by combination with silicates and aluminates in the presence of water in what is called *hydraulic set*. Nearly all limes set to some extent by carbonation, which is the only way that the purest limes gain strength.

The hydraulic set is a property exhibited by limes which contain active clay impurities. In many cases the proportion of these impurities is low and the carbonation remains important, but for some limes the hydraulic set is predominant. The most active of the possible clay constituents is soluble *silica* (SiO_2), but other contributions come from *aluminia* (Al_2O_3) and from *ferric oxide* (Fe_2O_3) (Holmes and Wingate, 2002).

Air limes are highly workable and set quite slowly. Alternatively, hydraulic limes, and in particular naturally hydraulic limes (NHLs), get their initial strength from the reaction with water, after which the lime continues to build strength through carbonation. Hydraulic limes not only have this extra power of setting, but also are usually stronger than air lime/lime putty (Dorrian, 2004). Pure limes will not set under water, so for building in wet conditions including hydraulic engineering works, hydraulic limes are needed.

Similar ‘hydraulic’ properties can be achieved by adding certain pozzolans to a fat or air-lime mortar. These materials contain very finely divided clay or similarly fine minerals which have at some time been subjected to great heat. Examples are certain volcanic ashes such as the original Pozzolana from near Naples in Italy, the fly ash know as PFA which is produced in power stations which burn pulverized coal, and brick dusts prepared by crushing or grinding lightly-burnt clay bricks.

2.5.3. History of lime

Lime is traditionally the main binder of mortars, plasters and renders. The earliest known use of lime as a construction material was approximately 4000 BC as it was used for plastering the pyramids in Egypt (Boynton, 1980). It is not clear when the use of

lime in mortars originated; it is well acknowledged however that the Romans used lime based mortars extensively (Granger, 1931). The Pantheon in Rome with its 43m high dome is an outstanding example of their lime-concrete tradition. It is believed that the Romans were also the inventors of hydraulic mortars that contained lime and a pozzolans such as brick dust or volcanic ash. Examples of these types of applications included reservoirs, fish-ponds, and aqueducts (Davey, 1971). Lime has been used all over the world where limestone was available. Earliest examples of building lime can be found in Turkey and throughout the Middle East where highly worked, polished surfaces were and continue to be commonplace (Dorrian, 2004).

The use of lime as a binder continued undisturbed until the nineteenth century. In 1824 Joseph Aspdin, an English builder, patented a material called Portland Cement. It consisted of a blend of limestone, clay and other minerals in carefully controlled proportions which were calcined and ground into fine particles. The consistency and higher strength levels of Portland cement allowed it to replace natural cements in mortars. Portland cement by itself had poor workability, but when combined with lime provided an excellent balance between strength and workability. The addition of Portland cement to lime mortars increased the speed of the construction process for masonry building due to faster strength development (Holmes and Wingate, 2002). As a consequence, the introduction of cement led to the decline in the use of lime, culminating in its virtual disappearance by the mid 20th century (Dorrian, 2004).

In these days, the need for speed that drives the construction industry is not compatible with the long time setting of lime putty and therefore it gets often discarded. Even with the availability of pozzolanic additives and hydraulic limes, as confirmed by Brown (2005), the use of cement is habitually preferred.

2.5.4. Advantages and disadvantages of using lime

There are many advantages of using lime mortar (Holmes and Wingate, 2002). Follows a review of the most relevant:

a) *Breathability* which is a direct consequence of the high porosity and high permeability of lime. Lime mortars protect the other materials in a building structure by

handling moisture movements through the building, and by defending masonry materials from harmful salts. This property assists the drying out of buildings and the avoidance of condensation problems, which greatly contributes to the comfort of people using the buildings.

b) *Autogenous healing*. All materials expand and contract with changes in moisture content and temperature. When building made with lime are subjected to small movements they are more likely to develop fine cracks than the individual large cracks which occur in stiffer cement-bound buildings. Water penetration into these fine cracks can dissolve 'free' lime and bring it to the surface. As the water evaporates, this lime is deposited and begins to heal the cracks.

c) *Low thermal conductivity*. Lime affects the surface temperatures within buildings, making plaster in cool climates feel warmer to the touch than cement plasters. It contributes to a feeling of comfort both in cool and warm climates.

d) W*orkability* which depends on lime plasticity and water retention. It is the ability of a mortar or plaster to remain smooth and mouldable even against the suction it may experience from porous building materials. Good workability greatly assists good workmanship, helping to achieve full joints with good bonding to the other materials involved.

e) *Durability*. If it is used properly, lime is exceptionally durable. Outstanding examples are the Great Wall of China, the Pantheon in Rome and the little remaining plaster on the top of the Egyptian pyramids. All of them survived for hundreds of years.

The main disadvantages of lime are:

a) *Lack of strength*. Most limes do not provide great strength, but for one and two-storey buildings that is not needed, and even much larger buildings can be designed for low-stress materials if the geometry is correct. Hydraulic limes are usually stronger than Air limes.

b) *Setting time*. Limes in general take much more time to set than cement. The hardening of air limes takes place slowly over weeks and months as the lime reacts with carbon dioxide in the air. It is therefore most appropriate for interior work and some exterior work. Hydraulic limes carbonate with the addition of both water and air, and take less time to set than air limes. Its use should be considered where there is a high degree of exposure to weathering (Brown, 2005).

2.5.5. Recent revival of lime use

Cement mortars and modern plasters have been used in recent years for conservation and repair works of historic buildings. Over the past 20-30 years, due to the emerging evidence of the damage they caused, it has been recognized that hard, cement-rich mortars are unsuitable for use on old buildings. Lime is therefore enjoying a strong revival in the building conservation industry (Pritchett, 2003). Aside from its use in historic buildings, evidence of the structural, aesthetic and environmental properties of lime has seen an escalating interest in its use in new buildings as well (Dorrian, 2004).

Mortars and renders made with cement are much denser than those made with lime and are much less permeable. The passage of air and moisture through the material is restricted, and a coating of cement mortar effectively blocks the pores of the wood, stone, brick and old lime mortars, and traps damp holding it captive. This characteristic and the hardness of its set, pose serious problems for traditional structures which need to ‘breathe’ (Brown, 2005).

A cement mortar, being denser and less porous than a lime mortar, traps moisture within the fabric. This in turn reduces the thermal performance of the wall, and in cold weather the temperature of the wall may fall to the point where moisture in the interior starts to condense on its face, soaking in and encouraging the development of timber decay and other damp related problems (Brown, 2005).

2.5.6. Situation in Ireland

Limestone, the main raw material for the production of lime, characterise a great fraction of the geology of the country and it is therefore vastly available. As it was

claimed by an anonymous writer in the Dublin Penny Journal (1832) when talking about the Dublin limestone district: "[it] is but a portion of the immense field which extends throughout the greater part of Ireland, being found in every county save Derry, Antrim, and Wicklow, constituting the substratum of the great valleys, and resting on the rocks of sandstone, schist, conglomerate and trap, which compose the mountain chains and insulated hills". Moreover, according to Brown (2005), the purity and wide variety of limes currently available in the country, makes it possible for the user to choose the appropriate material according to the particular use for which it is needed.

Dorrian (2004) claims that lime has been used in almost all pre-1900 buildings in Ireland, and almost the entirety of the buildings the nation is proud of derive a large part of their aesthetic beauty from lime. Therefore their conservation only depends on the ability of the Irish to revive and preserve the skills and knowledge for such an interesting building material.

Clogrennane Lime Ltd., located in Co. Carlow, is the single producer of lime in the country. The construction industry is just a small section of the end uses for their production, while the majority currently serves the industrial, pharmaceutical, environmental, and agricultural sectors (Clogrennane Lime Limited, 2007).

2.6. Lime-hemp as a construction material and building method

Lime-hemp is a biocomposite material formed by the mixture of the woody core of the hemp plant, also known as hurd, and a lime based binder with the addition of water. Hemp acts as the lightweight filler, or aggregate, and lime is the binder and preservative. When setting, the composite forms a rigid lightweight material with excellent insulation and durability characteristics (HLCPA, 2006). Hemp hurds are usually a by-product of the fibre processing industry and, being naturally rich in silica content, they help the hydraulic set of lime. The mix sets in few hours, while due to the petrification process it acquires a stone-like consistence over time (Michka, 1994).

The lime-hemp biocomposite may be used as a solid wall, as much as cement-concrete, either free standing or as an infill within a post and beam timber frame structure. It can also be cast as blocks and used as an insulating plaster (Woolley, 2006). It is usually

poured into timber shuttering and successively tamped to make sure it is properly packed in. Recently, in order to make the operation faster and cost efficient, some builders have started to spray the mix by using specialist equipment (O'Thompson, 2007 pers. comm.). Figures 2.6 and 2.7 show the appearance of lime-hemp both just mixed and once set.

Figure 2.6 - Lime-hemp mix

Source: Wolley & Bevan , 2007

Figure 2.7 - Lime-hemp on a timber frame

Source: Wolley & Bevan , 2007

2.6.1. Past and current history

The use of hemp mixed with lime in the building sector has come into the limelight since the early '90s. It seems though, that the technique was already known and practiced about 1500 years ago. In the south of France, archaeologists have found a bridge built with a mix of lime and hemp during the Merovingian period, i.e. 500-751 CE (O'Flynn, 2001).

2.6.1.1. France

In more recent times, lime-hemp composites began to be employed in France, in the Troyes region, for the conservation of historic buildings as a replacement to old wattle and daub infill materials in medieval half-timbered buildings (Wolley, 2006). Originally the infill was covered with a lime render but, during the second half of the twentieth

century, repairs were made using cement based renders. As a result the walls could no longer breathe and moisture trapped in between, caused the infill to swell and the render to pop off.

Lime-hemp was therefore rediscovered as a solution for the damages caused by the incorrect use of cement. There is neither evidence of the people who first used hemp as ingredient in the mix, nor the exact period when it was started to be employed, but being Troyes the major hemp producing region of France, the connection becomes fairly obvious (Allin, 2005).

The technique immediately underwent a revival of interest in the country and thanks to three people in particular its potential was further developed and tested in different applications (Allin, 2005). France Périer with her own company 'Isochanvre' begun to produce and distribute lime-hemp as an alternative to cement; Bernard Boyeux with the association 'Construire en Chanvre' and Yves Khun with the 'Association d'Adam' helped to bring together the different stakeholders in the new born industry.

There are today several hundred houses made with lime-hemp in France and around 4,000 tons of hemp hurds are used annually by the building industry, making an overall value of € 35 million (Wolley, 2006). Scientific research and continuous testing is carried out by the 'Centre Scientifique et Technique du Batiment' (Centre for building Science and Techniques) and the 'Ecole Nationale des Travaux Public de l'Etat (National School of Public works of State), as well as by the multinational Lhoist group, the biggest manufacturer of industrial lime in the world (Allin, 2005).

2.6.1.2. United Kingdom

Lime-hemp in the UK is a relatively new concept. It has been officially pioneered by Ralph Carpenter of Modece Architects in the south of England for the Suffolk Housing Society in 2001, as part of a social housing development. The project was monitored and evaluated by the Building Research Establishment, a research consultancy in the field of sustainable building, with the aim of investigating structural, thermal, acoustic, permeability and durability qualities; reduction in waste generated on site; environmental impact; and construction costs (BRE, 2002).

Lime Technology, a company operating in the development of lime based building products, in collaboration with Lhoist UK and Hemcore, the major processing company of industrial hemp in the UK, currently manufactures and distributes hemp hurds and lime binder under the Tradical® Hemcrete® trademark (Lime Technology, 2006).

Further projects have been realised during very recent times. In September 2006 a massive warehouse and distribution centre has been completed in Southwold, Suffolk by employing 100,000 lime-hemp blocks and 1,000 m^3 lime-hemp concrete around a load bearing steel frame (Campbell, 2006). In February 2007, Lime Technology's head office in Didcot, Oxfordshire has been completely refurbished by employing 110 m^3 of lime-hemp concrete (Lime Technology, 2006). Due for completion by the end of 2007 there is a three storey environmental education centre in Machynlleth, Wales where lime-hemp is being used for casting the walling system (WISE, 2007). Other private buildings have been definitely built in the country but it is difficult to retrieve public evidence of them.

Research on lime-hemp is currently carried out in the UK by different universities. The main centres are the University of Bath; the University of Wales in Bangor; the University of London with its Centre of Alternative Technologies; the Plymouth University; and the Queen University of Belfast (Woolley, 2007 pers. comm.).

Unfortunately being lime-hemp a new reality in the building sector, it is not covered by official standards or guidelines (Wolley, 2006). For this reason, in 2006, a number of businesses and professionals have joined to form the Hemp Lime Construction Products Association (HLCPA). Further aims are to promote the use of hemp-lime products in the UK construction industry, and to promote its benefits to the mainstream construction industry.

2.6.1.3. Ireland

Ireland is slightly behind the UK in the exploration of the potential of lime-hemp. Henry O'Thompson, owner of 'The Oldbuilders Company' and the main Irish lime-hemp builder to date, completed the first Irish lime-hemp construction in Clones, Co.

Monaghan during 2004 (Coyle, 2004). According to O'Thompson (2007, pers. comm.), Lorna Burrow of Kinvara, Co. Galway must be acknowledged for being the first to start building using the technique in Ireland even if the construction was never completed. Steve Allin from Co. Kerry was one of the primary pioneers in building with hemp in the country. He runs an environmental design consultancy business but he does not independently carry out the building work. In 2005 he published the book 'Building with Hemp'.

The overall number of houses built with the lime-hemp technique in Ireland is not known. O'Thompson claims to have built seven of them and, even if he is not aware of how many there are at the moment, he is sure there are others, probably made by self builders (2007, pers. comm.). The first passive house made with lime-hemp is currently being built in Co. Galway (Daly, 2007 pers. comm.).

Scientific research is carried out in the country on lime-hemp at the University College Dublin at undergraduate level. With the exception of only one undergraduate dissertation by Thomas Flanagan at the Dublin Institute of Technology (2006), the present work is believed to be the first at postgraduate level. The reader is advised to explore the results of this research for a detailed analysis of the Irish situation concerning the lime-hemp industry in Ireland.

2.6.2. Uses

Lime-hemp lends itself to a wide range of applications, including domestic, commercial and industrial. Follows a review of its main current applications:

a) *Insulating wall infill* – Lime-hemp has a typical compressive strength of 0.2–1.0 N/mm2 (HLCPA, 2006) and therefore is not normally used in load bearing applications. It is recommended to use it in combination with a timber frame designed to carry the structural loads; however steel and concrete frames have been proved to be effective as well (Lime Technology, 2006).

   The mix is either poured and tamped into timber shuttering or sprayed by using an internal (or external) permanent shuttering. The thickness of the wall can vary from

200mm to 500mm and it is not necessary the use of sheathing boards, vapour barriers, insulation quilts or blown-in cellulose (Woolley, 2006). Internal plastering may be avoided but it is however needed externally for protecting the wall against weathering.

The material is also available in blocks with either structural or thermal properties (Lime Technology, 2006). Blocks need to be laid using lime mortar but, according to Wolley (2006), it is a more expensive option and many of the benefits of casting lime-hemp concrete on site are lost.

b) *Roof insulation* – Having high insulation qualities, lime-hemp may also be applied on roofs by using an internal permanent shuttering and by spraying the mix between the rafters. According to Allin (2005), the mixture must have only sufficient lime to coat the hemp particles and fix them to each other, making the whole a weak mass. The structure does not have to be overloaded and for this reason the mix has to be extremely lightweight. Figure 2.8 shows an example of roof application.

Figure 2.8 – Lime-hemp as roof insulation

Source: Wolley & Bevan , 2007

c) *Insulating wall plaster (internal/external)* – The mix has proven to be effective also for plastering works. In order to produce a workable material, it must contain a higher quantity of lime (Allin, 2005). Other than in hemp buildings, lime-hemp plaster is proving its success on conventional walls and it is extremely effective in the thermal upgrading of old stone buildings (McCabe, 2007 pers. comm.). It maintains isolation qualities, can cope with some dampness issues and remains warm to the touch (Woolley, 2006).

d) *Ground/intermediate floor insulating slab & insulating floor screed* – Lime-hemp may also be cast as solid floor in substitution to cement. It can serve as a screed and it is ideal for under-floor heating (Wolley, 2006). Tiles can be laid on the top of it, and it also avoids the use of toxic synthetic materials.

2.6.3. Properties

The reasons for the increasing interest in lime-hemp biocomposite must be explained for fully understanding its potential. Lime and hemp have already been used by humanity for centuries. They are now showing extremely interesting results when combined in a biocomposite. Nonetheless research is continuously undertaken for better understanding its behaviour as well as determining guidelines and best practices for the construction sector to be followed.

2.6.3.1. Thermal insulation and thermal inertia

The thermal performance of building is a complex issue to asses. Despite heat spreads in three different ways (conduction, convection and radiation), building regulations concentrate on heat loss by conductivity. The 'U-value', a limit prescribed by the regulations, measures the heat flow through 1 m^2 of wall, floor or roof for 1°C difference in temperature between its sides (Lime Technology, 2006). The higher it is the lower is the insulation performance.

According to the results of the Haverhill test by BRE (2002) the U-value of the biocomposite building was higher than that measured in the standard building. However the internal temperature in the lime-hemp structure tended to be 2°C higher than the

standard building, regardless of having the same fuel consumption for the period. It has therefore been argued that the U-value is not a proper method to assess the thermal performance of lime-hemp (Woolley, 2006).

Nonetheless, according to the measured levels, the U-values of the biocomposite are below the current threshold in the British and Irish regulations. With a wall thickness of 300 mm measured U-value is 0.3 W/m^2K, 0.22 W/m^2K for 400 mm and 0.18 W/m^2K for 500 mm (Lime Technology, 2006).

A second report by BRE (2003) consisting in a thermographic inspection found that the lime-hemp building external temperature was about 5°C lower than the standard building. The biocomposite eliminates any form of thermal bridging by completely isolating the supporting wooden structure. Moreover the construction resulted to be airtight thus avoiding any loss of heat from the inside.

Thermal inertia is the ability of a material to store calorific energy and to release it over a longer period of time. Périer (2001) recognise it in the ability of lime-hemp to control differences in temperature and therefore to help making the building more comfortable. When the biocomposite is exposed to the sun it warms up very little, and when the outside temperature drops it is able to release heat to balance the difference in temperature between the inside and outside. The property is also confirmed by the BRE's tests (2001) in Haverhill.

Further research is however needed in order to prove 'once and for all' the thermal advantages of lime-hemp versus the standard building materials. The concept is validated by Woolley when he states (2006, pg. 143) that "until more research has been done, it is not possible to give a conclusive evaluation of this".

2.6.3.2. 'Breathability' and healthy building

Lime-hemp combines the vapour permeability of lime and the hygroscopicity of hemp, i.e. the capacity of the hurds to absorb high quantities of vapour water. Walls and floors of a lime-hemp building can 'breathe' thus absorbing moisture and successively releasing it trough evaporation. This feature avoids the build up of dampness and

associate deterioration within the materials, as well as reducing the moisture content inside the building. The overall effect is a more healthy and natural environment, and the reduced the need for air conditioning (HLCPA, 2006).

2.6.3.3. Carbon sequestration

Hemp absorbs carbon dioxide in the atmosphere during growth. According to Pervais (2003) 325 kg of CO_2 are stored in one tonnes of dried hemp. Lime-hemp construction is therefore an extremely effective way to combat global warming. Lime Technology (2006) claims that 110 kg CO_2/m^3 get sequestrated in the building when the biocomposite is sprayed, which become up to 165 kg/m^3 when it is shuttered.

The mentioned estimate already contains the CO_2 emitted when producing lime, therefore it could be claimed that lime-hemp building is potentially carbon negative. Further evidence is provided by Wolley & Bevan (2007) when they state that 31kg of CO_2 per square meter is stored in a 300mm composite thick wall, which become $53kg/m^2$ with a thickness of 500mm. Additional savings in CO_2 emission are a direct consequence of the thermal performance of lime-hemp construction which reduces the heating requirements of the building (Rhydwen, 2006).

2.6.3.4. Sound insulation

According to the results of the acoustics test carried out by BRE during the Haverhill project (BRE, 2002), lime-hemp buildings did not perform as well as those traditionally built but they did meet the sound resistance requirement. Périer (2001) claims that lime-hemp is a very good sound absorber mostly when its surface is left unfinished. Research is currently in progress in order to maximise the potential of lime-hemp for it to be used in sound-proofing applications (Lime Technology, 2006).

2.6.3.5. Fire resistance

Lime-hemp is fire resistant without addition of toxic flame retardants. Périer (2001) states that, according to the tests carried out by the 'Centre Scientifique et Technique du Batiment', the biocomposite was classified as 'fireproof' without release of toxic or D-

flammable smoke, equal the French classification M1. It is also claimed that the mix resisted a four hours test at temperatures of up to 1,800°C.

2.6.3.6. Protection from infestation

Hemp is not edible by mice and rats and lime is unappealing, as well as used for centuries to maintain level of hygiene (Woolley, 2006). The use of lime throughout history shows that lime is perfect for preserving natural fibres and protects them from any kind of infestation.

CHAPTER THREE: METHODOLOGY

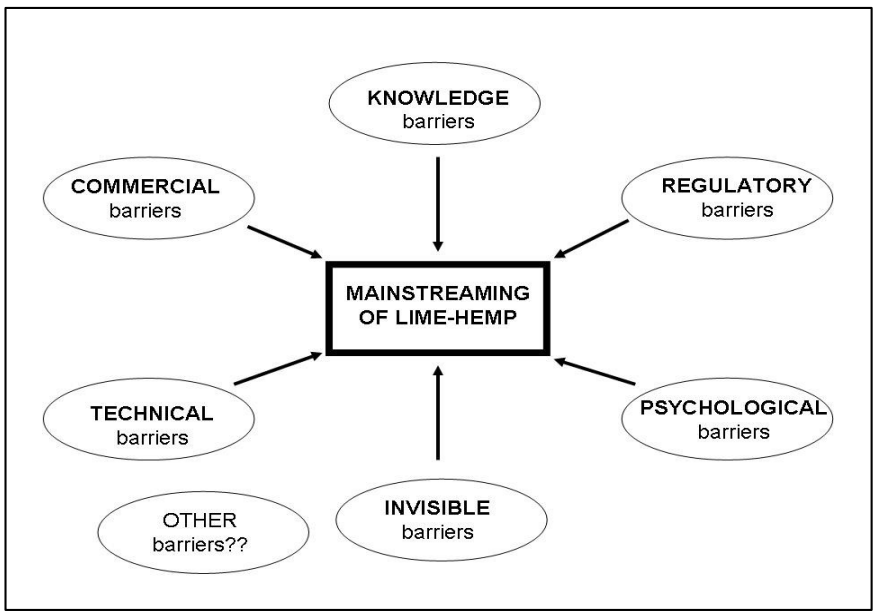
3.0. Introduction

The methodology applied to fulfil the aim of the present work is detailed in this chapter. Rationale and data collection tools are described in order for the reader to better understand the results of the research. The choice of the methods used is subjective and may not necessarily be the most efficient and effective for the achievement of the goal. The research might have been approached in a different manner by another author.

3.1. Identified barriers

The aim of the present research is to understand what the existing barriers to the take up of lime-hemp by the mainstream Irish construction industry are. A certain number of assumptions as well as a graphic representation of six assumed categories of existing barriers (Figure 3.1) provided a starting point for all the consequent work. Initial assumptions are based both on the reviewed literature and on the elaboration of the gathered information by the author. The initial set of suppositions has been deliberately left open to further additions that would arise during the course of the research. It is advised to read through chapter *4* (results) for a detailed analysis of the justifications that have brought to the preliminary list of assumptions.

Figure 3.1 – Representation of the assumption on the existing barriers



Source: produced by the author

The six groups barriers range (technical, commercial, knowledge, regulatory, psychological, and invisible) has been voluntarily kept broad in order to cover as much as possible the variety of issues involved in the potential mainstreaming of the lime-hemp biocomposite.

Technical barriers concern issues related to the husbandry and processing of hemp, as well as the production of lime-hemp and its employment by the construction sector. Commercial barriers relate to the diverse economic issues concerning hemp as a crop, lime-hemp as a building material, as well as the consumers' perception. Technical and commercial issues regarding lime have not been intentionally considered, lime is already well known and has been used for centuries in Ireland. Moreover the existence of a local lime production and market has not been regarded as a potential obstacle for the large adoption of lime-hemp.

Knowledge barriers are related to the lack of awareness on lime-hemp among the potential stakeholders involved in its industry. Farmers being the first step of the needed production chain; architects, builders and the construction industry in general being those who would work on a daily basis with the biocomposite; and consumers representing the final market where the product would be sold. As long as there is a generalised lack of knowledge it is very unlikely to see a widespread take up of lime-hemp.

Regulatory barriers comprise a series of issues depending on the current legislation. They may be broken up in three main subcategories: the necessity for farmers to obtain a licence from the authorities for growing hemp; the lack of an official certification on the biocomposite material; and issues related to the structural insurance of lime-hemp constructions.

Psychological and invisible barriers are the most difficult to objectively measure. The first group includes the association of hemp with marijuana, the illegal variety of hemp containing a psychoactive substance, and the false impression that concrete is the sole and most suitable construction material. Invisible barriers consist of the potential vested interest that might arise from the cement industry and the construction industry in general. Table 3.1 shows the initial list of identified barriers split into categories.

Table 3.1 – Initial list of assumed barriers

TECHNICAL	COMMERCIAL	KNOWLEDGE
Lack of knowledge in hemp growing	Difficulty to source hemp seeds	
Poor hemp quality	Poor hemp crop yield	Farmers' lack of knowledge
Lack of expertise in lime-hemp production	Necessary winter storage for hemp	Architects' lack of knowledge
Lack of expertise in lime-hemp use	High transportation costs	Builders' lack of knowledge
Non appropriate material	Farmers' profitability	Construction industry's lack of knowledge
Non load bearing material	Difficulty to start-up the hemp industry	Consumers' lack of knowledge
Weather-dependent construction	More profitable markets for hemp	Others…
Others…	Lack of the lime-hemp industry	
	Lack of economy of scale	
	Lime-Hemp expensive compared to other construction materials	
	Consumer resistance to innovation	
	Others…	

REGULATORY	PSYCHOLOGICAL	INVISIBLE
Farmers' difficulty to get Garda clearance for hemp cultivation	Hemp association with marijuana	Cement industry's vested interest
Lack of Agrément certificate	Misconception that "concrete built is better built"	Construction industry's vested interests
Difficulty to obtain certification	Others…	Others…
Difficulty to get structural insurance		
Others…		

Source: produced by the author

3.2. Techniques applied

The techniques applied to the research work consist primarily in the use of in-depth interviews. The addition of two questionnaires allowed to complete the collection of data where an interview was believed not to be suitable. The mix has been chosen with the aim of better exploring all the six categories of identified barriers. In some cases an in-depth interview with a key individual was needed to clarify and understand a particular barrier. In other cases a greater target of individuals belonging to the same group was essential to prove or disprove some particular assumptions; hence the questionnaire was considered to be the most appropriate tool.

Both techniques have been chosen with the primary aim of proving or disproving the author's initial assumptions, as well as a means to discover further barriers previously not considered.

3.2.1. In-depth interviews

In-depth interview is the main technique utilized for the collection of data in this research. It is defined by Arhinful *et al.* (1996) as a qualitative research technique consisting in a person to person discussion which can potentially lead to increased insight into people's thoughts, feelings, and behaviour on important issues. It may also be described as an open-ended discovery-oriented method (Guion, 2006).

The lime-hemp barriers issue required a profound analysis and the information needed was held by a few key individuals (or organisations) representing the main stakeholders. For this reason the in-depth interview has been considered the most appropriate method able to provide the author with insights, as well as to allow him to grasp the whole picture.

During the meetings, interviewees were introduced to the research with a brief explanation of its aims, as well as with the help of the graphic representation of the identified categories (Figure 3.1). A list of topics and semi-structured questions prepared in advance served to the author as an outline for the discussion, and to the interviewees as a means to explore one or more set of barriers.

The interviews have been recorded with the explicit authorization of the interviewees. In all cases the person interviewed seemed to be at ease, as well as to enjoy the conversation. Follow a list of the key individuals initially chosen with an explanation of the reasons that brought to their selection.

a) Alec Tong, owner of Tokn Grain Products Ltd. in Edenderry, Co. Offaly is an active Irish farmer operating in the agri-business sector. A recorded interview by RTE 'Farm Week' radio programme (*A look at the big issues relating to farming and food, 2006*) was the evidence of his high competence in the husbandry of hemp. Moreover in an article that appeared in the Irish Farmers Journal it was said that Mr. Tong's company was offering hemp contracts in the mid-Leinster region (Doyle, 2007a).

Mr. Tong has been selected to clarify a variety of issues belonging to technical, commercial, knowledge, regulatory and psychological barriers. Being hemp the main constituent of the lime-hemp mix, the role of farmers becomes fairly relevant for the potential success of the biocomposite.

b) Marcus McCabe, environmentalist and owner of Ark Nursery Ltd. in Clones, Co. Monaghan is the proprietor of the first hemp construction completed in Ireland (Coyle, 2004). Sure of its success he intends to be the first entrepreneur to open a hemp processing as well as lime-hemp producing facility in Northern Ireland sometime in spring 2008 (McCabe, 2007 pers. comm.).

   Being very well informed on the lime-hemp production process and industry, Mr. McCabe was selected with the hope to collect useful insights on technical, commercial, knowledge, regulatory and invisible barriers. He was believed to be the most informed person on the industrial aspects of lime-hemp production in the country.

c) Henry O'Thompson, owner of The Oldbuilders Company in Birr, Co. Offaly has been operating in the conservation and restoration of buildings sector for years and has a good experience in the use of lime. Moreover he is one of the main pioneers in lime-hemp building in the country and has built seven such constructions so far (O'Thompson, 2007 pers. comm.). Mr. O'Thompson has been selected to help the author in shedding light on all the six categories of barriers.

d) Sean Balfe is the director of the Irish Agrément Board, the public Irish authority in charge of producing 'Agrément' certifications. According to their website (IAB, 2007), an Agrément certificate is "designed specifically for new building materials, products and processes that do not yet have a long history of use and for which published national standards do not yet exist". Mr. Balfe was thought to be necessary for clarifying a very important regulatory barrier.

e) Michael O'Grady works for Homebond in the position of Technical Service Manager. Homebond is the major structural insurance company in the Irish

construction sector. Insurance cover is a very delicate regulatory barrier and Mr. O'Grady has been selected to facilitate the author in its better understanding.

f) Brendan Lynch is the Honorary Secretary of the Irish Concrete Society, and he works as Technical Advisory Manager for Irish Cement Ltd. Having many year of experience in the concrete industry, Mr. Lynch has been chosen to provide his own views on aspects related to the psychological and invisible barriers category.

g) A spokesperson from the Irish Construction Industry Federation (CIF). The CIF currently represents and serve over 3,000 members in all areas of the sector. The primary aim was to get a somewhat contradictory perspective in order to shed light on the potential vested interests that could arise against the large take up of lime-hemp. The assessment of CIF's awareness and perception on lime-hemp was the secondary aim.

The insights provided by the interviewees were believed to allow a further development of the initial list of barriers. It was also hoped to verify, as well as strengthen some of the interviewees' statements thanks to the process of triangulation, i.e. the use of multiple perspectives to interpret a single set of information.

3.2.1.1. Interviews bias

The author is aware about the possible bias arising during the course of an in-depth interview. Many variables are likely to compromise the quality and reliability of the responses provided by the interviewees. The interviewers' preparation, his own appearance, his tone of voice for example are all aspects that could play against his credibility. The interviewers' personal involvement with the research could make him seek out answers supporting preconceived notions. The respondent may also be prone to please the interviewer with the answers he is exactly looking for. The awareness of the interviewee that the discussion is being recorded may also prevent him to be fully relaxed and therefore to provide comprehensive information.

A certain set of measures have been adopted by the author in order to reduce any bias to the minimum. All the interviews have been carried out in venues decided by the person

interviewed; an introductory overview on the research was provided in order to make the interviewee aware about the scientific approach employed; and the Dublin Institute of Technology has always been mentioned as the hosting organisation for the research. All the questions have been stated and the discussion carried out by the interviewer by keeping an external position to the issues object of the research. Nonetheless, it is not possible to exclude the complete lack of bias in the results.

3.2.2. Questionnaires

In addition to the six in-depth interviews, it has been considered appropriate to produce and hand out two sets of questionnaires. Questionnaires have targeted two groups of stakeholders: architects and consumers. The overall aim of the questionnaires was to address both their knowledge and perceptions on lime-hemp in order to shed light on some particular aspects of the assumed barriers, mostly commercial, knowledge and psychological.

Architects are those who generally produce the building project and those who should be aware about new materials or new solutions that can possibly be applied to construction. Their role in the take up of the biocomposite is believed to be very important and the author assumed there was an overall lack of knowledge among them.

The author also assumed that consumers normally show resistance to innovation and are often victim of misconceptions. Their knowledge as well as psychological perception of lime-hemp and hemp were the main aspects the questionnaire aimed to collect.

In both cases, the reason for choosing a questionnaire as preferred method lays in the fact that it was believed that one single in-depth interview would not be enough to provide satisfying results able to prove or confute the author’s assumptions.

Questions asked are made of a mix between closed and open-ended questions. The questionnaires have been projected for respondents not to spend too much time during their completion (10-15 minutes), as well as to be filled in and returned in digital format via email. This would have facilitated and speeded up their distribution as well as their

follow up. A copy of both questionnaires is available in the appendix section (Appendix B.1. and B.2.). Follows some details of the chosen samples:

a) Architects – A random sample of 50 professionals, members of the Royal Institute of Architects of Ireland (RIAI), has been chosen amongst the 218 involved in residential building projects. The complete list, containing their contacts as well as email addresses, is publicly available on the RIAI's website (www.riai.ie). Questionnaires have been provided via email as an attached document ready to be filled in.

b) Consumers – A random sample of 100 individuals has been chosen from the 482 members of the Adamstown 'Neighbours.ie' on-line forum (Neighbours.ie, 2007). Adamstown is an ongoing urban mixed development about 20 km far from Dublin city centre. The first dwellings were completed very recently and the first residents have moved in since October 2006 (Adamstown.ie, 2007). The 'Neighbours.ie' on-line forum gives to anyone living in Adamstown or who is interested in buying a property there, the possibility to become a member and therefore discuss with the others about any kind of issue related to their community.

   Such a sample of consumers has been intentionally selected because, having recently bought a house or apartment, they were more likely to be already exposed to issues such as building materials, sustainability, relations with architect and builders or contractors, as well as familiar with choices on buildings in general. With the authorisation of the administrator of the forum, questionnaires have been provided via email as an attached document ready to be filled in.

3.2.2.1. Questionnaires bias

The possible response bias that may arise in the completion of the questionnaires has been considered by the author. Structure, formulation and content of the questions have been carefully thought about during the construction of the questionnaires in order to reduce the likelihood of any potential bias.

The author may not however be completely sure about the lack of bias in the questionnaires results. Other people, for whom the questionnaire was not intended, could have answered the questions instead of the targeted individuals. For particular reasons, later discussed in chapter *4*, some results may be biased by the particular character of the respondents.

3.3. Data analysis

The raw data gathered by means of interviews and questionnaires has been processed and later analysed. The recorded interviews have been transcribed. The data contained in the returned questionnaires has been extracted and imported into a spreadsheet for making its interpretation easier. The findings of the questionnaires have been summarised in two separate documents.

Processed data has been divided according to the type of barrier involved. With the use of a spreadsheet listing the initial assumptions, the processed data has been employed to prove or disprove them by using two different columns. A certain number of new barriers have also emerged, and have been considered for the subsequent listing of the results.

CHAPTER FOUR: RESULTS

4.0. Introduction

The results of the research are specified in the current chapter. The initial layout of assumed barriers (categories and list) is followed. Where new barriers have emerged, they are identified with the addition of the '*n.e.b.*' acronym (newly emerged barrier) next to the paragraph title.

Whatever is possible has been done in order to list every single barrier according to a logic as well as chronologic order within its own category. Issues relating to the husbandry of hemp are faced before those regarding the application of lime-hemp in construction for example; and architects' lack of knowledge comes before that of the consumers.

Every initially assumed barrier is introduced with details on the reasons that have brought to define it as such. The processed data resulting from the in-depth interviews as well as from the questionnaires is employed to prove or confute the initial assumptions. Therefore extracts from the interviews and findings of the questionnaires are aimed either at supporting or at invalidating them. In order for the reader to easily follow the results, the names of the interviewees will be omitted and simplified by using the description of their profession instead. Hence Mr. Alec Tong is the '*farmer'*, Mr. Marcus McCabe is the '*entrepreneur*', Mr. Henry O'Thompson is the '*builder*', Mr. Sean Balfe is the '*certification expert*', Mr. Michael O'Grady is the '*insurer*', and Mr. Brendan Lynch is the '*cement expert*'.

Results are subsequently analysed and discussed in chapter *5*. The reader is suggested to read through the results before their analysis and discussion. This would provide a complete background for a comprehensive understanding of the various issues involved in the potential mainstreaming of lime-hemp in the Irish construction industry.

4.0.1. Interviews details

Mr. Michael O'Grady, the '*insurer*', was the only one who never agreed on a face to face meeting. However, following some phone calls and the provision of the list of the topics on which the interview would be based on, he has been kind enough to return his own written insights via ordinary mail.

The documentation has been considered as if it was the result of an interview. The author is however aware that any result based on the information provided by Mr. O'Grady may be challenged by the reader. Nonetheless the author is convinced that a face to face interview would not have changed the accuracy and insights of the data provided.

Mr. Brendan Lynch, the '*cement expert*', during the face to face meeting claimed not to be prepared enough for carrying out the interview. He kept a list of the issues the author wanted to discuss and returned a written report via email in two weeks time.

Also in this case the documentation provided has been considered as if it was the result of a face to face interview. The author does not see any reason why the interviewee might have provided data having a lower significance for the purposes of the research.

The diverse attempts to approach the Construction Industry Federation asking for the possibility to interview a spokesperson never succeeded, and forced the author to give up. The seventh planned in-depth interview had therefore to be cancelled. Any insight concerning the CIF either comes from the point of view of the interviewed key individuals or from the author's one.

The transcript of all the in-depth interviews as well as copy of the documents provided by Mr. O'Grady, the '*insurer*', and Mr. Lynch, the '*cement expert*', are included in the appendix section (Appendix A.1, A.2., A.3, A.4, A.5., and A.6.)

4.0.2. Questionnaires details

The questionnaires retuned by the architects amounted to 16 out of 50, equal to a response rate of 32%. The questionnaires returned by consumers amounted to 26 out of 100 equal to a response rate of 26%. In both cases the response rate was considered sufficient to represent the stakeholder group and to provide with satisfactory results. Nonetheless the author is aware that, due to the low response rate of the questionnaires, any kind of generalisation based on them might be questioned by the reader.

The templates of the two questionnaires are included in the appendix section (Appendix B.1. and B.2.).

4.1. Technical Issues

Technical issues may be classified in three main subcategories: agricultural aspects relating to the husbandry of hemp as a crop; industrial aspects concerning both the processing of hemp and the production of lime-hemp; and practical aspects relating to the use of the biocomposite during construction.

4.1.1. Lack of knowledge in hemp growing

Hemp is a new crop for Irish farmers. With the exception of some hemp grown during the 1938-45 period for bird seed (Neenan, 1969), the only trials have been carried out by the Teagasc between 1996 and 1998 (Crowley, 2001). Farmers are therefore generally unaware on the crop itself as well as on the growing techniques involved.

The *farmer* however suggested that the needed knowledge to grow hemp is small. According to him those interested in the crop are ex sugar beet growers since hemp is a rotational crop like sugar beet. It takes the same kind of seedbed, the time of sowing is similar but the time of harvesting is much better, i.e. September rather than November, December or January. That would leave the farmers the opportunity to sow a winter crop immediately afterwards, thus optimising the use of fertile land.

4.1.2. Hemp harvesting *(n.e.b)*

Hemp, due to its height and to the strength of its fibre, requires a particular harvesting equipment. During the Teagasc assessments, it was found that hemp could cause problems when existing farm machines were employed (Crowley, 2001). The *farmer* stated that farmers usually do not own their combine harvesters but must hire contractors for carrying out the harvest. This has been confirmed by the *entrepreneur* who claimed that the biggest barrier for farmers is the lack of harvesters. He clearly argued that farmers will not grow hemp unless they are sure on how to harvest it.

Nonetheless the *farmer* said he is dealing with a German company producing harvesters on the possibility to manufacture an ad-hoc header to be adapted on the combines already existing in Ireland. At the time of the interview, the *entrepreneur* had just bought Ireland's first hemp harvester. Doyle (2007b) officialised the success of the harvesting demonstration organised in October at the *farmer*'s hemp field. The *entrepreneur* also confirmed (2007 pers. comm.) that the accomplishment of the first Irish hemp harvest was sufficient to convince those farmers interested but still hesitant.

4.1.3. Poor hemp quality

A poor crop quality leading to a poorer product is suggested by BRE (2004) as one of the technical barriers to the take up of building materials based on crops. Neenan (1969) claimed that the quality of hemp yarns and twines, produced during the first Irish scientific evaluation of hemp in the '60s, were shown to be inferior to British Standard specifications.

Both the *farmer* and the *entrepreneur* confirmed that hemp fibre quality is not needed for the production of lime-hemp. The biocomposite only incorporates the wooden core of hemp (hurd) which is not dependent on the fibre quality. Because of the particular Irish climate conditions, it would be impossible to grow fine fibre materials.

4.1.4. Lack of expertise in lime-hemp production

Lime-hemp has never been produced in Ireland so far. The industry does not exist yet and therefore it has been assumed that the lack of know-how might represent a barrier to the take up of the biocomposite in the country. Nonetheless, according to the information gathered during the interviews, it does not seem to be a key issue.

The *entrepreneur* described the whole production process with the help of a graphic flow chart. Every singular process and machinery has been carefully detailed. The production of lime-hemp, provided the availability of the necessary equipment, is a low technology industry and the needed expertise can easily be gained. The *entrepreneur* also claimed that, once the first processing factory is operational, it can be simply replicated in different locations around the country.

4.1.5. Lack of expertise in lime-hemp use

Lime-hemp building technique is fairly new in Ireland. With the exception of very few self-build enthusiasts, only one professional builder, and some design consultants who have already gained some experience, the mainstream construction sector was assumed to lack the necessary know-how.

The *builder* confirmed that the Irish construction industry does not have the knowledge in relation to sustainable methods of construction in general. He blamed factors such as certain limits imposed by regulations as well as general market conditions. Nonetheless he claimed that the use of lime-hemp does not require great intelligence or technical ability, though involving a certain amount of understanding and training. According to him, “any ‘thinking’ builder would be able to use lime-hemp”.

Lime Technology (UK) in association with Joseph Little Architects (Irish professional), organised a two-days theory and practice training course for Irish builders during autumn ’06 and spring ’07 (Little, 2007 pers. comm.). This was considered as evidence of the ease in the acquisition of minimal skills.

4.1.6. Non appropriate material

Lime-hemp has a typical compressive strength of 0.2–1.0 N/mm^2 (HLCPA, 2006). Cement-concrete typical strengths range from 20 N/mm2 to 65 N/mm^2 (Irish Concrete Society, 2007). It has therefore been assumed that the biocomposite will never entirely substitute cement. The unsuitability of lime-hemp to some kind of applications might as well be a limitation in its take up by the construction industry.

According to the *builder* the specific application must be considered. He agrees that lime-hemp is not appropriate for building bridges or structures where cement-concrete is proven to be necessary due to its properties. Nonetheless he believes that, due to the global environmental problems as well as to the unsustainability of cement, natural materials should be used in as many applications as possible. Low/medium rise residential and commercial buildings for example could be easily made with lime-hemp.

4.1.7. Non load bearing material

Lime hemp, due to its fairly low compressive strength, is not normally used in load bearing applications. Lime Technology (2006) recommends the use of the biocomposite in combination with a supporting frame made of timber, steel or concrete. This limitation has been assumed as a potential drawback limiting the mainstreaming of the biocomposite.

According to the *builder*, there is a point up to which lime-hemp could be weight bearing. With a 500 mm thickness, the wall possibly becomes light weight bearing and it might sustain the weight of the roof in low rise application. However he believes that looking for the load bearing property is not really necessary because a structuring frame is useful to create the shape of the building and to support it. Stronger composites can be obtained by increasing the proportion of lime and therefore becoming load bearing. The *builder* noted than in this way though thermal performance is lost, and with it the most interesting properties of lime-hemp.

4.1.8. Weather-dependent construction

Breathability is one of the most interesting properties of lime-hemp. The biocomposite in fact combines the vapour permeability of lime and the hygroscopicity of hemp, i.e. the capacity of the hurds to absorb high quantities of vapour water. Lime plaster is vapour permeable too. It has therefore been assumed that, under severe weather conditions, the lime-hemp construction might become subject to levels of moisture too high. This would facilitate mould growth and irreparable damage to the supporting frame if made of timber. The mentioned risk would definitely act as a barrier to lime-hemp mainstreaming.

The *builder* recognised some concern in the very exposed conditions that might incur in the west, north-west regions of the country (e.g. Connemara and Donegal) due to the continuous wind blown 'horizontal' rain. However he claimed to have developed an alternative that consists in stepping the external plaster out from the lime-hemp wall. This solution would leave a 20 mm ventilated gap between the biocomposite and the external plaster thus avoiding any moisture issue.

4.1.9. Seasonal constraint in the use of lime-hemp *(n.e.b)*

The *builder* claimed there are no particular seasonal constraints in the use of lime-hemp. The only issue he noted concerns the plastering work. Right after construction the lime-hemp wall remains damp and feeds a lot of moisture to the lime plaster for an extended period of time. In the presence of frost, the moisture inside the lime freezes and expands thus blowing off the plastering work. As a general rule of thumb, the *builder* claimed that lime plastering should not be carried out when the external temperature is below 5°C.

4.2. Commercial Issues

Commercial issues relate to a variety of economic aspects assumed to be relevant for making lime-hemp competitive on the market as well as demanded by the final consumers. Profitability for farmers growing hemp as well as for the hemp processing /

lime-hemp producing industry are the main issues explored in this section. Aspects on competition and potential consumers demand are also given the due importance.

4.2.1. Difficulty to source hemp seeds

Farmers are allowed to grow only legal varieties of hemp. According to the European legislation, seeds must belong to an approved list and produce hemp containing less then 0.2% by weight of THC (Council Regulation (EC) 953, 2006). Ireland does not commercially grow any hemp and therefore seeds are not locally available. Due to the increasing interest for non-food crops like hemp all over Europe, it has been assumed that Irish farmers could encounter difficulties in sourcing certified seeds.

The *farmer* disproved the assumption saying that there are no difficulties at the moment. Together with other Irish farmers, he has been buying EU certified seeds from France and Germany. He also added that farmers are not allowed to re-sow the seeds they produce because, as most of the crops, hemp must respect the criteria imposed by the seed houses.

4.2.2. Poor hemp crop yield

BRE (2004) lists poor crop yields as a commercial barrier to the take up of building materials based on crops. Nonetheless according to Crowley (2001), the yields achieved during the Teagasc's scientific assessment of hemp were encouraging, resulting in an average of 12.5 t/ha of whole stems over three years. It has however been considered that only an Irish farmer could shed light on the issue.

The *farmer*, though admitting to be at his first attempt to grow hemp, said that the hemp yield in the country is acceptable. When trying to convince the other farmers, he said to prefer to be conservative claiming a minimum yield of 12.5 t/ha. However he believes that a higher yield per acre of hemp should be achieved in Ireland compared to the continent because of the particular wet weather conditions. He also said to be in association with the Wageningen University in the Netherlands where scientific research for increasing the hemp yield is in progress.

4.2.3. Necessary winter storage for hemp

Hemp is normally harvested in September and needs to be stored before being processed. Hemp bales are bulky (Tong, 2007 pers. comm.) and, as claimed by Crowley (2001), storage techniques for up to one year are required before commercial development could take place in the country. It has been supposed that this might represent a constraint reducing the profitability of the crop for the Irish farmers.

The *farmer* however noticed that hemp storage is not an issue. It could easily be done in an open building with a roof, the same method used to store hay. He claimed that the final price of hemp would not be increased by the storage operations because storage buildings are already existent and owned by the farmers. The *entrepreneur* stated that in the contracts he offers, farmers are paid to store the hemp they grow and it works. He claimed that farmers already own the necessary barns and, if they did not, their building cost would be very low. He suggested that in Wales, authorities offer grants to farmers for storing hemp and thought it would be a good idea to introduce such a solution in Ireland too.

4.2.4. High transportation costs

Hemp has a low bulk density and hence its value per tonne is fairly low. The transportation of hemp from the farm to the processing facility is a major issue with the costs being in the region of € 18 per tonnes in England (ADAS, 2005). Moreover, higher transport cost per tonne of finished product need a high value per tonne, and relatively high density to keep unit costs down (ADAS, 2005). The concept is confirmed further on by Rhydwen (2006) when he states that hemp cultivation is only likely to be competitive if transportation of the straw is kept to a minimum.

The *farmer* validated the assumption stating that Irish processing facilities must avail of local farmers growing hemp. He believes there should be three or four processing plant locations in the Leinster and Munster regions for keeping transport distances as short as possible. The *entrepreneur* claimed that a 30 km radius distance between farms and processing facility is considered acceptable in France, while in Germany it rises to 50

km. His personal opinion was that radius distance should be 15 km so that farmers would be able to take care of the transport by using their own tractors.

4.2.5. Farmers' profitability

The profitability of farmers growing hemp is a necessary condition for the existence of the lime-hemp industry. All the main parts of the hemp crop (fibre, hurds, and seeds) have a market and virtually hemp is a very interesting cash crop. Rhydwen (2006) believes that the profitability of hemp is reliant on marketing every part of the hemp plant. According to him however, the cultivation of hemp as a dual crop (hurds and seeds) in the south of England seems to have a reasonable economic potential granting a profit to farmers of € 400 per hectare, considering a yield of 5,5 tons of straw and 1 ton of seeds (Rhydwen, 2006).

Unfortunately, being a new crop, there is no official data on the profitability of hemp in Ireland. Low profitability has therefore been assumed as a possible barrier limiting the mainstreaming of the biocomposite construction material.

According to the *farmer* there is no other crop today that matches the economic results of hemp. In 2007 he offered € 150 per ton of hemp straw at 15-20% dry matter delivered to Edenderry, Co. Offaly. With an average yield of 12.5 t/ha, farmers would cash in a total revenue of € 1,875 per hectare. The involved costs, about € 875 per hectare, would consist of ploughing, tilling, sowing, seeds, fertilizer, and harvesting. Total profit would be € 1,000 per hectare. In case the farmers decided to harvest seeds too (average yield of 1.25 t/ha), they would be paid about € 500 per ton on the market. This would increase the profit to about € 1,600 per hectare. Profit, the *farmer* said, will rise proportionally for any future increase of yield per hectare thanks to agronomics and breeding improvements.

4.2.6. Difficulty to start-up the hemp industry

The hemp industry does not exist yet in Ireland. Being a new business, the presence of a certain number of barriers that could slow down its appearance or make its existence even impossible has been supposed. No literature was available on the topic, and it was

thought that only someone with experience could be helpful in the exploration of such a key issue.

The *entrepreneur*, thanks to his own experience in setting up a hemp processing / lime-hemp producing facility, identified three main difficulties. They consist of lack of understanding from the financial sector, the need for a stable supply from farmers, and the attitude of the Government.

According to the *entrepreneur*, finance is the biggest problem. Hemp having so many different final uses, he claimed that banks and equity investors in general get bewildered with the high amount of information before they can absorb it. Their lack of understanding prevents them from being confident in investing. He said he started to make some progress with the investors when he decided to focus the discussion on lime-hemp excluding any other use for the crop.

The presence of a stable supply from farmers is, according to the *entrepreneur*, the second main issue. He thinks it is better to deal with farmers groups instead of single individuals. He excluded the possibility of owning or renting the land for directly cultivating hemp. A part from the need to be a very experienced farmer, that would add to the processing activity a huge amount of practical problems. He claimed to have spent two years in a project cultivating relationships with the farmers before starting with the processing facility.

The attitude of the Government is a further key question. The *entrepreneur* decided to locate his own business in Limavady, Co. Londonderry, Northern Ireland due to the higher cooperation from the British Government compared to the Irish one. For example he stated that in 2005 it took four days to get the licences to grow hemp in Northern Ireland while six months were necessary in the Republic of Ireland.

4.2.7. More profitable markets for hemp

Hemp once processed can be employed to produce a multitude of final products. Competition between the different uses might potentially make lime-hemp production less interesting than others and therefore become a barrier to its development. The

presence of more economic markets for ‘non-food crops’ is also considered by BRE (2004) as a commercial barrier to the take up of building materials based on crops.

According to the *farmer*, due to the Irish climatic conditions, hemp cannot be grown to make fine fibre materials which would be indeed more profitable. It can however be grown in the country and, after processing, the hurds would find their way into lime-hemp and the fibre into insulation mats. Another market he believes might arise comes from the oil extracted from the seeds. However it would not compete with the lime-hemp production.

The *entrepreneur* confirmed the possible existence of a seed oil market. He added there might be a very little market for quality paper produced with the hemp fibre. An interesting market that will probably appear in the future, he said, it is the use of very finely chopped fibres mixed with special resins to make bio-plastic. He believes however that before thinking at additional uses for hemp, a profitable business must be created and lime-hemp seems to be the right one. When the supply chain exists, then it will be possible to build on that.

4.2.8. Lack of the lime-hemp industry

The lime-hemp supply chain does not exist yet in Ireland. The construction industry will never be able to widely take up the biocomposite material if it is not readily available. The stakeholders interviewed therefore expressed their position on the issue.

According to the *entrepreneur* the market for lime-hemp is huge and already exists. He claimed that it has never been promoted so far even if it could be easily done. He also noticed the presence of a certain number of architect supporting lime-hemp as the right starting point. In ten years, he believes a supply chain will exist and anyone will be able to easily source lime-hemp on the market.

The *builder* does not see any reason why there should not be a domestic lime-hemp industry in Ireland. According to him, that would require some entrepreneurs with € 2-3 million to invest in setting up a processing plant. Once the plant is there, he believes

there would be plenty of farmers willing to supply hemp, and that would definitely help in making lime-hemp locally available.

4.2.9. Lack of economy of scale

A certain level of production is needed for the necessary return on the investment to be obtained. It has been assumed that the lack of a proper scale would make lime-hemp production unprofitable and as a consequence make its broad uptake unlikely.

The *entrepreneur* believes that a large scale of production is not needed for profitably producing lime-hemp. He claimed that the whole business required an investment of € 2 million. According to him, 10,000 tons of hemp straw would be enough to supply a factory processing 2 – 2.5 tons of hemp per hour. The facility would be dependant on a few farms and it could be easily replicable in different locations around the country. That would reduce the incidence of the transportation cost on the price of hemp as well as create local employment.

4.2.10. Lime-Hemp expensive compared to other construction materials

BRE (2002), after the assessment of the Haverhill construction, concluded that the cost of the lime-hemp buildings was € 790 per square metre compared to € 717 for the traditional constructions, equal to a 10% cost difference. It was however claimed that some further savings, in time and labour costs, were reasonable to be expected if more houses had been constructed using lime-hemp. The applied technique consisted in pouring and tamping the mix into timber shuttering which is more expensive compared to the spraying technique. It has been assumed that the cost difference of lime-hemp might be a constraint to its widespread diffusion.

Both the *entrepreneur* and the *builder* noted that the hemp hurds, the primary constituent of lime-hemp, are produced and sold in the UK at about € 250-300 per ton. The cost gets doubled if transportation to Ireland is added. Therefore they both agreed on the necessity of a local hemp processing / lime-hemp producing industry in order to make this type of construction widespread in the country. The *builder* claimed that if a sufficient market demand was considered, and the use of mechanisation like a pumping

machine for spraying the biocomposite was introduced, the final cost would be reduced further on making lime-hemp extremely competitive among standard construction materials and methods.

4.2.11. Consumer resistance to innovation

Consumers are resistant to innovation by definition. BRE (2004) considered it as a commercial barrier to the take up of building materials based on crops. This feature is not easy to assess because it involves many variables and psychological aspects that would need an entire research project to be properly explored. However, with the help of a questionnaire, it has been tried to shed some light on it with particular reference to lime-hemp.

When asked if they would buy a house or an apartment made with lime-hemp, 60% of the respondents said they would not. The majority of the reasons provided evidenced a complete lack of awareness on the biocomposite and therefore the involved impossibility to make a choice. It would be interesting to ask the same question in a few years when lime-hemp will be probably much more known by the average consumer.

4.2.12. Image of lime-hemp spoiled by DIY enthusiasts *(n.e.b)*

Wolley (2006) recognizes the existence of a number of cases where self-build enthusiasts, who learned about lime-hemp construction through the Internet, constructed sub-standard buildings because of the lack of professional advice. The image of lime-hemp construction could be spoiled due to this kind of situations and thus lose credibility in the new emerging market.

The *builder* admitted the issue to be one of his biggest fears after many years in the construction business. He claimed to have seen many cases where enthusiastic non builders have used hemp in an inappropriate way. A work badly carried out with lime-hemp can easily end up with a rotten wall as well as irreparable damage to the structure if wooden frame is used.

4.2.13. Lack of a number of constructed examples *(n.e.b)*

Lime-hemp construction is emerging only recently in Ireland. There are just a few constructions where the technique has been applied. The *builder* confirmed that the majority of them are not officially known because made by self builders. In order to help the biocomposite to become mainstream, a higher number of constructed examples is needed for both demonstration and assessment purposes. The concept was validated by the *cement expert* when he suggested that in addition to research, practical demonstration of suitability and economic feasibility would be requirements to encourage the uptake of lime-hemp.

4.3. Knowledge Issues

Knowledge issues regard the generalized lack of awareness on the biocomposite among the different stakeholders that could potentially be involved in the industry. Farmers, architects, builders, the construction industry in general, and consumers are those who were initially considered in the assumptions. Two new groups have subsequently emerged during the analysis of the collected data: the financial sector, and the Government.

The assumptions on the stakeholders' lack of knowledge are not based on the existing literature. No such kind of information has been found. Nonetheless it has been considered as having the maximum importance.

4.3.1. Farmers' lack of knowledge

Farmers are at the first stage of the lime-hemp production chain and provide the most important raw material for its manufacture. It has therefore been assumed that their awareness on hemp, its growing techniques, as well as its different uses are key issues for the development of any activity based on the crop, the lime-hemp industry in particular.

The *farmer* claimed that Irish farmers in general know nothing about hemp. The crop is totally new for them. However, looking at its high profitability, the ease of the growing

technique involved and the general benefits compared to a similar rotational crop like sugar beet, hemp will probably become a common cash crop amongst Irish farmers during the next few years.

4.3.2. Architects' lack of knowledge

Architects were believed to be another category of stakeholders whose awareness on lime-hemp is extremely important. They are those who make the project for a construction as well as those who advise the customers on a variety of issues. Their preparation on lime-hemp is however part of a bigger concept called ‘green architecture’ or as already mentioned in paragraph *2.3* on ‘natural building’.

The *builder* claimed there has been a surge of interest from architects in ecologically friendly ideas. According to him, it is becoming a niche where architects can specialize on. He personally knows Tom Woolley, professor of architecture at the Queen University Belfast and one of the primary academic promoters and researchers of lime-hemp. People graduating from these kinds of schools, the *builders* said, are more easily exposed to recent issues and more likely to have an interest in lime-hemp.

The *entrepreneur* confirmed what the *builder* said by claiming that there already is a number of architects promoting lime-hemp, as well as a lot of young students graduating in architecture that are excited about the biocomposite. He sees a bright future for the new material and he does not consider the architects’ lack of knowledge a big issue.

The results of the architects’ questionnaire are in line with the insights already provided by the *builder* and the *entrepreneur*. More than a half of the respondents (56%) are involved in ‘green building’ projects and the majority of them belongs to the class age ‘from 26 to 35’ years. Among the respondents, 44% are aware of lime-hemp and once again they belong to young class ages (‘from 26 to 35’ and ‘from 36 to 45’ years old). Awareness on the biocomposite is proven by their good knowledge of its strengths and weaknesses. It is important to note that no direct relation between ‘green building’ involvement and lime-hemp knowledge was found. The results further demonstrate that young architects are more exposed to current issues, and that the recent introduction of

‘natural building’ techniques in the academic world is reflected in the professional reality.

The author is however aware that the reliability of the results of the questionnaire might be biased by replies provided primarily by professionals already exposed to the issue. According to the findings, 44% of the responding architects is in fact aware of lime-hemp. Generalisations based on this result would not be justified; it is preferred to consider the result as confirmation of what already suggested by the *builder* and the *entrepreneur*.

4.3.3. Builders' lack of knowledge

Builders are a group of key stakeholders whose awareness on lime-hemp is fundamental for its broad uptake. Looking at the little number of existing constructed buildings it was logically assumed that Irish builders are generally unaware about the biocomposite.

The *builder* confirmed the assumption. He claimed that Irish builders are commonly not aware about it. According to him, the building industry is very conservative and made of a group of people who are extremely resistant to innovation and new products. He also believes that in the building industry there is a general perception that man-made materials are somehow superior to natural products.

4.3.4. Construction industry's lack of knowledge

The construction industry in general was assumed not to be aware about lime-hemp. Sustainable building techniques are still a minuscule emerging market in Ireland. Therefore the mainstream building industry was presumed not to consider at all ‘natural building’ methods, lime-hemp in particular.

Unfortunately, as already mentioned, it was not possible to carry out an in-depth interview with a spokesperson from the Irish Construction Industry Federation. The only consideration the author feels to express as well as considering it as a result is that there is a complete lack of both interest and knowledge on sustainability as a general issue. Further evidence is the impossibility to find any report or relevant information on

sustainable construction in the CIF's website (www.cif.ie). For this reasons, lime-hemp biocomposite and construction techniques are believed to be generally unknown by the Irish construction industry.

4.3.5. Consumers' lack of knowledge

The current lack of a market for lime-hemp was the factor that made logically assume consumers are not aware about the biocomposite. They are at the last stage of the supply chain and, for a successful broad development of lime-hemp, they have to be aware and well informed about any aspect related to the material.

The results of the consumers' questionnaire confirmed the assumptions. It showed that only 27% of the respondents are aware about the existence of the biocomposite. Nonetheless there is a complete lack of knowledge on its strengths and weaknesses. Among the respondents, 56% are interested in having information about it for a variety of reasons like future purchases, curiosity, and general knowledge for future decision making. The results however reflected a general unawareness of consumers on the materials used to build the house/apartment they lived in, i.e. 66% of them do not know. It was interesting to find out that a large majority of the respondents (82%) would be interested to know the material employed in the buildings they owned. This is considered by the author as a failure, deliberate or not, of the construction industry to inform consumers.

4.3.6. Financial sector's lack of knowledge *(n.e.b)*

The financial sector's lack of knowledge has not been considered in the assumptions. Nonetheless during the interview, the *entrepreneur* noted the lack of understanding among the people who provide financing as one of his biggest problems. The issue has already been discussed among the commercial barriers, in particular when analysing the difficulties to start-up the hemp industry. It is however believed to be extremely relevant in this context as well.

4.3.7. Government's lack of knowledge *(n.e.b)*

The Government's lack of knowledge was not considered among the assumptions. During the analysis of the colleted data, the role of the Government emerged. Both the *builder* and the *entrepreneur* suggested that the Government could assume a key role in helping lime-hemp to become mainstream. It could support farmers and entrepreneurs by providing grants and subsidies, as well as speeding up the provision of growing licences. It could also help supporting scientific research. Unfortunately none of those seems to be happening for the moment.

4.4. Regulatory Issues

Regulatory barriers comprise a series of issues directly depending on the current legislation. They are considered to be extremely important for the mainstreaming of the biocomposite. This set of issues may be broken up in three main subcategories: the necessity for farmers to obtain a licence from the authorities for growing hemp; the lack of an official certification on the biocomposite material; and issues related to the structural insurance of lime-hemp constructions.

4.4.1. Farmers' need to get Garda clearance for hemp cultivation

Hemp (*Cannabis sativa* L.) is classified as a controlled drug under the misuse of drugs regulations in the Republic of Ireland (Irish Statute Book, 1988). According to the European legislation, farmers are allowed to grow hemp as long as the seeds belong to the approved variety list and produce hemp containing less then 0.2% by weight of THC (Council Regulation (EC) 953, 2006). In Ireland farmers can apply for a growing licence to the Department of Health and Children (Marriott, 2004). Garda Síochána, Ireland's national police, must certify that the requesting farmer never committed any penal offence (Tong, 2007 pers. comm.).

The bureaucracy involved in the cultivation of hemp has been assumed to be a constraint limiting the willingness of farmers to grow the crop and therefore the overall uptake of lime-hemp. The *farmer* disproved the assumption by saying that licences are easily obtained as long as the applicant is a good character and has no blemishes. He

does not see the licensing procedure as an obstacle and he is completely in favour of it in order to avoid any untrustworthy individual becoming involved with the growth of hemp in the country.

4.4.2. Cooperation from the authorities in the release of the authorisations *(n.e.b)*

The cooperation from the authorities in the release of the authorisations for growing hemp has already been mentioned among the commercial barriers, in particular when analysing the difficulties to start up the hemp industry. The *entrepreneur* in fact decided to locate his own business in Limavady, Co. Londonderry, Northern Ireland due to the higher cooperation from the British Government compared to the Irish one.

In this section the issue is newly considered as regulatory barrier with reference to the Republic of Ireland. The *farmer* confirmed the delays in the provision of the licences encountered in 2005. According to him the delays happened only because it was the first time a number of farmers applied for commercially growing hemp. However, he claimed to be sympathetic with the authorities of the Republic and believes that they will be more amenable as they become more familiar with the new crop.

4.4.3. Lack of Agrément certificate

The Building Regulations are the main regulatory system ruling over building standards in Ireland. They set minimum standards of performance and provide a set of guidelines for construction (O'Siochru, 2005). Compliance with the Building Regulations in the country is primarily undertaken and provided by architects and builders (Daly, 2007). However, architects are heavily reliant on the certification of both the products and the entire construction systems because of the responsibility they must assume when they provide a 'certificate of compliance'.

For composite construction systems, in Ireland there is a particular national certificate: the Irish Agrément certificate. It is defined by the Irish Agrément Board (2007), the public authority in charge of producing it, as "designed specifically for new building materials, products and processes that do not yet have a long history of use and for

which published national standards do not yet exist". In substance, it tests composite construction systems for the very particular climatic conditions experienced in Ireland.

Many new construction systems yet do not have Agrément certificates but instead rely on 'self certification' by architects for the design, and similarly on certification by the contractor for the built quality and performance (O'Siochru, 2005). This is the case of lime-hemp. It has therefore been assumed that the lack of Agrément certificate would act as a barrier to its mainstreaming, mostly by avoiding architects to take the full responsibility for a construction method for which no official assessment exists.

The *builder* confirmed the assumption by claiming that a lot of architects are reluctant in signing projects for the lack of certification on lime-hemp. The idea is reinforced further on by the findings from the architects' questionnaire. Almost the entirety of the respondents (94%) would not assume the responsibility of a lime-hemp construction project with a certificate of compliance in case their customer asked for it. Their reasons vary from lack of experience to lack of knowledge, but they all relate to the lack of an Agrément certificate.

The *entrepreneur* is aware about the necessity of such a certification. He claimed not to have had time to work on that yet, but he had it planned for 2008. The processing facility, he said, will be operative around spring 2008 and working at only 10% of the full capacity. Moreover the produced lime-hemp will be momentarily sold as insulating wall plaster where the Agrément certificate is not needed.

4.4.4. Difficulty to obtain certification

The Standards Section of the Irish Department of Heritage Environment and Local Government seeks for a 60 years durability standard on main building elements for any form of social housing grant aid or for any form of tax exemption or relief for housing (O'Siochru, 2005). According to Walsh & Colley (2006), other than compliance with the Building Regulations, the Irish Agrément Board during the assessment process for an Agrément certificate also looks at the 60 years durability standard. This particular requirement has been assumed to be difficult to assess for lime-hemp being a fairly recent construction method.

O'Siochru (2005) mentions a project called ‘Saor’ where a building design team would have worked closely with the Royal Institute of Architect of Ireland (RIAI) and the Environment Protection Agency (EPA) in order to develop an open certification for the lime-hemp/timber frame construction system. Unfortunately the RIAI and the EPA could not reach an agreement on the needed funding for the project and the process was momentarily suspended (O'Siochru, 2007 pers. comm.). The event has been assumed as a further evidence of the difficulties to obtain the certification on the biocomposite construction system.

The *certification expert* confirmed that the Irish Agrément Board’s duty is to make sure the assessed building method meets the requirements by the Building Regulations. In addition he confirmed it also looks at the 60 years durability standard of the product with consideration to the Irish climate conditions. He claimed that the durability standard is assessed by considering anything that is relevant for determining the durability of the biocomposite, e.g. existing constructions in different countries with similar weather conditions to Ireland, or other biological materials that have already been used in connection with lime to reinforce it historically over time.

The *certification expert* does not see the lack of certification on lime-hemp as the main barrier. He claimed that the Irish Agrément Board would certainly consider anybody looking for the certification of the biocomposite. According to him, it would be certified quite quickly provided that it can be shown that it meets both the requirements by the Building Regulations and the durability standard. He also stated that it would be possible for an association or group of builders to obtain the certification if they came up with the specification of lime-hemp together with the controls in manufacturing and installing it.

4.4.5. Difficulty to get structural insurance

The lack of certification affects the ease to obtain a structural insurance coverage on the lime-hemp construction. According to O'Siochru (2005), the certification gains its effectiveness through the legal systems for property transfer and insurance. Lending

agencies in fact require that the property is insured before mortgages or other finance are advanced against it as collateral.

Homebond, the major provider of structural insurance cover in the Irish construction sector, is reputed not to provide its cover unless the new materials employed in the building have an Agrément certificate (Walsh & Colley, 2006). According to Morgan (2004), in Ireland it is virtually impossible to get an insurance cover if the house about to be built is different from a traditional concrete and cement or timber frame structure.

A research has been recently carried out among the most prominent home insurance companies in Ireland, Homebond excluded (Flanagan, 2006). It was found that about two thirds of the companies surveyed were willing to insure a lime-hemp structure but only under stringent conditions: the premium was doubled, in some cases even more than that, compared to a traditionally built house.

The *builder* recognised the barrier as an odd situation limited to the Irish reality. He claimed that the Hemp Lime Construction Products Association in the UK has amongst his founding members Zurich Insurance, which is the English equivalent of the Irish Homebond. In France he said it does not seem to be an issue. According to him in Ireland Homebond has no incentives to enlarge its coverage to new sustainable building methods and therefore it just stays behind what prescribed by the Building Regulations.

The *insurer* only stated that Homebond looks for compliance with the national Building Regulations. Where new or non-conventional methods of construction or new materials are used, Homebond seeks for an appropriate certification from a competent accredited body, such as the Irish Agrément Board or equivalent, which demonstrates suitability for intended use and conditions of use, as well as compliance with the relevant Irish Building Regulations.

4.4.6. Lack of vision for sustainability from the authorities *(n.e.b)*

There seems to be a complete lack of vision for sustainability from the Irish authorities. Sustainability is not at the top of their agenda. It is talked about but finally only treated

cosmetically. This kind of approach is certainly slowing down the lime-hemp industry as well as the broad uptake of the biocomposite in the construction sector.

The *builder* suggested that when society has goals like reducing carbon dioxide emissions or becoming more self-sufficient by producing goods in the country, the authorities should take the first step and implement policies to facilitate their achievement. He believed that it is up to the Government helping farmers and entrepreneurs with grants and incentives so that the risk gets shared.

The *entrepreneur* agreed that Governments are not doing anything real about sustainability. He claimed there is no support at all for sustainable industries, and that he did not receive any grant or subsidy from either the Irish or the British Governments. According to him Governments could support hemp farming by subsidizing the construction of storage barns, as well as supplying capital for hemp processing businesses. Fast track planning permissions and hemp growing licensing together with a real commitment into research would be two other examples suggested by the *entrepreneur*.

4.5. Psychological Issues

Psychological issues relate to a set of preconceived ideas looming in the mind of people. They are believed to be objectively wrong and usually a result of the mix between lack of information and misinformation. Very often they are the product of propagandistic policies aimed at defending the interests of small groups which may derive private benefit from them. The mainstreaming of lime-hemp might suffer from the existence of such psychological bias.

4.5.1. Hemp association with marijuana

Hemp contains THC, a psychoactive substance, in almost the entirety of its varieties. In legal hemp strains, the quantity of the psychoactive substance is so low that its use for undesired purposes would not make any sense. This explains the reason why farmers are now allowed to grow the crop as long as they abide to certain rules.

It is proven that in the United States during the 1930's, a group of private industries worried about the potential of hemp did their best in order to stop its cultivation by lobbying the Government and demonizing marijuana through public propaganda (Gibson, 2006). The crop was successively declared illegal almost all over the globe. Even if more and more people are today rediscovering the difference between hemp and marijuana, their strict association is still very strong.

Young (2005) claims that the general increased level of hemp knowledge will reduce its association with marijuana. At the same time the whole hemp industry credibility would increase and, in turn, the willingness of governing bodies to allocate cultivation permits would follow suit.

It has been assumed that hemp association with marijuana might slow down the uptake of lime-hemp among its stakeholders. The *builder* confirmed that in the US it is widely spoken that authorities demonise hemp for its marijuana connection. However, he said, nobody officially claims it neither in Ireland nor in the rest of Europe. The *farmer* said that the description of 'industrial hemp' emphasises its industrial aspect and help farmers in general to segregate the connection with marijuana in their mind.

On the consumer side, according to the finding from the consumers' questionnaire, the association of hemp with marijuana is still quite strong. A list of the ten main uses of hemp has been provided and consumers have been asked what they related hemp to. The majority of them (73%) associated hemp to 'dope', 70% to 'clothing', 35% to 'paper', 35% to 'ropes & nets', 19% to 'construction & insulation materials', 15% to 'cosmetics', 8% to 'medicines', 4% to 'animal bedding', and no one to 'human food' or 'animal food'.

4.5.2. Misconception that "concrete built is better built"

'Concrete built is better built' is the title of a promotional video by the Irish Concrete Federation (ICF, 2007). Cement-concrete has been the most used building material during the last fifty years and very likely the only one known by the majority of the people today. The concrete industry is praising concrete to the detriment of any other

material with a variety of information on beneficial properties like durability, insulation, fire resistance, re-sale value, and even environmental benefits.

It has therefore been assumed that consumers in general have the false impression that concrete is the sole and most suitable construction material for any kind of application (and for their houses in particular). The *builder* agreed that most of the people consider concrete a better solution than any environmentally friendly building method, lime-hemp included. According to him, the reasons are due to general misunderstanding as well as good propaganda from the cement industry. He added that there is ample evidence that cement is not a long lasting material. Cement buildings, he said, have been around for a recent period of time and people are not yet aware that many are delaminating after fifty years.

The *cement expert* claimed that concrete has proven itself suitable for a wide range of uses at reasonable cost and without requiring a high level of maintenance. It has stood, he said, the test of time and people can rely on its durability. According to him, these are the reasons why structures built with concrete or concrete products are generally regarded as safe investments.

On the consumer side, according to the results from the questionnaire, half of the respondents believed that ‘concrete built is better built’ than environmentally friendly materials. However some of the reasons provided are a demonstration that their perception is motivated by lack of information. Answers like ‘sound proofness’, ‘better insulation’, ‘durability’ seem more like a mere repetition of the concrete industry propaganda rather than coming from the consumers’ personal experience. Some responses like “it is what people always told me” or “it is all I know really” and “it is more traditional” are further evidence of the overall misinformation.

4.5.3. Misunderstanding of the consumers on the ‘ecological agenda’ concept *(n.e.b)*

The construction industry’s ‘green-washing’ attitude as approach to sustainability has already been discussed in paragraph *2.2.3*. Unfortunately it seems that such misconduct is reflected into the consumers’ behaviour.

According to the *builder*'s experience, people generally believe that having an ecological agenda means saving heating costs. He stated that it is one of the remarkable propaganda accuse over the general building industry that produces various forms of synthetic insulation. He reminded that ecologically saving in building means using materials which are ecologically friendly and sustainable in the building process, as well as allowing to save money by reducing the heating requirements.

4.6. Invisible Issues

Invisible issues regard the potential vested interest that might arise from the cement industry and the construction industry in general. The substitution of lime-hemp to cement-concrete, brick, blocks, and insulation materials could be perceived as a threat by the already existing industries in case of a widespread uptake of the biocomposite.

4.6.1. Cement industry's vested interest

Lime-hemp building technique is a sustainable substitute of cement-concrete and therefore it has been assumed that the cement industry could be threatened by its potential mainstreaming.

The *builder* disproved the assumption. He does not think that the cement industry would ever perceive lime-hemp as a threat. Of all the limestone that is burned he said, only 2% goes to make lime and only 7% of that small fraction is used within the building industry. In any event, should it turn around, the cement industry would be in the position to supply lime. He claimed that in France, one of the biggest promoters of the lime-hemp business is the Lhoist group, one of the main producers of cement in Europe. Lime-hemp could definitely be an opportunity for the cement industry.

According to the *cement expert* lime-hemp might well be a competitor of cement, along with other existing materials like timber and steel. Each would have benefits and disadvantages. He claimed that all industries would in any case attempt to defend their position and the investments already made to bring it to the present state. Anyway,

according to him, this does not suggest that new products and methods cannot evolve and grow since development itself is always ongoing.

4.6.2. Construction industry's vested interests

Lime-hemp biocomposite, apart from cement, replaces many different construction materials currently used. According to Woolley (2006), lime-hemp makes the use of sheathing boards, vapour barriers, insulation quilts or blown-in cellulose redundant. Moreover, its versatility of uses as insulating wall infill, roof insulation, insulating wall plaster, floor insulating slab and screed, would certainly reduce the use of those materials currently used for such purposes. For these reasons, it has been supposed that the construction industry in general would try to slow down or prevent the widespread uptake of lime-hemp.

The *builder* supposed that the main manufacturers of the alternatives to lime-hemp, the synthetic insulation material industry in particular, would be opposed to the mainstreaming of the biocomposite. He did not know what they could actually do in practice though. The *entrepreneur* claimed that it is always very difficult to know what goes on in the background. He is sure there already are vested interests, but according to him they are unnecessary. He believes that the lime-hemp industry will remain a small reality in the overall construction sector thus unable to put anybody out of business.

CHAPTER FIVE: ANALYSIS AND DISCUSSION

5.0. Introduction

The results of the research previously specified will be analysed and discussed in the current chapter. Barriers have been classified further on according to their priority, which is the level of attention they require if mainstreaming of lime-hemp in the short/medium term is considered as the goal to be achieved. The key findings of the research are subsequently discussed. This will allow the reader to better understand the author's perspective, and possibly serve as a starting point for further research.

5.1. Priority levels

The data gathered with the help of in-depth interviews as well as with questionnaires allowed the exploration of every single barrier initially assumed. As already mentioned, a certain number of new barriers have emerged during the analysis of the collected data. Once again they are identified with the addition of the '*n.e.b.*' acronym (newly emerged barrier).

A mere list of barriers would be useless if a practical interpretation was not provided. Therefore every single barrier has been given a priority level according to the attention it requires. Three levels of priority (low, medium, and high) linked to three colours (green, yellow, and red) have been used as a further classification of the identified barriers:

- Low priority (green) → Barrier not existent or if existing, which can either be easily overcome or which is already about to be solved. Priority on this set of barriers is low and therefore it requires the minimum attention. It is however essential to be aware of it being part of the whole system and being linked to other more important barriers.
- Medium priority (yellow) → Barrier existent which requires a certain level of attention. Either it is already in the process of being solved, or it is directly dependant on the solution of a higher priority barrier. This set of barriers is indeed important even if not deserving the maximum attention.

– High priority (red) → Barrier existent requiring the highest level of attention. The entirety of the collected data proved and reinforced its existence and importance. It is here where the most effort needs to be put for lime-hemp to become mainstream.

Tables 5.1, 5.2, 5.3, 5.4, 5.5, and 5.6 show the complete list of barriers linked to their priority level. In each category (technical, commercial, knowledge, regulatory, psychological, and invisible), barriers are reviewed grouping them according to their priority level.

5.1.1. Technical Barriers

Technical barriers, as shown in Table 5.1, have all low and medium priority. This is definitely a good starting point for the mainstreaming of the biocomposite. It generally means that there are no major technical constraints in the whole supply chain including the growth of the crop, and the production and the use of the construction material itself.

Table 5.1 – Technical barriers and priority level

TECHNICAL	
LOW	Lack of knowledge in hemp growing
MEDIUM	Hemp harvesting (*n.e.b.*)
LOW	Poor hemp quality
LOW	Lack of expertise in lime-hemp production
MEDIUM	Lack of expertise in lime-hemp use
MEDIUM	Non appropriate material
MEDIUM	Non load bearing material
MEDIUM	Weather-dependent construction
LOW	Season constraint in the use of lime-hemp (*n.e.b.*)

Source: produced by the author

Knowledge in growing hemp is not an issue for Irish farmers. Those who are already familiar with sugar beet would be able to apply their know-how to the cultivation of hemp. Quality of the crop fibre is not relevant for lime-hemp. Only the wooden core of hemp, which is not dependent on the fibre quality, is employed. Expertise in lime-hemp production can be easily gained. The production process does not require sophisticated machinery and processing facilities can be easily replicated. There are no seasonal

constraints in the use of the biocomposite. The only necessary expedient is to avoid lime plastering on lime-hemp walls when the external temperature is below 5°C.

The harvesting of hemp was once an issue but it is about to be solved. The first hemp harvester is now available in the country and ad-hoc headers adaptable to the existing combines are about to be developed. The use of lime-hemp requires understanding and training but any existing builder would be able to develop them. Training courses have been already organised and will continue to be in the future. Lime-hemp will never completely substitute cement-concrete because of its poor strength. Nonetheless it will easily find its niche in certain types of construction where high compressive strength is not needed or in combination with frames made of timber, steel, or concrete, materials definitely more suitable to support loads. Some issues arisen on lime-hemp use under very exposed weather conditions are about to be solved with expedients that keep the lime-hemp wall protected.

5.1.2. Commercial barriers

Commercial barriers, as shown in Table 5.2, present a balanced mix of priorities. Three of them have been red tagged meaning that they require the maximum attention. They are not however the most important being directly dependant on the existence of other barriers, namely regulatory and knowledge.

Table 5.2 – Commercial barriers and priority level

COMMERCIAL	
LOW	Difficulty to source hemp seeds
LOW	Poor hemp crop yield
LOW	Necessary winter storage for hemp
MEDIUM	High transportation costs
LOW	Farmers' profitability
HIGH	Difficulty to start-up the hemp industry
LOW	More profitable markets for hemp
MEDIUM	Lack of the lime-hemp industry
LOW	Lack of economy of scale
MEDIUM	Lime-Hemp expensive compared to other construction materials
MEDIUM	Consumer resistance to innovation
HIGH	Image of lime-hemp spoiled by DIY enthusiasts (*n.e.b.*)

HIGH	Lack of a number of constructed examples (*n.e.b.*)

Source: produced by the author

Certified hemp seeds are currently sourced outside Ireland in France and Germany. In the medium-term future, when the Irish hemp industry is established, the local availability of seeds will not be excluded. The hemp yield on Irish soil is acceptable and, thanks to the particular wet conditions, it is believed to be higher than in the continental Europe. Research on cross-breeding different hemp varieties will likely bring to a higher yield in the future. Storage for dry hemp straw is not an issue because barns are already existent and owned by farmers. The availability of public grants for the construction of storage buildings would improve the situation further. Farmers' profitability in growing hemp is very appealing. It seems there are no other crops currently matching the economic results of hemp. Moreover the profitability of the crop is directly linked to the mentioned potential improvements of yields in the future. Hemp hurds do not seem to have competing uses being usually a by-product of the hemp processing industry. Future markets arising from the exploitation of hemp will not compete with the production of lime-hemp. Large scale of production is not needed for the lime-hemp industry to be profitable. The production facility would in fact be dependant on a few farms and it could be easily replicable in different locations around the country.

Transportation of the dried hemp straw weighs on the profitability of the lime-hemp industry. In order to reduce its incidence, hemp farms should be located within a 15-30 km radius range distance from the processing facility. The lack of the lime-hemp industry does not seem to be justified by the absence of demand or supply. A vast potential final market as well as farmers who would be able to supply hemp already exist. They both depend on the presence of processing facilities though. The existence of a final market, together with the application by spraying would reduce the overall cost of the biocomposite making it competitive among the standard construction materials and building techniques. Moreover increased awareness among consumers would reduce their resistance to the innovation introduced by lime-hemp.

The lime-hemp industry is facing some difficulties during its emergence. The main one is financial, and in particular consists in the lack of understanding among those who

provide funding. The many potential uses of hemp seem to confuse investors and make them reluctant to invest in the business. Further difficulties concern the need of a stable supply from farmers and therefore the necessity for them to be organised, as well as the little amenability of public authorities.

Lime-hemp seems to be popular among self-builders. Unfortunately this is creating image related problems due to their lack of professional advice resulting in sub-standard constructions. The overall awareness on this new building method is further reduced by the absence of major constructed examples. They are indeed needed for both demonstration and assessment purposes.

High priority commercial barriers are believed to be dependant on the lack of general awareness on the biocomposite (knowledge barriers), and the lack of an official certification provided in the form of Agrément certificate (regulatory barrier). Solving the two would consequently help in reducing the stress on the just mentioned commercial issues.

5.1.3. Knowledge barriers

Knowledge barriers, as shown in Table 5.3, display the highest rate of 'high priority' issues. This is not a surprising result as lime-hemp is fairly new as well as an unusual construction material and building method. Maximum effort should be put in increasing the overall awareness on the biocomposite for it to become mainstream in the short-medium term.

Table 5.3 – Knowledge barriers and priority level

KNOWLEDGE	
MEDIUM	Farmers' lack of knowledge
LOW	Architects' lack of knowledge
HIGH	Builders' lack of knowledge
HIGH	Construction industry's lack of knowledge
HIGH	Consumers' lack of knowledge
HIGH	Financial sector's lack of knowledge (*n.e.b.*)
HIGH	Government's lack of knowledge (*n.e.b.*)

Source: produced by the author

Architects, among the different stakeholders, seem to be those with the highest awareness on lime-hemp. Green architecture has recently become a niche in the market and the introduction of lime-hemp in the academic debate seems to have increased awareness on it, mainly among young architects who recently graduated.

Farmers are generally unaware about hemp as a crop and, as a consequence, on its different uses. Nonetheless that does not appear to be an issue. Looking at the high profitability of hemp, the ease of growing it, and the benefits compared to similar rotational crops, it is likely to become a common crop in Ireland in the short future.

Builders and the Irish construction industry in general are unaware about the existence and potential of lime-hemp. The perception that man-made materials are somehow superior to natural products seems to prevail among them. Their conservative attitude and the recognised construction industry's 'green-washing' approach increases the urgency in the resolution of the arisen knowledge barriers.

Consumers are generally not aware about the materials used to build the constructions they own or they live in. Those who claim to be aware about the existence of lime-hemp are completely uninformed about its benefits and drawbacks.

The financial sector has already been mentioned as a constraint to the emergence of the lime-hemp industry. Lack of knowledge on the biocomposite and on the potential of hemp as a crop are its main deficiencies.

The Government is another main stakeholder which seems to be unaware about the existence and the potential of lime-hemp, and which is doing nothing to promote it. Knowledge by the Government is considered to be essential for the biocomposite to become mainstream.

5.1.4. Regulatory barriers

Regulatory barriers, as shown in Table 5.4, present a mix of priorities, the majority of them characterised by a 'red' label. Among this category lies what is believed to be one

of the most important barriers restraining lime-hemp from being broadly accepted by the construction sector, i.e. the lack of an official certification.

Table 5.4 – Regulatory barriers and priority level

REGULATORY	
LOW	Farmers' need to obtain Garda clearance for hemp cultivation
HIGH	Cooperation from the authorities in the release of the authorisations (*n.e.b.*)
HIGH	Lack of Agrément certificate
LOW	Difficulty to obtain certification
MEDIUM	Difficulty to get structural insurance
HIGH	Lack of vision for sustainability from the authorities (*n.e.b.*)

Source: produced by the author

Farmers must have a clean criminal record to be allowed to grow hemp. It does not seem difficult for them to obtain growing licences though. The involved bureaucracy is perceived as a good mean to keep untrustworthy individuals out of the hemp business in the country.

Currently there seems to be a lack of cooperation from Irish authorities in the provision of growing licences. It is very important for farmers to obtain fast feedbacks when they apply for growing permits. Delays in sowing could jeopardize a successful harvest. The issue will hopefully be solved in the short future once authorities become more familiar with the new crop.

Lime-hemp does not have an official certification yet. In Ireland, because of a particular regulatory system, it appears to be of utmost importance for new building materials and construction systems to be endorsed by the Irish Agrément board with an Agrément certificate. Architects, builders, and structural insurance providers rarely assume the responsibility of new constructions without such certification. Even if no attempts to obtain the needed certification have been done yet, there seem to be no difficulties provided that it is demonstrated that lime-hemp meets both the requirements by the building regulations and the 60 years durability standard.

The difficulty to obtain structural insurance has been considered in particular and it has resulted in being directly dependent on the availability of an Agrément certificate. Once

the certification is obtained, there would be no problem at all for lime-hemp to be accepted by structural insurance providers.

Other than lacking knowledge on lime-hemp, the Irish Government is displaying lack of vision for sustainability. It seems that sustainability is only cosmetically dealt with, even if environmental and social issues are recognised as deserving the maximum attention. Again, the Government's support is believed to be essential for the biocomposite to become mainstream.

5.1.5. Psychological barriers

Psychological barriers, as shown in Table 5.5, deserve a good level of attention. However, only one barrier has been red tagged because it is believed to require the highest priority. Once again there is an evident link between lack of knowledge and psychological issues.

Table 5.5 – Psychological barriers and priority level

PSYCHOLOGICAL	
MEDIUM	Hemp association with marijuana
HIGH	Misconception that "concrete built is better built"
MEDIUM	Misunderstanding of the consumers on the 'ecological agenda' concept (*n.e.b.*)

Source: produced by the author

Officially hemp and marijuana are completely different. Nonetheless the majority of consumers seem to primarily associate hemp to recreational drug uses. It is believed this will progressively disappear with the general increased level of knowledge on hemp and its multiple beneficial uses.

Consumers are misled by the construction industry and brought to believe that having an 'ecological agenda' only means saving heating costs. Unfortunately this goes to the detriment of real ecologically friendly materials and solutions like lime-hemp. The increased awareness on sustainability among consumers will likely align them with reality as time passes.

Cement-concrete has been the most used building material during the last fifty years as well as the most known by the majority of the people today. Consumers generally seem to perceive it as a better solution than environmental friendly materials. Again, a more diffused knowledge on sustainable building is needed to avoid this kind of misconceptions. Lime-hemp and its widespread diffusion would only benefit from this.

5.1.6. Invisible barriers

Invisible barriers are shown in table 10.6. Only one out of two has been considered requiring high priority.

Table 5.6 – Invisible barriers and priority level

INVISIBLE	
LOW	Cement industry's vested interest
HIGH	Construction industry's vested interests

Source: produced by the author

It appears that the huge size of the cement industry will never be threatened by the emerging lime-hemp industry. Moreover, the latter could become an opportunity for the cement industry as limestone is the raw material for the production of both lime and cement.

Vested interest are likely to emerge from the manufacturers of those building materials made redundant by lime-hemp. It is not possible to know what kind of actions will be undertaken to slow down the take up of lime-hemp though. It is however an aspect that does not have to be underestimated.

5.2. Key findings

The key findings of the research are discussed in the following paragraphs. The overall barriers issue is apparently depending on two main deficiencies: the absence of an official certification and the lack of generalised awareness on the biocomposite. In addition, the role of the Government is believed to be of utmost importance although it is seemingly subject to certain limits.

5.2.1. Emergence of the lime-hemp industry in Ireland

In the modern construction industry it is unusual to link agriculture and industry for the production of building materials. Lime-hemp is therefore an exception since it is made up of a mix between an agricultural crop (hemp) and an earth derived material (lime).

The results of the research proved that attempts to set the conditions for an Irish lime-hemp industry are in progress. The *entrepreneur* said the first hemp processing / lime-hemp producing facility will open sometime in spring 2008 (McCabe, 2007 pers. comm.). The factory will be located in Northern Ireland and will be supplied by farmers from both sides of the border. The *farmer* is dealing with the logistic and supply management by offering contracts to Irish farmers in the mid-Leinster region (Doyle, 2007a). This will assure a stable supply to the processing facility, thus partially solving one of the commercial barriers discussed in paragraph *4.2.6* i.e. 'Difficulty to start-up the hemp industry'.

It is interesting to note that the emergence of the Irish lime-hemp industry is a completely bottom-up approach. Without the presence of any kind of public incentive or policy, a number of private individuals are rediscovering the potential of hemp, and thanks to the beneficial properties of lime-hemp, they are finding a niche market in the building industry.

Demand for lime-hemp is there but unsatisfied. The *entrepreneur* has been producing lime-hemp on a small scale by manually mixing lime sourced on the Irish market and hemp hurds sourced in England for the last two years. Due to his limited production capacity, the mix has been sold as a plaster for the renovation of old cottages. Despite the high cost of importing hemp from England, he confirmed he has been able to still make a good profit (McCabe, 2007 pers. comm.). The *entrepreneur* claimed to have customers in the UK who are willing to buy the entire future production of his processing facility. This adds further evidence to the actual existence of demand for lime-hemp. However, a proper research on the exact market potential for lime-hemp is believed to be necessary in order for the industry to be aware on the limits to its growth.

On the supply side there seem to be no real issues. The high profitability of hemp as claimed by the *farmer* is about € 1,000 per hectare with an average yield of 12.5 t/ha. In case seeds were harvested, profitability would rise to € 1,600 per hectare. There are currently no crops matching this level of economic result (Tong, 2007 pers. comm.). Issues like the need to develop harvesting and storage techniques, as identified by Crowley (2001), seem not to be relevant anymore. Ad-hoc harvesters for hemp are now available and the first official hemp harvesting in Ireland has been a success (Doyle, 2007b). The *farmer* confirmed that storage barns already exist as they are no different from those used for storing hay. The situation would improve further on if public grants were offered for the construction of storage buildings, as advised by the *entrepreneur*.

The interesting agronomical properties of the crop make it very attractive to farmers. As claimed by Gibson (2006) hemp requires very little care after germination and it also eliminates weeds and other pests from fields during growth. The *farmer* confirmed this by stating that once the crop is sown around the end of April, beginning of May, the gate of the field can be closed until the harvesting time comes in September. There seems to be no doubts that if the yield and economics of the crop respect the expectations, hemp will likely attract an increasing number of farmers in the incoming years.

5.2.2. The role of regulations in the mainstreaming of lime-hemp

Lime-hemp lends itself to a variety of different applications. It can be employed as insulating wall infill in connection with a supporting frame made of timber, steel or concrete. It can be used as insulation on roofs as well as internal/external insulating plaster on walls. It can also be cast as ground/intermediate floor insulating slab, and as insulating floor screed.

In renovation works there seem to be no regulatory problems for the use of the biocomposite. The existence of a niche market where lime-hemp is employed as plaster in the retrofitting of old cottages, as per the *entrepreneur*'s current business, can be considered as a proof of this. In newly built though, a series of constraints are limiting the broad use of the construction material.

The lack of Agrément certificate is in fact creating difficulties for architects, builders, and providers of structural insurance. Architects and builders are reliant on such certification because of the responsibility they must assume when providing their certificate of compliance with the building regulations. Insurance providers, at the same time, do not justifiably feel protected without an official acknowledgment that lime-hemp fulfils the requirements as provided for by the building regulations.

It is believed that the resulting atmosphere of uncertainty and lack of confidence is what primarily limits the mainstreaming of lime- hemp in the country. It is in the interest of the stakeholders involved that the biocomposite gets assessed with the aim of obtaining an Agrément certificate. The first attempt to apply for the needed certification did not succeed because of disagreements on funding the application among the proponents involved (O'Siochru, 2007 pers. comm.). According to the results of the research (see paragraph *4.4.4*) there are no particular difficulties for the obtainment of the certification though. As long as it is proved that lime-hemp meets the requirements provided by the building regulations, as well as the 60 years durability standard, it will be successfully assessed.

A panel of architects, builders, entrepreneurs and supporting organisations would make up the necessary knowledge, skills, and influence needed to succeed in the certification of lime-hemp. As already suggested by Flanagan (2006), further research aimed at assessing the compliance of lime-hemp construction with the Irish building regulation would definitely increase the chances of a successful certification process.

Once the certification is obtained, new opportunities will certainly start to appear for the construction material and the industries behind it. It is therefore in the interest of the overall community that lime-hemp is certified by the Irish Agrément Board. It would be of primary importance that the certification is achieved with a non proprietary feature. In this way the commercial exploitation of the construction technique by a single company and thus its monopolisation would be avoided. Conversely, any architect and builder would be allowed to employ lime-hemp building technique in their projects, thus making the widespread take up of the biocomposite more likely.

The intervention of the Government as supporting organisation in the certification process would be desirable for making it more official and helping to spread knowledge on it. The delicate role of the Government is however discussed in the following paragraphs.

5.2.3. The role of knowledge in the mainstreaming of lime-hemp

The results of this research showed there is an overall lack of knowledge on lime-hemp among the key stakeholders who could potentially benefit from its widespread take up. The construction industry and builders in particular, consumers, the financial sector, and the Government unfortunately show little or no awareness on the biocomposite. Apparently their lack of knowledge is the second barrier in order of importance limiting its mainstreaming after the just mentioned certification issue.

Knowledge on lime-hemp is something that goes hand in hand with its widespread use. The more it is employed in construction and thus gaining high visibility, the more general awareness it is likely to raise. Therefore on one side it is believed knowledge will naturally increase following a virtuous circle pattern. The obtainment of the Agrément certification would definitely help in this direction.

On the other side, the knowledge process could be speeded up if the Government recognised the social, economic and environmental features linked to hemp as a crop and to lime-hemp as a construction material. A wide range of spin offs would in fact be generated with the emergence of the lime-hemp industry.

The agricultural sector would benefit at first. Given the decline in farming and the need for alternative crops, hemp would be appealing due to the ease in its cultivation and its high profitability. Farmers would benefit and consequently the local economy. The *farmer* and the *entrepreneur* confirmed that hemp processing / lime-hemp producing facilities need to be located within a short radius from farms, therefore improving local employment and the overall local economy. The multiple uses of hemp make it a potential raw material suitable for other new industries (see paragraph *4.2.7*) able to bring further benefits to the local economy.

Lime-hemp would be a locally produced construction material. This would partly reduce Irish dependence on importations and save the local economy from price fluctuations on the international markets. The employment of lime-hemp in construction would make the realisation of sustainable and healthy buildings possible. The sequestration of carbon dioxide in constructions (see paragraph *2.6.3.3*) would reduce greenhouse gas emissions and help Ireland to achieve the needed reductions in line with what is to be provided for by the Kyoto Protocol (EPA, 2006). The thermal properties of lime-hemp (see paragraph *2.6.3.1*) would reduce the heating requirements of buildings and consequently carbon dioxide emissions. Those living or working inside a lime-hemp building would benefit from the healthier and more natural environment resulting from the 'breathability' of its walls (see paragraph *2.6.3.2*).

It appears that the emergence of the lime-hemp industry is a win-win-win solution where the society, the economy, and the environment would all benefit. For these reasons, it is believed that the Government should take an active role in encouraging and promoting lime-hemp. As suggested by the *builder*, and the *entrepreneur*, a simple public policy in the right direction would be the distribution of subsidies to farmers for the construction of hemp storage barns. Another effortless intervention would be the acceleration of the lead time in releasing licenses for growing hemp. Incentives to entrepreneurs aimed at setting up new processing facilities as well as to fund scientific research on the biocomposite would represent far-sighted public strategy and show the necessary commitment lime-hemp deserves.

Finally the increased general knowledge on lime-hemp would positively weigh on the resolution of both commercial and psychological barriers. On one side it would make investors more amenable in funding lime-hemp businesses and projects, as well as avoid that sub-standard self built constructions spoil the credibility of the biocomposite. On the other side it would help to clarify the consumers' wrong association of hemp with marijuana, and it would prevent misconceptions that man-made materials are generally better than natural material; in particular the idea that "concrete built is better built".

5.2.4. Government and systemic perspective

The necessary support of the Government in the mainstreaming of lime-hemp and the

underlying reasons have just been discussed. It has been said that general knowledge on the biocomposite would be increased by the Government's intervention. However this is unlikely to happen as long as public authorities show lack of vision for sustainability, as emerged during the analysis of the results (see paragraph *4.4.6*).

Lack of vision for sustainability might be explained by the difficulty for public institutions to face reality with a systemic perspective. Authorities commonly cope with and try to solve only one issue at a time. It often happens that the solution of one problem is what creates others. A systemic approach though, tries to consider an issue in its broader context. Problems are faced upstream so that their solution is more effective and, instead of multiplying them, opportunities are likely to emerge. A clear example of the concept is shown by the way the Irish Government recently dealt with the demise of the sugar industry.

The Government has been apparently aware of the existence of lime-hemp since 2005. The *builder* claimed to have received a handshake by the Irish minister of the environment during a sustainable building show in September 2005 when he was awarded an environmentally friendly prize (O'Thompson, 2007, pers. comm.). Lime-hemp was considered to be the most innovative products at the show. He said to have had the opportunity to give the minister a quick talk on the potential of hemp as an agriculturally grown product that could be produced in Ireland, on lime-hemp as a construction material mainly made of hemp, on the potential number of work force that would emerge with the new industry, and on the benefits of using the biocomposite in construction. The *builder* said the talk was unfortunately not followed up in any way by the minister.

The *farmer* suggested that those interested in hemp are ex sugar beet growers since they are both rotational crops and share the same seed bed (see paragraph *4.1.1*). In order to cope with the demise of the sugar beet industry, the Irish Government distributed during 2006 about € 145 million among sugar beet farmers and contractors, employee redundancy payments and pension funds (Carolan, 2007). The *builder* claimed that a good share of the subsidies already ended up in housing developments on very cheap land that was previously destined for agricultural purposes.

The demise of the sugar beet could have been transformed in an opportunity for the hemp industry if only the Government had seen the link between the two. Part of the money could have been invested in the lime-hemp industry with good probability of partially saving employment and the local economy. Unfortunately it did not happen. Lack of awareness must be blamed but most of all, it is believed to be a matter of lack of systemic perspective of the authorities who are unable to perceive reality from a wider point of view.

CHAPTER SIX: CONCLUSIONS

6.0. Introduction

The current unsustainability of the building industry in developed countries is contributing to reduce the overall capacity of the Earth to support life. Energy and resources are wastefully used and consumed in the sector, and there is little debate on their potential depletion. Moreover the negative effects of many synthetic mainstream construction materials on human health are often overlooked even if there is ample evidence of the related symptoms.

Unfortunately there seems to be few signs showing a change in the course of action. A conservative attitude prevails in the construction industry, and the few changes put in place are superficial and only aimed at improving the image of the industry more than trying to pursue real sustainability.

Solutions already exist. It is demonstrated that the sustainable use of natural materials in construction has benefits for the human health, the economy and the environment. Lime-hemp, among the various natural building techniques, is apparently turning out to be very interesting and promising as one of the possible alternatives for the construction industry of the twenty-first century.

6.1. Lime-hemp and sustainability

The overall sustainability of lime-hemp makes it appealing from three different points of view: environmentally, economically and socially. On the environmental side, lime-hemp is ideally in line with *The Natural Step*'s four sustainability principles (see paragraph *2.1.2*); it reduces carbon dioxide emissions thanks to his thermal properties, and works as a carbon sink capturing carbon dioxide in the structure of buildings (see paragraph *2.6.3.3*); it makes various synthetic materials redundant thus reducing dependence on fossil fuels (see paragraph *4.6.2*); it is a low waste material and, at the end of the lifecycle while the lime content is fully recyclable, the hemp hurds are completely biodegradable.

On the economic side, lime-hemp is sustainable being a local produced material. It directly links agriculture and industry therefore giving back the due importance to the primary sector. It reduces dependence on importation of raw and finished construction materials. Local economy benefits because of the existence of a local lime-hemp industry and the rise in local employment is a direct consequence.

Lime-hemp is also beneficial on the social side. As the local economy flourishes, i.e. appearance of a new industry and increased employment, so does the local community. Farming is declining in the most developed countries thus hemp would give farmers an alternative crop and source of incomes. The healthy nature of lime-hemp buildings is a further benefit for the overall community.

6.2. Lime-hemp in Ireland

Ireland could be the third country in Europe, after France and the UK, where lime-hemp becomes a mainstream construction material and building method. Necessary condition is the existence of a local lime-hemp processing industry and in fact, it has emerged that a first attempt to set up the indispensable supply chain is currently taking place in the country.

There are however other barriers which are slowing down the overall mainstream process. They have been the object of the research and it has therefore been possible to identify the most important issues.

6.2.1. Regulatory and knowledge barriers

Among the six category of identified barriers (technical, commercial, regulatory, knowledge, psychological, and invisible) two of them, namely regulatory and knowledge, emerged as the most important. Their solution would make the wide take up of lime-hemp in the country much more likely.

On the regulatory side, the existence of an Agrément certificate would help making the biocomposite more popular among architect, builders, and providers of structural insurance, as well as reducing their lack of confidence by providing a guarantee on the

reliability of lime-hemp. The lack of certification is apparently the main issue constraining the wider use of the material.

On the knowledge side much has still to be done. With the exception of architects who are seemingly aware of lime-hemp and farmers who are starting to discover hemp because of its profitability and ease of cultivation; the other considered stakeholders (construction industry, builders, consumers, financial sector, and Government) generally lack awareness on it.

6.2.2. Support of the Government

The support of the Government is believed to be a necessary key factor in the mainstreaming of lime-hemp. The biocomposite represents a win-win-win solution for the economy, the community, and the environment. Its promotion is therefore in the interest of the public authorities. Policies like the distribution of incentives to entrepreneurs in the lime-hemp business or the provision of subsidies to farmers for the construction of hemp storage barns are the best examples of public intervention. The Government might also play an important role in increasing the overall awareness on lime-hemp.

The current absence of support from the Government is believed to be explained by its inability to perceive reality from a system perspective. Instead of looking at the core elements of a complex system, attention is often focused on single issues without paying attention at how they are actually linked to others.

6.3. Application of the research

The results and key findings of the research will hopefully be useful for those stakeholders who have some interest in the mainstreaming of lime-hemp. It is hoped the research could provide them with a clear idea of the overall background where lime-hemp is placed, as well as act as a support tool for any decision based on the emerging lime-hemp industry.

The research is also aimed at increasing the limited level of awareness on lime-hemp in Ireland. If applied as information tool, it could help to reduce the overall lack of knowledge, thus tackling the second most important barrier slowing down its wide take up.

The author hopes the present work might become a ‘stepping stone’ for further research on the subject in Ireland. Lime-hemp deserves it and it is in the interest of the whole community that these kinds of innovations are furthered for the benefit of all.

6.4. Limitations

The main limitation of the research consists in the poor representation of some of the involved stakeholders’ views.

The Irish construction industry’s point of view is poorly considered. As already mentioned an in-depth interview with a spokesperson from the Construction Industry Federation was initially planned as part of the methodology. Unfortunately it has not been possible to conduct the interview because of the lack of response from the organisation. All the results in which the construction industry is mentioned are however opinions of both the actual interviewees and the author.

A survey among building contractors as well as producers of material made redundant by lime-hemp would have completed the research. Unfortunately it has not been possible to carry it out because of time constraints over the project. Irish farmers are not represented properly too. A survey among ex sugar beet growers would have probably provided further evidence of what has already emerged. Again, time constraints did not permit it.

Finally, as already mentioned local production of lime has been voluntarily overlooked. Lime is already well known and it has been used for centuries in Ireland. Moreover the existence of a local lime production and market has not been regarded as a potential obstacle for the large adoption of lime-hemp. However deepening the observation of the link between lime production and lime-hemp processing would have provided further insights.

6.5. Recommendations and further research

The Government's support of the lime-hemp industry is highly recommended. The justification has been already discussed in paragraph *5.2.3* and *6.2.2*. Simple public policies could consist in the distribution of subsidies to farmers for the construction of storage barns for hemp straw, or in the acceleration of the lead time in releasing licenses for growing hemp. More far-sighted policies could consist in the provision of incentives to entrepreneurs aimed at setting up new processing facilities as well as funding for scientific research on the biocomposite.

The organisation of a competition among building contractors for the construction of a number of lime-hemp building would fulfil multiple aims:

1. training: it would be an opportunity for builders to learn the necessary know-how involved in lime-hemp construction;
2. demonstration: it would create the needed momentum and help to increase the overall knowledge on the technique;
3. assessment: it would give the opportunity to carry out the required assessments for proving the properties of lime-hemp.

Further research is indeed needed. The most important and urgent at the moment is to assess the compliance of lime-hemp with the Irish building regulation aiming at the obtainment of the Agrément certificate. For the same purpose research is needed to prove the 60 years durability requirement.

Research assessing the market potential of the biocomposite is believed to be necessary too. Every single market according to the end use of lime-hemp (plastering, floors, wall infill, roof insulation) have to be carefully explored. This would avoid over (or under) estimations and improve decision-making in general.

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APPENDIX A

APPENDIX A.1.

TRANSCRIPT OF MR. ALEC TONG'S IN-DEPTH INTERVIEW

1. On the regulatory requirements to grow hemp in Ireland

You need a licence from the dept. of health and children certified by garda cigona that you are a good character having no blemishes. The application form is 10 pages, it is put through the dept. of health and children will send it to garda and to the single farm payments units. You have to furnish a map of the area where you want to grow hemp which has GPS coordinates on it. The field may not be visible from any public road but we have that arrangement amended because due to the practicalities of Ireland that is not possible. The regulations at the moment are that it may be grown close to non primary roads. If it is grown close to a primary road it has to be shielded with ???. After that you get your licence, you have to state the variety that you are going to sow, you have to furnish the seeds certificate labels to the department. You are then responsible to the security of the crop after harvesting and transportation to the processing facility.

The police comes and inspect where you are going to sow the crop once your licence has been granted and the return the result of the inspection to the dept. of health and children.

I want to emphasize that you must abide by the rules and regulation which I completely agree with, because I don't want any untrustworthy persons becoming involved in the production of hemp in Ireland. Someone who could try to break the law or try to grow the illegal stuff. In Northern Ireland and continental Europe it is not so severely controlled. I visited hemp fields in France, Germany and Poland.

We are sympathetic to the authorities of Ireland and we believe that they will become more amenable as they become more familiar with the crop.

2. On the difficulties to obtain the licence from Dept. of Health & Children

As long as you have no blemishes and you have not done anything wrong you easily get it.

3. On the hassle to obtaining growing licences

No, I am in favour of it because I don't want anyone unwanted being involved in it.

4. On the farmers currently growing hemp in Ireland

There are three other farmers other than myself. I am looking for an alternative crop. We think that it is an ideal rotational crop to replace the sugar beet.

5. On the article appeared on the Farmers Journal where Mr. Tong offered contracts for growing hemp.

Quite a large number of farmers responded. I think we had 23 replies but only 3 got their licence because the time delay was so great. We provided them with the application form in order to facilitate the process. All the others phoned saying that time was going by and they were going to sow another crop. However they are all willing to grow hemp for the next year.

6. On the farmers' perception on hemp

Farmers know nothing about it, nothing at all. The crop is totally new for them. The description of "industrial hemp" avoids them relating it to marijuana. We try to emphasize the industrial aspect in order to segregate the marijuana connection in their mind.

7. On the profitability of hemp for farmers

I believe so. We are offering €150 per ton at 15-20% dry matter delivered to Edenderry. We say the farmers should grow 5 tons per acre but we are trying to be conservative. According to the Bernard Rice at Teagasc ... *[ref. TEAGASC's report on hemp medium density fibreboards].*

If you think that you get €750 to the acre. Ploughing, tilling and sawing is about €150 per acre, seeds are €50 (10 kilos at € 5 per kilo), fertilizer is about €75 (this year was €250 per ton). Your input costs are about €350 per acre. Harvesting cost is €75. You're about €425 per acre and your gross is 750. The difference is € 375 per acre. And if you have seeds, they would worth €500 per ton. If you harvests 0,5 ton per acre you are doing well and that is another € 250 to the acre. There is no other crop today that matches this kind of results.

We also believe that in Ireland we should achieve a higher yield per acre than they do on the continent because of our wet weather.

8. On the necessary knowledge to grow hemp

The husbandry of the crop is more particular than sugar beet. It has all to do with the preparation with the seedbed and the sowing of the crop. After that there is nothing else to do.
The people we hope will be interested in this crop are ex sugar beet growers. Sugar beet is gone. Hemp is a rotational crop as sugar beet, it takes the same kind of seedbed, the time of sowing is similar but the time of harvesting is much better because you are harvesting in September rather than beet in November, December, January. And you can sow your winter crop immediately afterwards.

It is very similar to beet: the sowing temperature is 10° at 10 cm deep. End of April, beginning of May is the opportune time to sow. Frost is not a problem because the plant can survive up to -3°; under that the crop could be damaged. This is why we were watching the ground temperature this year very carefully. In beet crops you get 20tons per acre of which 15 tons is water. In hemp you get 5 tons of which 1 ton is water.

In logistics your CO2 footprint is much lower, you don't use herbicides, fungicides or insecticides. The amount of fertilizer is small compared to all other crops. Once you sow the crop in the end of April, beginning of May you close the gate and don't come back until September.

The needed knowledge to grow hemp is small. We could definitely advise. This is our second year of growing hemp. Last year the seeds did not arrive in time and we couldn't saw before the 16th of June but we couldn't harvest it before February. Last year we had 22 acres, this year 18 acres.

9. On the multiple uses of hemp

There is no use at the moment. We are growing hemp in order to use fibre for insulation and hurds for lime-hemp. We believe there is a large market for insulation in Ireland. There are 1,77 million old houses in Ireland that require to be brought up to the modern insulation standards.

For the moment we are trying to do it all by ourselves (growing, processing and making insulations mats). In order to make a decortication facility economically viable you need 2500 acres per annum.

We cannot grow hemp in Ireland to make the fine fibres materials because of the climate. We will never get the same high quality they get in Poland.

Another market could be the oil extracted from the seeds. The reason why I got interested in growing hemp: I looked at willow and said: "no". Ties up too much land, too long, harvesting long time in the year and too wet. It would only be a biomass grown for being burned and that means only rotating CO2. Next I looked into myscantus, I saw it growing and said: "no, it has the same problem". The next crop I considered was oilseed rape. The energy balance was negative. There are 400.000 hectares cultivate as tillage in Ireland. You can only grow oilseed rape as a rotational crop that means you would have 100.000 hectares cultivated with oilseed rape. That would yield maximum 400.000 tons of rapes and out of that you would get 1/3 (135.000 tons) of oil. The oil would supply Ireland for only 13 days and your energy balance is negative and you would also have 275.000 tons of press cake. If you feed animals they produce methane gas. Then I looked into reed canary grass. It grows nicely on peat land but it is extremely invasive, it spreads all over the place. They I thought about wheat but the energy balance is not very good.

So, the next one was hemp. The fibres for insulation locks up CO2, your cost of growing it is small, the hurds used for lime-hemp or directly for insulation locks up permanently CO2. And then it is a rotational crop, it suits rotational farmers, and you do grow better crops after any rotations. To me that was the best one of all.

Even in Teagasc, in Northern Ireland government departments they all know because in Ireland there is 92% of the tilled agricultural land, 8% is tillage. The silage are the, they know-how to

store, the harvesting machines are there, all they need to know is how to process the fibres into insulation.
With a bio-refinery you can refine the core and extract the sugars and ???

Lime-hemp could also be used to dryline by spraying a 2 inches thick layer on the outside of masonry build houses.

APPENDIX A.2.

TRANSCRIPT OF MR. MARCUS MC CABE'S IN-DEPTH INTERVIEW

1. On his own involvement with lime-hemp

We have built this office and two of the buildings where we live, just down the road. We have been also supplying lime-hemp mainly as a plaster for renovation of old cottages where it is very good for that. Where you have for example earth and stones, or limestone built especially where previously it has been used cement plaster becoming very very damp. We take it off, put on hemp and lime in the inside and on the outside, put some drainage on the floor and around the outside and suddenly you got dryline using hemp lime. At the moment what people do is putting stud frame or plastic sheet and plaster board. So they hide the problem while something horrible is going on behind and nothing breathes and all comes out and eventually the house gets knocked down. Whereas if you actually take everything away, expose the walls and put the hemp-lime on, then the house construction breath again, dries the walls out and you can rescue the building. It's extremely good for very old buildings. So we are doing a lot of work on that. For instance about two weeks ago we sent some material to quite a famous building called "Ross an arie" (???). "Ross an arie" is right below where the battle of the boyne took place, it is a building right were the army crossed the river. The people living there decided to use hemp and lime. People use it once and they they see what it does and then they keep coming back, builders as well.

You know the way concrete has an appeal for builders? Because of its strength. Hemp and lime it's a different kind of appeal but it has an appeal to builders because it solves problems that no other material would solve. You can pack it into the holes, you put it on thick without it falling off, it holds its form very easily, it is very sticky and it has a different kind of strength compared to concrete. It's strength is exactly in its flexibility, that's what the strength is. If it is put under pressure, it doesn't crack.

Basically what we are doing know is supplying small amounts without advertising at all.

1.1 On the source of the material employed

The hemp is coming from the south of England (hemcore bedding) and the lime from whiterhino (Ireland). We mix them up and decide the quantities of hemp and lime in the mix according to the use. Plaster is completely different from the mix you use for filling a wall. For the wall you need a very dry mix and not very plastic, if you need to put up plaster it needs to be wet and very plastic. It depends on the application.

1.2. On the interest to set up an hemp processing facility

On Tuesday and Wednesday I am going over to Germany to buy Ireland's first hemp harvester (€ 250.000) a class jaguar specially adapted for hemp. The engine and all of that is class and the front part here is gone and there is one specially made for hemp. It is the same harvester hemcore uses in the UK. Basically it chops the hemp, first at the base and then there is a drum cutting the stems in short pieces. Because the whole problem with hemp is the fibre. The length of the stems has to be shorter than the circumference of the rotors in the machines at the processing factory. Otherwise it would wraps around the rotors and create fires and nightmares, etc...

The biggest barrier for farmers is the lack of a harvester. Farmers won't grow hemp unless they know how to harvest it.

This is the layout that we have got for the factory. We have got German engineers coming over hopefully in September/October to start installing all our equipment. We own a lot of machines. The machines in red is what we already own, all the black machines we are buying new. We are investing about €2million in this whole operation. We have to take it seriously because we spent so much money at this stage, on the equipment that we already own. We've got about 70 machines already but we need more to get the whole process line working. The engineers have done all the work on the flows and how it should work but also we are taking in the lime as well, as part of this set up. So that the primary processing of the hemp, you've got the harverster, it comes through these machines here, you've got the fibre and the shives separated, and then it

goes to be mixed with lime, all in one factory. Possibly the paper as well, we don't know that yet and that depends. We are looking for another company to take the fibre from this point for making paper. Because their waste is lime and that will all happen under one roof. Most of the hemp industries in Europe are just producing the hemp hurds as animal bedding. Whereas we are not going to sell beddings at all, hopefully. It will all come out and mixed with lime. Come, I'll show you some mix...

Hemcore is doing this material and they are selling it around 250-300€ per ton but importing it in Ireland and considering the transport cost becomes 600€ per ton. Today I can buy this, add lime to it and still make good profit.

When people go into a hemp building, as soon as they go in, they can feel the atmosphere pleasant, warm.

Hopefully at the end of this week we will have decided whether we are gonna go down with the paper or not. If we do not go with paper we will probably put the fibre up an put it together with the lime mixes. Producing insulation mats would require further 2 million euro for the machine, but nonetheless we are considering that.

1.3 On the location of the facility
In Limavady, Northern Ireland. In the Foyle basin, no frost, we've got some of the best lands of the island around there, a lot of tillage farmers, what you need obviously. There is the farm over here, just on the other side that is 3000 hectares.

Just to give you an idea. A typical house, considering the volume of the walls (length x height x thickness), and the floors and the ceilings, you come up with an average of 200 cubic meters. Let's say we can produce 10.000 tons flat out of hemp each year. A half of that will be hurds so that it would be 5000 tons. Converting them in volume (multiplying by 5) makes 25.000 cubic meters. Divided by 200 it makes 125 houses. It's nothing! It's tiny! That would be our maximum capacity with a 24hours per day.

I have tried to explain this to bankers, and finance people, and they kept asking: "where are you going to sell it". It is not a problem. You know that eco-village down in Cloughjordan, Co. Tipperary? That's 132 houses... Here is another way at looking at it. Let's say you are a government minister. This new government in England, they want to go, I was talking to a guy and I will meet him tomorrow, and he's working with the Dept. of the Environment, advising on sustainable building, he's got a ".co.uk" email address ☺ He is talking about going carbon neutral by 2015 and he's talking about building 3million houses. Let's say they're going to build even just 1million houses, multiplied by 200 is giving us a 200 million cubic meters of hemp. Divided by 5 makes 40 millions tons of hemp hurds, divided by 10 tons per hectare, that is 400.000 hectares. This is what you would need to build 1/3 of the houses in the uk with limehemp. It is not possible, there's not enough land. I know the tillage area of Ireland is about 100.000 acres. But that's still not enough for beef in Ireland. And that does not take in account oil seeds, for biodiesel or anything else. There is not enough land to actually do it all.

Or another way to looking at this is that every farmer need to grow hemp to reach the target. I would like to show you a slide that shows a good comparison in the growth of barley after hemp has been grown the year before. So you got one plant of barley 6 inches high were hemp has not been grown and then a twice as high plant where hemp was. No other differences, no extra fertilizer, no sprays or anything else. Just the presence of the hemp has a magical effect. So last year we found it very hard
This year we found it still very hard offering the equal price of wheat which is going up very high in price at the moment, and that was just enough to convince twenty farmers this year. Now the whole thing has completely changed. Now that they saw the crop growing hemp last year, and are seeing it growing this year. They discussed and all the worries have gone out and they now realized: "yes, hemp is the crop". If you look at miscanthus they are offering 90€ per ton, willows worth 50 or 60 € per ton, hemp 180€ per ton. None of the other biomass crops can compete with hemp. But then all the biomass cost is just fuel, so they are competing with coal, peat and oil. Hemp is fibre, building material and so on...

2. On the difficulties and barriers in setting up the hemp industry in Ireland

Finance is the biggest problem. Lack of understanding among the people who provide financing. They just don't know what you are talking about. Their lack of understanding prevents them from being confident in investing, but they can't because they don't know what you are talking about. I'm talking about banks, equity investors. I met them two or three times. I had the guy here last week and he just got confused, "hemp, fibre, hmm, what what??" They get bewildered with the amount of information. You give them so much information that they get confused before they can absorb it, that's a huge barrier for those with cash, unless the persons already knew by themselves, that might have a chance. The biggest mistake for anyone trying to sell hemp as an industry, is to go on with 15000-20000 different products, mobile phones, plastic covers, paper, cds... Forget about all of that! And just say: "oh, we are gonna make this or that. We started to make some progress with the project only when we started to talk only about hemp and lime and no other product. Just forgot, don't tell them, about fiber, seeds, just don't mention them. Stick to one product and then you begin to make some progress.

Farmers. You need a stable supply from them. Before you set up a hemp industry you need to know that you have got your land base. You are dealing with a lot of individuals which is not really a good arrangement. It's better to deal with farmers groups and then you're still dealing with a lot of individuals but at least it is more under structure. Unless you have to own enough land. The other way would be to go and rent out land by yourself. But that creates a huge amount of practical problems for anybody setting up. You need to be a very experienced farmer for start and you have to be able to react quickly and go, that day at that hour to rescue something or to make it happen quickly. It's about speed you know. That's a big barrier. We spent an awful amount of time cultivating farmers, we spent two years in a project cultivating relationships with the farmers. We finally rescued the farmers in Limavady and in the south with Alec Tong.

Another big barrier for us was the attitude of the government. In Northern Ireland it took four days to get licences to grow. In the south of Ireland it took six months and the licence came in October '05 which was too late to sow. We couldn't actually use that licence until spring 2006. But then more farmers come in and we needed more licences. In Northern Ireland the Dept. of the Agriculture works together with the Police to make the things happen because they want industry, the government makes it happen. So if you got a cooperative government getting your licences it is an easy job, actually it would make your job impossible if the government doesn't cooperate, because you have to invest millions of euros and not getting a piece of paper would jeopardize the whole business; you need to know that there is cooperation from the government. That was a big factor influencing our decision to locate the business in Limavady. Because we will work on both side of the border, we realised that it was better to stay in the North. So that is another big barrier to the entry.

I think another big barrier is generally the process itself because it is complicated. The suppliers of the machinery concentrate on king fibre, and that is not necessary. And people who are coming in are going to take the advice on the machinery, processor, manufacturers, but because they are coming from the history of textiles they are fixed on king fibre, but the get the fibre to about 50% hurd contamination it's gonna cost about 1,5-2 million. But in order to get it under 5% or close to 2% it is gonna cost as much money again for that last percentage. So anybody coming in and not understanding that, is gonna see a very very big capital investment that might not be actually necessary, especially if you are going for something like paper where it doesn't matter if there is hurd in it, because it going to get chopped anyway. If you are going for mats, insulation mats, then you would need a high quality fibre. If you look at MacCann & Byrne, they are selling fibre insulation headquartered in Germany, € 16 per square meter if they are selling it at builders. € 8 of that price is transport. Fibre glass costs €7 so, €8 and then profit is at the top of that. So if you are processing in Ireland, and supply the market directly you could be competitive with the fibre glass. No point in a tonne of feather like, you don't transport a tonne of feathers. Today they manage to sell it because it is a premium market, it is all because of marketing and image. The builder out there is gonna go for the cheapest thing, to give him cheap fibre glass, and then all that scratching and breathing and all that terrible stuff that comes with it. Fibre glass is a huge market out there. I think that hemp fibre must be equal to or less than fibre glass. But again, the fibres: massive, massive volumes. Hemp fibre weights 50 Kg per cubic meter, so you would have 20 cubic meters per tonne. So you would have a factory producing 10000 tons, would produce about 50.000 cubic meters of fibre making insulation mats.

The barrier represented by the farmers would change though, because they now want to grow it.

Then I think the market is huge out there but it hasn't been cultivated. It could be very easily cultivated, and people are already promoting it, see architects and so on. But there actually isn't a phone number or a website or any way for someone to buy it at the moment. There is no place where I could go in and buy it. I could buy a solar panel, a wood pellet stove, but not lime-hemp. But hopefully in ten years time you can. The supply chain is not created yet.

3. On the scale of production needed in order to make a processing facility profitable
At least 2-2,5 tons per hour for this factory. There is an ancient story. The engineers working on this, they designed the 10 tons per hour factory and the investors invested 3,5 million euro and the project collapsed because of the planning permission. They didn't realised what involved in investing 3,5 million euro. So many lorries and so much traffic became so big in the area that it would run into a problem with transport and the farmers. As a consequence we had to downsize the project. I was considering to go with 4,5-5 tons per hour, but since the business is easily replicable. The other thing is that if you watch for the paper, each farm could easily supply one or two factories. Like a quarry.

4. On the more profitable markets for hemp compared to the construction industry
I think probably there is a very little market for the paper, especially quality paper. I haven't had time to research it very well, I don't know how much, like if you for example are a law firm they use very high quality paper, because it has to last for a long time. I don't know what that paper fetches per tonne, but I would say quite a lot. Again, books, money paper, bible paper, rizla papers.
Any other market where fibres are chopped very finely and mixed with some sort of resin and to make bioplastic: cases, laptops, and so on. You would need a different group of machines. At the moment in this line the waste that is coming out is dust, mostly the gums that are slightly rotted. You know, the gums binding the fibre to the wooden core. Those gums are sticky, like resin compounds. There is an extraction system but they are ??? to ??? scales in order to take these gums out. They could be recombined with fibres to make bioplastics. The only problem is that they are water-soluble. They would be fine for phones, cases, laptops or something like that. But it wouldn't be ok for a car, or anything exposed to the rain.

There are plenty of things anyway. If you go for example into the seeds,
At the beginning that was my focus but I realised very quickly that I had to focus on one product, otherwise... Once you have a profitable business then you could begin to build on that.

5. On the transportation issue
The French say 30Km, the German say 50Km radius from the factory. This year the farmers down south have entered into contacts with us to supply 200-250 Km, because they want to, because they think it is still profitable to transport over that distance and remain profitable. Anyway, my personal opinion is that it should be 15 Km and that is all transported by tractor by the farmer. The farmers would do that for you. If you give them a good price and you say "you transport it" and they are close, they would do it themselves. Because they always have free time, especially on some days. And then you would get the farmers storing the bales. Because you couldn't store 10.000 tons; it is a huge amount, huge cubic meters, about 100.000 cubic meters. (one tonne of hemp is 5 cubic meters when is chopped in hurds. When baled, it is even more that that because of the air in each bale and the between them). In our contracts with the farmers, we pay them to store the hemp and that works. They already have the barns and if they don't the cost would be very low. In Wales there are grants for hemp storage and we would like to bring them here as well.

6. On the lack of knowledge about lime-hemp
I think what happening is that you have got architects pushing it, and you've got a lot of young students architects who are all excited about it, so they all know about it. People interested in eco-building (articles, newspapers, etc) they all know about it but as we said there is no supply at the moment. I think the problem is gonna be more keeping the demand that is already there and supply it in the future. As soon as the supply chain comes in, I think the demand will grow very easily. We have clients in the UK and they said they will take everything we will produce. That's what they are saying but now we have no signed paper from them. Another thing is that a business supplying only one customer is not a good idea.

7. On the issues in the processing of hemp

We start at the farm, you are looking at sowing around the middle of April, end of May. No herbicides, pesticides are needed. You harvest in the end of August, beginning of September. The big issue is with living seed in this country, because you are taking a big risk with the weather. That would be a variety thing. That's where the government could help a lot, you know. By breeding seeds varieties, you get the straw and the seeds.

The bales arrive at the factory, and you measure the moisture content. The limit is 18-20%, it can't go below that. Otherwise there would be big problems. That has to be in the contract with farmers. In the first couple of years we didn't insist, we let them think how to keep it below the 20% because they were frightened. After this we will say, 20% we pay a good price, over it the price would go way down. It is practical as far as this is concerned.

We can bring in dry green hemp, it doesn't need to be retted. They can cut it during a week with good weather. If it doesn't get any rain at all, they can bale it even after 3-4 days if the sun is hot. This is a big advantage because if we said in the contract that it has to be retted, then farmers would have to wait for the rain and then again the sun for drying up. It would be too risky.

Than it comes in, there is a bale opener. It is brought up here, there is a screen to take out stones and metal parts. Then it drops into the hammer mill. It smashes the hemp: brakes the fibre, brakes the stalk, and it goes through a series of machines.

There fans collect all the dust and all the hurds trough pipes. The dust is taken out. The hurds get screened, and they fall down going to a silo for the hurds while they fibres into a different direction. Eventually what happens is that the fibre gets into a fibre press. We could put the fibre into a more processing but we will likely leave all these machines out if we go down the paper road. If we don't, we will have to leave these machines in. We could sell these machines that we already have, generating some cash and room for the paper line. That would also produce lime avoiding us to buy it outside. I am not sure yet if we will be self-sufficient with lime, I will know that by tomorrow. At the moment what they are talking about, it is a process that produces 1500 tons of lime they have to get rid of per annum. We would need 10 to 20.000 tons of lime. If they can increase the amount of lime produced then it would become much more interesting for us. Otherwise we would buy lime. Nonetheless, that would mean there are 1500 tons of lime that we don't have to buy.

The lime is coming in here. It goes through different processes, it gets sleeked (when it reacts with the water, a very hot reaction). They it is weighted, mixed with the hurds and then put into big bags, goes into a lorry or into buckets. Three different ways to deliver the final product as well as different mixes (filling a wall, plastering, insulating etc...) all controlled by the computer. In our point of view most of the profit would be in the buckets. It would much better for us to plaster 2000 houses than to build 125 houses, because you know it makes a big difference in the price. You can sell a bucket for €10, but if you fill a bag than it sounds like a big more money. And for some reasons, for plastering a house, buckets are very handy. So we are gonna push that first and leave the others as a possibility because we would need a huge amount of cash in the beginning.

7.1. On the resistance of lime-hemp in buckets

I would say a long time. If the lid is sealed and the bucket full, it would last indefinitely. Because water needs air to evaporate and lime needs carbon dioxide to react.

We also have the possibility to bale the hurds into horse bedding bags as well if we want to. I hope we will never have to use it.

The dust goes into fuel briquettes. But I actually would like to investigate the possibility to mix dust with lime to make a plaster in between blocks. And the other thing we could make is blocks with not many changes in the process.

8. On the farmers currently growing hemp in Ireland

Nineteen farmers in Northern Ireland and three in the south and they are all supplying us. We are the only hemp processors as far as I know. I hope next year and in the following years, this figure will go up in order of magnitude. We have now around 100 hectares of growing hemp and we would need a 1000 to make all these machines working.

9. On the vested interests against the take up of lime-hemp

It is always very hard to know what is going on in the background. I think there might be something going on in the background actually. As I said I did have some serious problems in the south, myself you know. All of that seems to die away now again (???). And it is hard to know where these things are coming from. The industry is so small and so much not a threat. They just do not need to worry about it. Just to give you an idea, I was over in Queen's Cement. I was there in the quarry, in the quarry man office that I knew. We were having a chat and one of the drivers came in with one of these big dumpers and I said: "oh well, that what comes out of the separation plant for the day". He said, there are 5000 tons in (gravel, sand, etc...) from 8 o'clock to 1 o'clock during one morning. And we are talking about 10.000 tons a year. It is so small! There is no capacity, no threat at all.

Eventually I suppose if this industry grows, it will become a threat. But at that point everything will be changed. I think that at that point the government would be welcoming us. The governments are all talking about sustainability but they are not doing anything real about it. It is all cosmetic what they are doing. I have got an architect, we are involved in waste water, she wanted a reed bed for a big building of 3000 people. And I said, ok well, 3000 people are a lot if you want to try treat the affluent there and not elsewhere. What you should do I said is put in a vacuum system for all the toilets, extract the energy out of the affluent, you cut down from 20 liters to 1,5 liter per person, take the energy out and put it in a combined heat and power system and that way you deal with all the BOD in a very nice system. And then the remaining affluent you can put it down through the side of the building and grow some nice flowers and garden. But no way you can put the raw affluent trough the reed bed, it is too much. And I knew from her that she didn't want to hear that, she really just wanted do see some plants and reeds outside the building, just a cosmetic thing.

I think there is a lot of that with the governments that should really think the whole thing right through. There is definitely not enough land to deal with the peak oil situation or the post peak oil situation. Even if there was enough land, what crops are you gonna grow? Hemp has to be at the top of the list. There is not support at all. We didn't get one penny as support from the government yet.

Coming back to the vested interest. I think there is, but it is unnecessary and we are such a small little flame in the whole thing that we are not going to put anybody out of business.

10. On the position of the government

Maybe the green government in the South will change the situation. If the government wanted to support farming, they could support the farmers with storage for hemp. Very basic, a few grants for sheds. They could also supply capital for businesses who are setting up hemp industries like our own. Another would be fast track planning permissions and licensing.

What happens in the north is that the government gives us enough responsibility in vetting the farmers. Checking the fields beside the roads, schools, churches, to make sure they are out of sight. This year we had a farmer and we said: "no, you can't. there is a housing estate there an you are too close". That is what the government wanted to hear from us. And then the police visited one of the most remote fields because they heard that some criminals were about to come out and take some of the hemp. The police wanted to close down the whole field but we said "no no no, just let it an see what happens". Nothing happened yet. Because the only thing they would be interested in is flowers. There are no flowers yet and it is going to be harvested before flowering anyway.

The government could really really help with licensing, new buildings for hemp and research. We supply the dept. of agriculture with seeds and they take years to pay us. And then they just do some miserable research. Too big salaries and no real corporate jobs, no business taking action, not very good. But at the same time they could do comparisons between the different varieties. Autumn sowing for example could be very interesting in these times. You could sow your hemp in September-October, it would germinate then and you could get a very high yield. Because if it goes trough the winter than it could really start from midway in spring. The aim is to increase the tonnage. There is one report talking about 22tons of dry matter per hectare in the south, huge tonnage. Then it would be interesting dealing with biowaste back to industrial crops.

The government could help an awful lot.

11. On further barrier not previously considered

We haven't had time yet to work on the certification issue. We know that we need to. We still have time. The production that we have for the next year would be enough for at most 12 houses. There is only 10% of our full production. I think for people putting up plaster there is no need for a certification. For building I don't even think there's the need of the timber frame. Concrete shuttering and then pour the hemp-lime mix in it. Maybe just some light timber around windows and doors.

There have been lots of hemp businesses collapses as well. One was in the UK, Springsdale worth 7milliion pounds lost by the banks. One of the ??? suppliers was caught with a loss of 200.000 Euro. I knew the guy, he was a good person but didn't pay.

We employed one of the farmers. He is the farmers liaison officer. He is a farmer but he represents us. He's all the time thinking about farmers and I can feel from him what we need to do next, like for the example for the seeds that we collect. This year for example, not for our fault, but because of the supplier we had a problem with providing our farmers with the seeds. I had to drive directly to France and get them myself.

APPENDIX A.3.

TRANSCRIPT OF MR. HENRY O'THOMPSON'S IN-DEPTH INTERVIEW

1. On the construction industry's lack of knowledge in relation to sustainable methods of construction

Very much so. If the path was made easy, if the market demanded it, if the regulations didn't inhibit it there would be more taking it out. It is obviously related to the list of barriers that you have already evidenced. There are always ??? with new products, new ideas, particularly sustainable ones. It takes a few to start it, it takes a few more to get a little momentum on it and it really takes some commitment from some of the "big boys" once they have seen it, seen that it works before they put the money in it. It seems reasonable enough some developers building a few hundred homes it is a big risk to go hemp and lime without having seen a few smaller projects and a little time to see them work successfully.

2. On the builders' awareness on lime-hemp

I would say that by at large the builders are not aware of this. And those who are aware, the building industry is a very conservative group of people who hates innovation and new products. And there is a general perception in the building industry that somehow man made materials wherever they are, are somehow superior to natural products. I don't know why it is, but it is.

3. On the drawbacks of lime-hemp as building material

There is some concern in extremely exposed conditions that water penetrates. Because the product itself is vapour permeable and because the lime plaster you put over it is likewise vapour permeable, there is some concern in our climate, to say by distinction to the French climate, in the very extremely exposed conditions that might incur in the west, the north-west (Connemara, Donegal). We have literally a lot of horizontal rain, continuous horizontal rain. There is some concern that under those conditions moisture may build up to a point where it does not get to dry out. Now, having said that, that is using the current system rather then single skin no cavity wall with a plaster directly over it. We have developed an alternative, although we have not built it yet, that basically steps the outer skin out from the hemp. A 20mm to create a ventilated area between the plaster and the hemp. There would have a breathable membrane that would keep excessive moisture out from the hemp. So, that would alleviate one of the potential...

You would have a net, and then the plaster over the netting. Between the wooden barrier and the hemp wall there would be a gap of 10-20mm stopping the moisture to getting in. It does not seem to be a significant issue rather then in most of the rest of the country, but there is some concern under those conditions that it might occur.

Certainly being aware of damp issues in general is an issue. Because we know of a case where there was some form of continuous dampness that was exposed to the wall, and it accelerated and produced spores and mushrooms growth within the hemp. And it became to decay and the timber frame was ruined. The moisture level must stay at reasonable levels. If it is allowed to get above those levels, you would get organic growth.

One of my biggest fears after many years in the business are related to that. Because a large number of enthusiasts are currently getting involved in hemp as distinct from the professional aspect of the building industry. That situation like that will occur a lot. I have certainly seen many cases where enthusiasts, non builders, have used hemp in a inappropriate way. And we are all concerned that, that would spoil the image of lime-hemp. There are main examples of bad DIY contructions. There are bad professional constructions too, but you know many badly installed DPCs is gonna produce a damp wall, that does not mean there is something wrong with DPCs. Likewise badly installed hemp will end up with a rotten wall. It is unfortunately because of the nature of hemp itself because it is gaining enthusiasts largely from the ... enthusiast individuals, people who just start exploring the building experience to know what is necessary in order to do it correctly and avoid those kind of problems.

3.1 On O'Thompson's experience with lime-hemp

I have been using it for four years I guess. I have learnt the most from the French, they are the pioneers in this whole thing. Very much I copy what they do, I certainly developed a few

techniques and methods and so on in terms of how floors, walls, windows and things like that work, but it terms of the basics the French have been using it for 15 years.
There is a French organisation called “Construire on Chanvre” they have a lot of literature and information, they have done all the studies over there and pretty much as far as I am concerned I did not re-invented the wheel. They understand it better then I do and I have copied them.

4. On the uses where lime-hemp is not appropriate
You would not build bridges with it. It has been recently used in England with a steel frame. This was on a commercial level, this was a chilling warehouse for Adam’s Brewery. It is a massive building, tens of thousands of square meters, I now forgot how big it is, but it is a considerable size one and it is basically a steel frame building. And all the non load bearing structure walls are hemp.

4.1 On the weight bearing features of lime-hemp
The French again are experimenting with this but I haven’t read the results yet. There is a point up to which lime-hemp could be weight bearing. We are certainly experimenting with thicker and thicker walls in order to get the best insulation and there are some indications at least that show that if you go 450-500mm wall, you are nearly passing levels in terms of heat loss. Once you get a 500mm thickness, possibly you are getting a light weight bearing wall. It might sustain the weight of the roof, I don’t know but it seems that people are looking in that direction. But, you know, the fact that you have a timber frame is not significant, it is something that is useful in order to create the shape of the building, in order to put the shuttering up, in order to shape the building you need a structure of some sort to hold it up, so I am not really sure that looking for the load bearing nirvana is really necessary.

5. On the load bearing bricks developed by Lime-Technology
They didn’t succeed. They were in charge of the Adams Brewery project and together with the HCLPA they decided some years back that the hemp-lime blocks was the way to go. I personally never thought that blocks was a good idea. There is no really sort of point in how business is having an effect on them (???), make them work around on an existing frame, having to cut them, having to use mortar. All of this things which diminish one of the great benefits of lime-hemp which is you end up with one piece effectively in your house, is one piece of hemp with no joints or anything to create air gaps, nothing to create thermal bridges is one of the great joys of hemp and lime. When you go for blocks you have all these problems, you end up with having the same problems as with conventional blocks.

Adams Brewery was supposed to be build using these blocks, but thanks to more research they found that you gain strengths by increasing the amount of lime to hemp but you also loose thermal value. So basically they could not get a structural brick that gave a decent thermal value. Once you had a structural brick they ended up having too much lime and not enough hemp.

Nonetheless you must take into consideration that there is a French company that manufacturing hemp-lime blocks. They are not particularly popular but it has been done.

6. On the season constraint in using lime-hemp
There are basically no season constraints. The only issue is the plastering of the wall afterwards is something that you want to avoid during the frost months. When you use lime in general you know, we don’t have very severe winters here in Ireland, but we do get frost, we do get minus x degrees, and generally you shouldn’t work with lime plaster under 5°C. Mixing lime and hemp and using in cold weather really does not seem to make any difference. It is when you have to plaster, which you do once you finish, that becomes problematic. The hemp-lime remains damp and feeds a lot of moisture to the lime plaster for an extended period of time, therefore your plaster remains vulnerable to frost for longer than usual. For example in this building here (a church) where we are putting lime plaster. If we were doing this in January, we would look at the weather forecasts for the next two weeks, and if there was heavy frost forecast we would not work. There is water in the lime, you have the same problem with cement as well, the only difference is that cement dries a lot faster. The water, the moisture inside the lime freezes and expands and basically it would blow off the plastering work.

7. On the needed expertise in using lime-hemp

Use of lime in general is not rocket science, but it does require a certain amount of understanding and training. Not really, any thinking builder would be able to use lime-hemp.

8. On the cost of building with lime-hemp

One of the biggest issues in Ireland really is the cost of importing stuff. Right now we do not have any domestic hemp industry. There is no reason why we couldn't have a domestic industry in Ireland. It requires some entrepreneur with 2-3 million to set up a processing plant. Once there is a processing plant there would be plenty of farmers willing to supply. A bag of hemp (20Kg) sells retail here in Ireland for €13 delivered. In England the same thing sells for €6-7 (NB don't quote me for this, you should check it out). A considerable amount of the cost of a bag of hemp is transportation. So you could certainly imagining the price of the hemp with a sufficient demand. The hemp we use is the waste; we are not even using the valuable parts of the plant. There is no reason why hemp could not be, with sizeable production, half of less the price of what it is now. If you then add mechanisation of the application, which we are now started to do as well. We now have a pumping machine to spraying lime-hemp where the jobs so far have been done by hand. The machine was invented again by the French and again we copied it. Ours is slightly different, we adapted a ganai (????) machine and we basically invented ours from scratch but it does the same thing with less moisture than what is required to do the job by hands and it is much faster. So that is reducing the labour cost, and then the cost of the material itself again, if there was a domestic industry, as we might reasonably expect.

9. On the misconception that concrete is better than environmentally friendly materials

Yes, indeed. It is an interesting concept but we go back to the issue of man-made fibers or man-made products vs. natural products or old products vs. new products. For some reason there is the perception that concrete and cement is a long lasting product, however in reality cement, concrete, Portland cement was invented I think in 1870. It only became widely used really from the 1950s, it was commonly used throughout the earlier part of the century but often as an expensive alternative to lime. The reason of this perception that concrete is a long lasting product yet it is based on the fact that is being around only on the last 50 years, and there is ample evidence that it is not a long lasting product. Because if you look at buildings generally, and particularly infrastructures that are heavily used, most of the buildings that were built with concrete are now delaminating in one way or another.

One of the things you will be told is that concrete/cement has been around since roman time. That is one of their greatest lies. Lime however has been around for centuries. The Egyptian used it, the Romans used it, the Chinese used it and in Ireland we have been using it for a couple of thousands years. And there is numerous evidence that buildings all over the country that survived for hundreds of years and many of them for thousands of years were built with lime. So the perception that somehow lime is not a long lasting product is bizarre. Evidence shows that buildings built with lime are long lasting, however cement buildings have been around for a recent period of time. So we don't know what it will happen to them, we do know that many are delaminating after 50 years, but we don't know how it is gonna be after a hundred years or two hundreds years, do we? We know that lime does. So nevertheless there is the public perception that cement is better and is long lasting and products like lime or things that go with lime are somehow untested but the reverse is true. Why the perception is there? It is there out of misunderstanding I suppose, or good propaganda from the cement industry.

Let's go back to the issue of cement and the Romans. It is something that is always quoted within the industry. Any facts or figures that they give you, check them out because they are eventually always wrong or they have a "slengterm" which is misleading. Now, I am not suggesting that cement is bad, cement is very necessary in a modern society and very necessary for many of the things we need, we need to build bridges at a reasonable cost, and the only way to build a big flyer is with cement. You couldn't build it with stones if you wanted to. Small bridges maybe can be built with stones but the big ones no. So I am not against cement; it has its place but it doesn't have its place in old historical buildings, it shouldn't be anywhere near them and because of our environmental issues, environmental problems, a lot of our buildings where possible should be built with lime and natural materials. Cement's basic ingredient is lime but there is a big difference between the two: cement is burned at a much higher temperature and it has a lot of others additives, over time it does not absorb CO2 like lime does so that environmentally is not as good.

I actually do not think the cement industry sees lime as a threat. The lime industry is so miniscule in comparison. I just give you some numbers: of all the lime that is burned from limestone, 2% goes to make lime. The biggest use of lime is not the building industry, it is the food industry and only 7% of that total amount of lime is used within the building industry. So by far, the cement industry shouldn't by any means fear the development of alternative building methods. In any event, should it turn around they are effectively in the position to effectively supply the lime. Now specifically again in France, one of the biggest promoters of the hemp-lime business is an organisation called Lhoist, which is one of the Europe biggest cement producer. They have a division that produces a proprietary mix called Tradical, which is a lime mix possible has a little cement in it, that is specifically designed to be used with hemp. So there's actually no reason why Roadstone or CRH should be concerned about this is being a threat. Because you have to bear in mind that one of the biggest cement producers in Europe has said "yeah, that is good stuff, we'll have a piece of that". By no means it is a threat but could certainly be an opportunity.

In coming back to this issue of cement and Rome, just in case it comes up. What the Romans invented was hydraulic lime. They took lime, which really did not go hard and they added what is called the "pozzolans" which is a hash from the volcano in Pozzuoli. They added this volcanic ash to the mix in lime and came up with the hydraulic lime. There is a product out there called Roman cement, which was actually invented by an English man in the early 19th century which was a natural occurring lime, a particular kind of limestone that had natural pozzolanic elements, so for some reason they called it the Roman cement. But actually it was invented by the English in the 19th century. The Romans invented hydraulic lime, and a particularly good one.

10. On O'Thompson's typical customer in lime-hemp construction

They are usually individuals who really have a strong ecological agenda and want to make a strong statement to that effect in the house they build. Anybody who is doing it, is putting the money where their mouth is because today it costs more. So they dip into their pocket and say "yes, I am prepared to put my money where my mouth is and spend more on this building and give myself a truly ecologically sustainable building". It is the truly dedicated eco-head. There is an awful amount of people who see us at building shows and when you ask if they have an ecological agenda, they may answer yes and then when you ask them what that is, they say we want to save heating costs. That is one of the remarkable propaganda accuse over the general building industry that produces plastics, various forms of insulations derivatives of plastic, by suggesting to the public that any form of insulation that save you save a few € in oil is ecologically friendly. To me that's George Orwellian new speak, it changes the meaning of a word, of an idea with something that is completely different. Ecologically saving building it is not something that make you save a few € in oil, it is using materials which are ecologically friendly and sustainable in the building process and at the same time saving a few € in oil. Filling your house with obnoxious formaldehyde based insulation is not a healthy idea, so the individuals living in there or for the environment even thought it may save that individuals a couple of hundred years in oil bills.

11. On the builders using lime-hemp

There are quite a few individuals as I mentioned before. The majority of them have built their own house. A fellow down in Kerry by the name of Steve Allin he's been one of the primary pioneers in building with hemp. He was involved before I was and he is not a builder as such, he does design work and he brings in the French guys to actually do the work.

12. On the current number of lime-hemp buildings in Ireland

I am aware that I am not aware of how many buildings there are. I know what I built, 6. One was designed and managed by Steve Allin in Co. Carlow, I build the Marcus McCabe one. There is a little one that was done even before any of us did, by a woman out near Kinvara but she never finished it. I believe that there are others that haven been done in Ireland that I just haven't specifically hear of them.

13. On the insurance coverage?

It does not seem to be an issue for the people we have done buildings for. The English HLCPA has amongst his founding members Zurich Insurance which are the equivalent of our Homebond in England. They are very enthusiastic about it for that country. Apparently it is not an issue in France. Here however I tried several times to communicate with Homebond. I told

them I could get sort ??? I ended up leaving messages, why I was calling, who I was, what it was about. They never had the accuracy to call me back apart from some secretary.
There is another competitor, Premier Guarantee, who I understand are more open to this forms of alternative constructions. The point is, a lot of this comes down to the government. It is in the position of making people do things. The Homebond is a classic example of this. Our problem would be considerably less if we could get Homebond to approve it. Now, Zurich insurance which is monumentally bigger on an international basis than Homebond is, if they are prepared to do it, and Homebond is not prepared to still speak to anybody about this. I mean what is this? Is it because they are too conservative that's what it is and they need legislation to say "wake up boys", you need to do something about this otherwise we're gonna kick you in the ass. They have no incentives to do it, they are walking with lockstep with the cement industry, why should they bother?

Unfortunately here in Ireland we frequently need, even for ideas that were born in Ireland, we need some Irish man that take it abroad, have success with it, show that it works because we don't believe in ourselves, we believe all the foreigners. The English are brilliant except when they invade us, and we always look to them.

14. On the architects' position in the mainstreaming of lime-hemp
There is quite a lot of interest now. There has been a surge in interest from architects in ecologically friendly ideas. It is becoming a niche as it were, a little thing where you can specialize on, like in conservation work there are conservational architects, there are now ecologically friendly architects. And that is good, because as result they are interested in it and I received quite a lot of interest from architects who are keen on it. And they are coming from the universities these days, people like yourself, one of the primary promoters and researchers of hemp-lime is professor Tom Woolley, he is one of the ones that definitely got it into the thought of the academic process and obviously people graduating from these schools have an interest in the hemp. We have done an awful lot to promote hemp, we go to a lot of builder shows, we have been on newspapers, we have been on the radio, we've been on tv. We have done much more than anyone else here in Ireland and as a result the work has gone out there, and certainly during those building shows one meets a lot of architects who certainly are keen but a little weary. Our building system here effectively says that the architect or an engineer has to sign off the building. There is no approval process for the hemp-lime, the architect is the one who says "I believe this is a structurally sound building ".

Because hemp-lime does not have an agrement certificate, it does make a lot of architects weary of it. The architect does not it thought, he always have to sign off the building before you get a bank loan for example. It is a particular character of Ireland. Most countries have specific building regulations.

15. On the vested interests against the take up of lime-hemp
The main manufacturers of the alternatives, which obviously cement and the synthetic fibre industry (like kingspan) or anybody producing synthetic insulation materials would be opposed to it I suppose. What they would actually do I don't know, now we're getting into conspiracy land which may or may not occur.

There seems to be remarkable disinterest from the authorities. If you think about hemp for instance, it is an agricultural product. We are still largely an agricultural country, with the demise of sugar beet, with the demise of product specific subsidies, you'd think from organisation like Teagasc, there would be a massive interest in looking at alternative agricultural products. And to an extent very recently there has been an high interest in elephant grass, myscanthus, but that is very recent and hemp theoretically could be massive. If we are in dreadful breach of the Kyoto agreement on the emissions. The numbers are very significant (30% of emissions produced by the construction industry). Why aren't we making an effort? Yes we are not replacing buildings, there is no reason why we couldn't build 25-30% of our housing with hemp and lime, and producing lime being largely a locally produced product well available all over the island, and hemp which could be grown by our farmers very rapidly and manufacturing that needs to be local that would cut back in our imports of foreign manufactured goods. Why wouldn't we do all these things? There is a remarkable lack of interest. I was at the sustainable building show in 2005 and I was awarded one of the environmentally friendly awards by the people running the show and I got my hand shaken by Dick Roche. He got beaten directly, right there at the show and he didn't have the slightest interest in following up on it in any way. I gave

him a quick run down on it: an agriculturally grown product that could be produced in Ireland, manufactured in Ireland, could be responsible of a colossal number of work force (??). Do you think it would fall over us to try and get something going on it?

Marcus McCabe has been trying for two years to raise funds to start up this manufacturing process. I think he may succeed in raising funds but I think he got the subsidies from across the border, not from our government. We are trying millions of dollars at farmers and greencore for closing down the sugar beet industry in Carlow, about €75million. Why couldn't 2 or 3 have gone to a hemp plant? Instead of throwing money, why don't use some of them in order to support the farmers, to give them somewhere to seed the next crop and provide some local employment?

15.1 On the association of hemp with marijuana could
In America is fairly widely spoken about that. Nobody says it here as such. It is not a problem for France. They are growing thousands of hectares, they have got half of the manufacturing facilities in Europe. The English have one manufacturer and they are growing hectares, the Germans, the Dutch, the Spanish, everybody.

16. On the possibility for lime-hemp to become mainstream
Yes, very much so. That is my primary goal. My business is conservation work, I do work on this kind of building, that is what I do for living. The hemp is what I am enthusiastic about, I spent money on it, I made money on it, I have probably subsidised every job I have done. Certainly my promotional work costs me money, many thousands of euro, and again I am doing that because I really believe that is one wonderful environmentally friendly product that could be very much mainstream and that is my goal.

The biggest disadvantage is financial. I was at the energy conference in Austria a couple of years back (don't quote me on these numbers) and they were talking about the take up of solar water heating, wood pallet stoves and a french guy showed a graph of how many people were installing solar water panels in the previous 10 years. And then they introduced subsidies, in the form of tax reduction and within a space of two years the uptake tripled and then a few years after that they increased the subsidies even more, and again that doubled the amount of uptakes on that. We are often looking at things like those, they are more expensive now, so if your goal is to reduce CO2 emissions, if your goal is to become more self sufficient on building products, then sometimes even in a capitalistic society we have to promote, somebody has to say "here is free incentives, go set up that plant and good luck make money". First of all there has to be a desire to do that, "our goal is to get there" but in order to get there it is wrong to say "no, we don't want to subsidise, we don't want to do this". The scale of production is so off, you know the scale is not even a bl ??. 1% of the construction industry but I think this is even an exaggeration. So, in order to get it going it means some saying "yes, that is our goal, we would like to see it happen. And we can push up production". Because theoretically there is no reason why it shouldn't be competitive with most of its alternative. And it is just the scale of production that is doing that. There has to be a first step, somebody has got to make that commitment. Why should some individual put up 3 million box and take the risk? When society has a goal, society says "we must reduce CO2 emissions". Society says "we must become more self sufficient", we must be able to produce goods in this country". That is what society is saying, society should provide the first step in subsidising some of this things. Why throwing millions of euro in a dying sugar beet industry? 75 million dollars have gone to ??? so that they set up housing developments in fucking Carlow. That is what they are doing with the sugar beet plant. In Carlow there must be an massive housing development like they did with subsidies. Priceless land in the middle of one of the most expensive part of the country

APPENDIX A.4.

TRANSCRIPT OF MR. SEAN BALFE'S IN-DEPTH INTERVIEW

1. On the need for the certification for building materials
The certification of any product is not driven by certifiers or by ??? authorities. It is driven by the users who want a certain product be certified so that they can show that it complies with a standard or that has been shown to meet the requirement of the regulations of any ??? item. So, we as certifiers, do not go into the market to see and look for emerging products in order to certify them and allow their mainstream use. We rely on builders or manufacturers who are developing the products and they come to us to seek their certification so that they can find acceptance in the market place. So when you say lack of certification that is not due to the IAB or somebody else failing to complete the certification.

If somebody came to us looking for a certification for a building system using lime-hemp, we would certainly consider it and put it through the assessment procedure to see if that can be done.

1.1 On the definition of "proper materials" in the building regulations
For building materials there are a number of ways to show that the material is a proper material and their compliance with existing standards or having an Irish Agrement Certificate or ETA or comply with technical specification of one of the member states. So there are a few different methods to show it.

2. On the duty of the Irish Agrément Board
We certify both the construction system and the material. If you are coming to us with lime-hemp we would be interested in the material itself and in the construction method. We would look at the U-values, timber frame sound, and how they would relate to each part of the building regulation. And the properly adopted building practice used with that material.

In addition to the requirement by the building regulation we also look at the durability of the product in the Irish market which is not invested by the building regulation.

2.1 On the assessment of the durability of materials
Well, there is already a certain amount of knowledge in the use of lime in cement/concrete for hundreds of years... There is a good deal of knowledge on how similar materials perform in various weather conditions. It is not only confined to lime, there are other biological materials that have already been used in connection with lime to reinforce it historically over time.

We consider anything that is relevant to us for determining the durability of the material, i.e. examples of building in another country with similar weather conditions to Ireland.

Lime is not new, it has been used for years now. The same is for biological materials used within that in order to reinforce it. There are very few products that are totally new without previous experience in their use. Ok, we are now talking about hemp. I am not an expert on lime-hemp. If we went and see the previous uses in history, we might discover that yet it has been used here or there, this way or another.

3. On the difference between ETA or CE marking, and Agrément Certificate
CE marking is a quality marking put by the manufacturer on the product stating that it meets certain requirements. Whatever requirements might be, the two requirements that generally arise are shown to comply with an harmonised standard or else having and ETA, which would be tested in accordance to an ETAG (European Technical Approval Guideline) and there is a number of tested specifications with common understanding of ??? *it gets very technical...*

In order to have a CE marking I need to have an ETA? If your products fall into those harmonised standards then you can CE mark your product on the bas of the performance of those standards. If no standards apply to your product you can apply to the EOTA (European Organisation for Technical Approval) in order to issue an ETA for your product. That ETA if it has an ETAG draft for your particular product (i.e. ETAG draft for insulations for concrete forms)

there is a list of them, this is for ??? product and linking with themselves. We sit on that for Ireland.

If there is no particular ETAG that can assess your product (a draft or a common understanding or assessment procedure) and will assess your product as unique product and issue the ETA to show the compliance with the requirements of ??? and then you can CE mark your product again.

So, an ETA and a harmonised standards are methods that you can use to CE mark your product and place them on the market on any European State. It is not mandatory to CE mark your product in Ireland, it is mandatory in France, Germany and other European States. When you place your product on the market it has to be shown that it can be used in accordance to the building regulation of member state.

An Irish Agremènt Certificate assesses the product according to the Irish building regulations in particular and it explains the uses where you can put up the product here in Ireland so that it complies with the building regulations.

4. On the certification process
We look at manufacturers or builders to come to us. They are responsible for installing the product and we expect from them to have the technical expertise to build whatever construction they intend to build out of the product. If somebody came to us interested in the certification of lime-hemp we would expect them to have the expertise on how to construct a building in accordance to the Irish building regulations using that particular material. We would appoint an assessor, we do not have anybody internally, maybe two or three people according to the different aspects. But ultimately we would expect the applicant to have the expertise. It is not a training process where you come to us with lime-hemp and we tell you how to build a house using this material. You have to come to us knowing how to do it.

We do not carry out any testing. We would look at whatever testing the builder/manufacturer already carried out on the product and we would consider that. If needed, we could arrange additional testing to be carried out by third parties.

Most of our fees are due to professional fees for assessing the product and/or building method and the performance of the product over the time. And to assess whatever testing is required to make sure that it meets the requirements of the regulations.

In a product like this we would particularly focus on the building method and make sure that it meets the requirements by the building regulations.

Just on that (timber frame), you would look at the report. There is a timber frame consulting report here in Ireland dated 2002. It identifies a lot of practices that are recommended to be adopted in Ireland. So we would consider the recommendation given by that report in assessing the lime-hemp construction method.

5. On the possibility for an association or a group of builders to apply for the certification
Yes, it would be possible for an association or group of builders to obtain the certification. If we had a group of builders that came up with the specification of the lime and the hemp and the controls in manufacturing it, and installing it, yes there would be no reason why a group couldn't obtain the certification.

6. On the possibility to obtain an open certification (non-proprietary)
That is not something that the IAB would do. If there was a national standard or European standard for the product that would essentially have open the certification because that would assure your product complies with that particular standard. We don't publish standards as such for the materials, we look at specific materials, either your lime-hemp or somebody's else external insulation or whatever. We look at the quality controls that they have in place, and yes, it is product specific. Whereas national standards produced can show, just as a cement manufacturer can show how its cement complies with the standards of block manufacturer, you can show how lime-hemp complies with a national standard.

7. On the lack of certification for existing conventional cavity masonry construction

Long history of use is a proof that the material performs adequately. That's the only test we apply to new products. We have in Ireland a situation where we identified cavity walls and blocks walls. The established condition of that type of construction, we have plenty of tradesman in place, the practice of building block walls is engrained into the Irish building psyche and a lot of skill tradesman ??? that. When you talk about lime-hemp there is an element of re-training the construction sector in Ireland, which is not there at the moment. And that is a huge barrier to overcome. With costs associated with that and securing your lime-hemp, that is the main barrier. And as well people buying houses, there is the psychological barrier "concrete built is better built" and in the end competition is always going to put barriers in your way.

As IAB we recognised as a huge ??? the traditional block wall construction. The construction sector knows how to build a block cavity wall that works, it is not possible to say the same for lime-hemp walls. So that is why if you look for the certification you have to know how to do it and you are capable of training whatever construction practice are required to build that adequately. And there is a huge shift, it is very difficult to move people from one practice to another.

8. On the lack of certification as the main barrier to the mainstreaming of lime-hemp
No, I don't see it as the main barrier. We had somebody that came to us with a similar product we would certainly certify it quite quickly provided that it can be shown that it meets the requirements provided by the regulations.

My personal view is that the main barrier would be gaining acceptance in the construction industry as building material. And for end users to have an acceptance of the material. So you will see resistance on the concrete people.

You are the first one asking me questions about this lime-hemp material. When you get so close to things, like you are doing, you might think that the whole world is considering it.

Generally builders are looking for commercial advantages over their competitors and they tend to use the cheapest product they can to meet the requirements by the building regulations. They are not particularly concerned about sustainable building and eco-housing or passive-housing. There is no interest, as far as I'm concerned, in the mainstream sector. They are happy to go with traditional methods. What drives them is the cost of the material.

APPENDIX A.5.

DOCUMENTATION PROVIDED BY MR. MICHAEL O'GRADY

Construction House,
Canal Road,
Dublin 6.

27th July 2007

Paolo Ronchetti
58 Crestfield Drive
Whitehall
Dublin 9

Tel: 1850 306300
Fax: (01) 496 6548
Email: info@HomeBond.ie
Website: www.HomeBond.ie

Dear Paolo

Please find enclosed partially completed questionnaire along with HomeBond publications outlining the requirements in relation to new building systems and materials. In general terms, Homebond look for compliance with National Building Regulations. Part D of the Irish Building Regulations, Materials and Workmanship, sets out the relevant criteria for building materials, in particular stating that materials must be suitable for intended use and conditions of use. Where new or non-conventional methods of construction or new materials are used, appropriate certification demonstrating suitability for intended use and conditions of use, and of compliance with the relevant Irish Building Regulations, from a competent accredited body such as the Irish Agrément Board or equivalent, is sought. The enclosed Right on the Site leaflet issue number 30 expands on the use of New Building Systems and New Methods of Construction and on the requirements for Building Materials under sections 1 and 2 respectively. I believe this document provides the answers to your questions 3, 4, and 5.

I hope this information is of some help to you.

Yours sincerely

Michael O'Grady
Technical Services Manager
HomeBond

Directors: F. Fahy (Chairman), J. Tiernan (President), E. Farrell, B.E., M.Eng.Sc., M.Sc.Mgmt., Ph.D., Dip. Arb., MCIArb., C.Eng., F.I.E.I. (Managing Director & Secretary), M.Browne, F.C.A., (Treasurer), P. Raggett (Vice - Chairman), M.J. Coleman, E. Gantley, M. Greene, B.L., B.Comm., M.Econ. Sc., S. McKeon, N.M. Mooney, B.E., Eur Ing., C.Eng., F.I.E.I., S. Neville, F. Rhatigan.

National House Building Guarantee Company Limited Registered Office: Construction House, Canal Road, Dublin 6 Registered in Dublin No. 61063
International Tel. No. 353 1 491 0210

Faculty of the Built Environment
Dept. of Environment & Planning
MSc Sustainable Development

RESEARCH QUESTIONNAIRE

The questionnaire is part of a research project aimed at assessing the barriers to the mainstreaming of lime-hemp as construction material and building method.

I would be grateful if you could return this questionnaire by no later than **31/07/07** to the following email address: paolo.ronchetti@gmail.com. If you need any assistance, or would like any other information, please contact me:

Paolo Ronchetti
58 Crestfield Drive
Whitehall
Dublin 9
Mobile: 085 7727437

The following questionnaire can be filled out in digital format. This will avoid the hassle to print it out and facilitate you in returning it as an email attachment. If you are not familiar with MS Word, please follow the instructions below:
- Fill in the grey fields;
- From the 'File' menu, click on 'Send To' and then on 'Mail Recipient';
- Type paolo.ronchetti@gmail.com in the recipient field and then click on 'Send a copy'.

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1. Homebond is the main provider of structural insurance for residential buildings in Ireland, can you confirm it?

Yes

2. Is the structural insurance for a new residential building a legal requirement? Please explain.

No

3. What are the parameters upon which you base your evaluation before deciding whether or not to provide your coverage?

See enclosed publications

4. How do you cope with new materials and new building methods? In particular with regards to the 'green building' methods and materials that are recently coming out as a response to the needed sustainability of the construction industry?

Again, see enclosed publications.

5. Lime-hemp does not have any certification yet (Agremènt Certificate or European Technical Approval). Would you provide your coverage on the following cases?

- **on a self certification by a qualified and indemnified professional?**
- **on the basis of studies done in the UK (for example by the Building Research Establishment)?**
- **on the evidence of an increasing number of houses being built all over Europe?**

6. What are the alternatives, as regards the structural insurance, for an Irish builder wanting to use lime-hemp today?

I don't know

7. According to you, is the current lack of certification for lime-hemp a substantial barrier that will not allow its mainstreaming?

I don't know.

8. Any comments?

See covering letter.

Thank you very much for having spent your time in filling the questionnaire. Your help is very much appreciated.

Best regards

Paolo Ronchetti
Dublin Institute of Technology

Right on the site

Information to Home Builders from HomeBond
HomeBond, Construction House, Canal Road, Dublin 6. Phone 1850 - 306 - 300

Issue No. 30 September 2003

HOMEBOND INFORMATION TO MEMBERS ON:

1 NEW BUILDING SYSTEMS / METHODS OF CONSTRUCTION

HomeBond wishes to remind all members of the importance of ensuring that proposed building systems and/or methods of construction are suitable for use in Ireland. Particular care is required in circumstances where it is proposed to introduce into Ireland building systems or methods of construction which have not traditionally been in use in Ireland.

Care must be taken to ensure:

1. The suitability (including the suitability of design, materials and construction methods in "on site" conditions) of any such system or method for use in the particular climatic conditions;
2. The proper training of personnel in the erection of such system or method;
3. Appropriate experienced supervision of the carrying out of work on site.

Recent failures of building systems in Canada (British Columbia), U.S.A. and New Zeland highlight the dangers associated with the adoption of building systems and/or methods of construction which do not properly take into account different climatic conditions or the extent of supervision of the works required so that any such system or methods operate in an appropriate manner to ensure the structural integrity and water tightness of the dwelling. (It is notable that the climatic conditions in the lower mainland of British Columbia are very similar to the conditions in Ireland).

Prior to the introduction of any building system or method of construction in respect of any dwelling, members must be in a position to produce satisfactory evidence that the proposed system or method is of appropriate design and is suitable for use in Ireland, and that the proposed procedures to be adopted will ensure proper and adequate supervision of the construction of the dwelling.

2 BUILDING REGULATIONS 1997 - MATERIALS

HomeBond reminds all members that the Building Regulations 1997 ("The Regulations") require that all works to which the Regulations apply must be carried out with proper materials (and in a workmanlike manner).

"Proper materials" are defined in the regulations as materials which are "fit for the use for which they are intended and for the conditions in which they are to be used". The Regulations also provide that materials are "proper materials" if they:

- Bear a CE Marking[1], or
- comply with an appropriate harmonised standard, European technical approval or national technical specification[2] or
- comply with an appropriate Irish standard or Irish Agrément Board Certificate or with an alternative national technical specification of any state which is a contracting party to the Agreement on the European Economic Area (as defined in the Regulations), which provides in use an equivalent level of safety and suitability[3].

1. As per the Construction Products Directive 89/106/EEC
2. As per Article 4(2) of the Construction Products Directive
3. Technical Guidance Document D advises that the National Standards Authority of Ireland may be consulted for advice in relation to equivalence.

APPENDIX A.6.

DOCUMENTATION PROVIDED BY MR. BRENDAN LYNCH

Faculty of the Built Environment
Dept. of Environment & Planning
MSc Sustainable Development

RESEARCH QUESTIONNAIRE

The questionnaire is part of a research project aimed at assessing the barriers to the mainstreaming of lime-hemp as construction material and building method.

I would be grateful if you could return this questionnaire by no later than **31/07/07** to the following email address: paolo.ronchetti@gmail.com. If you need any assistance, or would like any other information, please contact me:

Paolo Ronchetti
58 Crestfield Drive
Whitehall
Dublin 9
Mobile: 085 7727437

The following questionnaire can be filled out in digital format. This will avoid the hassle to print it out and facilitate you in returning it as an email attachment. If you are not familiar with MS Word, please follow the instructions below:

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1. You are technical advisory manager in Irish Cement Ltd. What is your position in "*The Irish Concrete Society*"?

Honorary secretary

2. Concrete is today the most commonly used building material. Some say that under a sustainability point of view its performance is pretty questionable (high CO2 emissions, high embodied energy, non recyclable). What is your opinion on the issue?

Sustainability principles eccompass three pillars - economic, social and environmental. Significant efforts continue to be made to reduce environmental impact, in terms of embodied energy, while for operating energy requirements (which accounts for approx. 90% of total energy input),the benifits of thermal mass can significantly reduce or eliminate the need for cooling of offices etc. or heating in homes. Concrete structures provide the basis for much of the necessary infrastructure of modern living (water supply, sewage treatment, housing,bridges, flood defences etc) at reasonable cost over a long lifetime. Concrete is recycable and this is occurring even at present.

3. The production of cement, accounts for 5 to 10% of the world's total CO2 emissions. Do you agree that in a moment in the history like the one we are living (climate change, increasing energy cost, peak oil), sustainable alternatives must be looked for and eventually applied?

The lower figure applies to Ireland. The cement industry is at the forefront of utilizing 'waste' materials as both raw materials and fuel. It is also furtherreducing its carbon footprint in producing lower carbon products by incorporating secondary materials in cements.

4. Are you aware about lime-hemp? What is your opinion on this "new" building material?

Not until our discussion. Like all new (and existing) materials it will have suitable uses, but could have significant drawbacks. Experience will determine its suitability as a major building material.

5. According to you, what are the technical limits of lime-hemp compared to concrete?

I do not have sufficient knowledge at present to comment.

6. What about the durability of lime vs. cement? Lime was used by the Romans and Ord.Port.Cem. became mainstream during the '50s.

As I mentioned in our discussions, 'cement' has developed over the centuries as people were searching for suitable binders. Lime and other types of cement go back to Roman times and beyond. Portland cement was 'discovered' in the 1700/1800's to provide a strong binder which was also resistant to water. This then developed into the product we know today where builders wanted better 'early' strength and specifiers chose 28 days as the age of strength measurement. 100% Portland cement share of the cement market has been reducing significantly over the last decade and will continue to decline but as a product it has particular benifits. Other blended cements will grow in use.The durability of most of these cements (compared to lime) is quite good in difficult or aggressive environments.

7. According to the preliminary results of a questionnaire I did, people consider concrete a better solution than lime-hemp or other environmental friendly building methods. How would you explain their perception? (good propaganda of the concrete industry? lack of alternative information? others?)

Concrete has proven itself suitable for a wide range of uses at reasonable cost and generally not requiring a high level of maintenance.It has stood the test of time and peiple can rely on its durability. Thus structures built with concrete or concrete products are generally regarded as a safe investment.

8. Do you think lime-hemp could become a threat to the cement/concrete industry in the residential construction market?

Thjis construction method may well be a competitor, along with other existing materials like timber and steel, and probably orther newer materials to come along. Each will have benifits and disadvantages.

9. Do you see any opportunity for the cement industry in relation to the take up of hemp hurds as construction material? I am referring to the addition of cement to hemp hurds.

This is research that could be undertaken, but it is probable that much work would need to be done to show that it is a worthwhile method that would offer benifits over other existing methods.

10. Do you think there are vested interests (concrete industry in particular) that are trying or will try to slow down the take up of lime-hemp as a mainstream material?

All industries will attempt to defend their position as a lot has already been invested in establishing any existing industry to get to its present stage. The concrete industry employs many people at present and in the wider construction sense, much experience todate is based on existing materials and practice. This does not suggest that new products/methods cannot evolve and grow - development is always ongoing.

11. According to you what are the main barriers to the mainstreaming of lime-hemp?

Research and practical demonstrations of suitability and economic feasibility would be requirements to encourage its uptake.

12. Do you have any suggestions for the research I am doing?

Only the issues referred to in earlier answers.

Thank you very much for having spent your time in filling the questionnaire. Your help is very much appreciated.

Best regards

Paolo Ronchetti
Dublin Institute of Technology

APPENDIX B

APPENDIX B.1.

CONSUMERS' QUESTIONNAIRE TEMPLATE

Faculty of the Built Environment
Dept. of Environment & Planning
MSc Sustainable Development

RESEARCH QUESTIONNAIRE

The questionnaire is part of a research project aimed at assessing the barriers to the mainstreaming of lime-hemp as construction material and building method. In particular home/apartment buyers' perception and awareness are the main data the current survey is trying to gather.

I would be grateful if you could return this questionnaire by no later than **15/08/07** to the following email address: research.dit@gmail.com. If you need any assistance, or would like any other information, please contact me:

Paolo Ronchetti
58 Crestfield Drive
Whitehall
Dublin 9
Mobile: 085 7727437

The information gathered will be kept confidential and you will not be able to be identified by filling out this form. The completion of this questionnaire is purely voluntary.

The following questionnaire can be filled out in digital format. This will avoid the hassle to print it out and facilitate you in returning it as an email attachment. If you are not familiar with MS Word, please follow the instructions below:
- Fill in the grey fields;
- From the 'File' menu, click on 'Send To' and then on 'Mail Recipient';
- Type research.dit@gmail.com in the recipient field and then click on 'Send a copy'.

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1. Please tick off your age range

☐ 18 ~ 25 ☐ 26 ~ 35 ☐ 36 ~ 45 ☐ 46 ~ 55 ☐ 56 ~ 65 ☐ over 65

2. Please tick off your gender

☐ male ☐ female

3. What is your annual income? Please tick off your income range

☐ up to € 25,000 ☐ from € 25,001 to € 35,000 ☐ from € 35,001 to € 45,000

☐ from € 45,001 to € 55,000 ☐ from € 55,001 to € 65,000

☐ from € 65,001 to 75,000 ☐ over 75,000

4. Have you recently bought a home/apartment?

☐ yes ☐ no

4.1 If yes, when? (month/year)

5. Are you considering to buy a home/apartment?

☐ yes ☐ no

5.1 If yes, when? (month/year)

6. Are you aware about the materials used to build your home/apartment (or the one you are considering to buy)?

☐ yes ☐ no

6.1 If yes, did you have to look for the information by yourself or was it provided by someone else? Who?

☐ by myself ☐ someone else (please state who)

6.2 If no, would you be interested to know what these materials are?

☐ yes ☐ no

7. Could you please rate the following aspects in order of importance for your home/apartment? (0=completely irrelevant – 5=very important)

- Water efficiency
- Sound proofing
- Indoor air quality
- Daylight
- Thermal peformance
- Running costs
- Low allergy & environmental friendly materials

8. What was the weight of environmental performance in the choice of your home/apartment (or the one you are considering to buy)?

☐ completely irrelevant
☐ irrelevant
☐ indifferent
☐ important
☐ very important

9. How much extra cost would you be prepared to pay on the purchase price of a home/apartment built with eco-friendly solutions?

- ☐ none
- ☐ 2%
- ☐ from 3% to 5 %
- ☐ from 6% to 10%
- ☐ over 10%

10. Do you think a concrete built house is better than one built with environmental friendly materials?

☐ yes ☐ no

10.1 Why?

11. Are you aware of lime-hemp material and building method?

☐ yes ☐ no

11.1 If yes, do you know what its strengths/weaknesses are?

11.2 If no, would you be interested in having information about it? Why?

☐ yes ☐ no (please state why)

12. Would you buy a home/apartment made with lime-hemp?

☐ yes ☐ no (please state why)

13. What do you relate hemp to? (please tick off one or more options)

- ☐ clothing
- ☐ cosmetics
- ☐ human food
- ☐ animal food
- ☐ dope
- ☐ construction/insulation material
- ☐ paper
- ☐ medicine
- ☐ animal bedding
- ☐ ropes & nets

14. Any comments?

Thank you very much for having spent your time in filling the questionnaire. Your help is very much appreciated.

Best regards

Paolo Ronchetti
Dublin Institute of Technology

APPENDIX B.2.

ARCHITECTS' QUESTIONNAIRE TEMPLATE

Faculty of the Built Environment
Dept. of Environment & Planning
MSc Sustainable Development

RESEARCH QUESTIONNAIRE

The questionnaire is part of a research project aimed at assessing the barriers to the mainstreaming of lime-hemp as construction material and building method. In particular architects' perception and awareness are the main data the current survey is trying to gather.

I would be grateful if you could return this questionnaire by no later than **15/08/07** to the following email address: dit.research@gmail.com. If you need any assistance, or would like any other information, please contact me:

Paolo Ronchetti
58 Crestfield Drive
Whitehall
Dublin 9
Mobile: 085 7727437

The information gathered will be kept confidential and you will not be able to be identified by filling out this form. The completion of this questionnaire is purely voluntary.

The following questionnaire can be filled out in digital format. This will avoid the hassle to print it out and facilitate you in returning it as an email attachment. If you are not familiar with MS Word, please follow the instructions below:
- Fill in the grey fields;
- From the 'File' menu, click on 'Send To' and then on 'Mail Recipient';
- Type dit.research@gmail.com in the recipient field and then click on 'Send a copy'.

---

1. Please tick off your age range

☐ under 25 ☐ 26 ~ 35 ☐ 36 ~ 45 ☐ 46 ~ 55 ☐ 56 ~ 65 ☐ over 65

2. Please tick off your gender

☐ male ☐ female

3. Are you involved in 'green' building projects?

☐ yes ☐ no

4. Has any customer of yours ever asked for sustainable solutions in construction?

☐ yes ☐ no

4.1 If yes, what are the most common requests?

5. Are you personally aware of lime-hemp material and building method?

☐ yes ☐ no

6. Has any customer of yours ever asked information about lime-hemp?

☐ yes ☐ no

7. According to you what are the strengths of lime-hemp?

8. According to you what are the weaknesses of lime-hemp?

9. Lime-hemp currently does not have any Agrèment Certificate or European Technical Approval. Would you assume the responsibility of a lime-hemp construction project with a certificate of compliance if your customer asked for it?

☐ yes ☐ no (please state why)

9.1 If you decided to do so, would you be covered by your professional indemnity insurance?

☐ yes ☐ no

10. Do you think lime-hemp could become a mainstream building material?

☐ yes ☐ no (please state why)

11. According to you what are the main barriers to the mainstreaming of lime-hemp?

12. Any comments?

Thank you very much for having spent your time in filling the questionnaire. Your help is very much appreciated.

Best regards

Paolo Ronchetti
Dublin Institute of Technology