Hemp + Lime

Examining the Feasibility of Building with Hemp and Lime

DESIGN AND DEMONSTRATION

We respectfully acknowledge that we live, study and work on unceded, traditional and ancestral Lenapehoking territories of the Lenape peoples.

DRAFT 4

Acknowledgments

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For full list of contributors please refer to page 14.

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THE NEW SCHOOL
PARSONS
HEALTHY
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Content

About The Guide

This guide examines the feasibility of hempcrete block production through hempcrete demonstration projects. Included are introductions to industrial hemp cultivation, hemp and lime use, the potential of manufacturing, and creation of hemp-based products to create a complete cycle of block production to construct affordable and healthier housing. The project explores the potential creation of job training and new jobs in agriculture and in the construction industry in small, underserved rural communities. For this project the Healthy Materials Lab, in partnership with local farmers, producers, and developers, aims to design and demonstrate how healthier building materials can be incorporated to create affordable housing in rural communities across the United States.

Fig 1.1

Fig 1.2 Healthy Materials' team working at HML office.

Fig 1. 3 Healthy Materials Lab Office.

About Healthy Materials Lab

Parsons School of Design research labs adopts a theory of change that draws from a comprehensive, interdisciplinary approach and a range of expertise in strategic design, positioning research within the context of social justice. Working on a range of projects that address systemic change, Parsons brings extensive expertise in the built environment, an understanding of the importance of communication design to drive change, a historic ability to develop and implement innovation in a range of design scenarios. Social justice is a core mission at Parsons.

The Healthy Material Lab (HML) was launched as one of the first Parsons Design Led Research Labs with the receipt of a grant to support the Healthy Affordable Material Project in 2015. HML is one of four partner organizations of the Healthy Affordable Materials Project. The Healthy Affordable Materials Project is a collaboration of the Healthy Building Network (HBN), HML, Health Product Declaration Collaborative (HPDC), and Green Science Policy Institute (GSPI). Funded by a grant from The JPB Foundation, the Healthy Affordable Materials Project seeks to improve the lives and health of residents living in affordable housing across the United States by reducing the use of toxics in the building product supply chain.
HML's work on the activities and goals of the HAMP project is focused on scaling positive impact to replicate, adapt, broadly inform and transform current building practices in the AH sector initially within the first three-year time frame of the grant and now within the second round of funding received in 2018.

In addition to the HAMP project, HML has expanded its practice-based research to include a wider range of populations including early childhood, seniors, rural populations and residents in post-industrial cities. We continue to evolve and adapt our work within the core context of social justice. We have formed new partnerships to support projects and adopt strategies acquired in our HAMP work and consistent with our Parsons' mission-driven agenda. Our most recent projects focus on more benign building products particularly hemp and lime-based products that are viable alternatives to petrochemically derived products.

Foreword

The design, construction, and production of buildings impacts both human and environmental health. Products manufactured in the current construction system affect human health at all stages of the life cycle, not only during their use, but also through their processing, manufacturing, and disposal. Cumulatively, the materials and processes that make our built environments contribute to a significant proportion of local and global economic activity.[1] However, these activities have the potential to both positively and negatively affect the health of people and the environment. From a planetary perspective, building materials consume large amounts of energy and add significant amounts of carbon dioxide (CO2) into the environment during the production and construction phases. For example, cement is a critical component of concrete and a ubiquitous construction product. Cement is the second most consumed commodity in the world after water[2] and is a major producer of CO2 emissions. While we consider the entire building ecosystem in our research, we prioritize the materials in their use phase where products and materials emit unnecessary and hazardous toxics into both exterior and interior environments.

Faced with a climate change crisis, there is an increasing demand for the construction industry to produce renewable, environmentally sustainable and benign construction materials. One of these alternative materials is a product sometimes called hempcrete. Hempcrete combines industrial hemp, lime, and water to create a building product with a range of valuable physical and natural chemical characteristics including fire resistance, lightness, thermal performance, and a low environmental impact, all of which make it a compelling choice in construction. Interest in hempcrete has gained steady momentum within the fields of architecture and design as a viable construction material.

The ingredients that make up hempcrete—industrial hemp and lime—are of interest in their own right. As a crop, industrial hemp can be reintroduced into rural communities and locally cultivated, minimizing transportation to a factory or site for subsequent production. Therefore, products utilizing industrial hemp have a reduced carbon footprint.[3] Additionally, hemp is an incredibly versatile crop, and up to 97% of the hemp plant can be used to create a range of valuable products: from the fibers for textiles; the cellulose of the stalk, which has been used in the production of non-petroleum-based plastics like cellophane and rayon;[4] and the seeds and oil of the flowers for food and oil. Hemp has been compared to other agricultural crops that have received attention for their diverse end uses. Corn, for example, which is grown for its edible kernels and ethanol production, also contributes post-consumption to the building industry. However, despite its abundance, covering over 97 million acres of land in the US, corn production consumes considerable amounts of natural freshwater resources via irrigation, requires pesticides, and is responsible for emitting over 5.6 million tons of nitrogen into the air from chemical fertilizers. Additionally, the methods required to make corn a viable resource for building materials would result in additional harmful emissions being released.[5] The cultivation of industrial hemp does not require irrigation, added fertilizer, or pesticides, making it a more sustainable agricultural material choice.

Until 2018, industrial hemp cultivation and use was regulated by the federal government, as hemp was a species classified as a controlled substance. Academic and other organizations could apply for licenses to grow and harvest industrial hemp. These restrictions have been gradually lifted, opening up agricultural and industrial opportunities. New York State recently passed legislation promoting a new carbon farming initiative in Columbia and Dutchess counties.[6] This legislation promotes sustainable farming practices such as industrial hemp cultivation that would use the crop to sequester carbon in the soil and improve soil productivity. And in December 2018, the Agriculture Improvement Act, otherwise known as the 2018 Farm Bill reclassed hemp from the Schedule I category to an agricultural commodity.

Fig 1.4 Cannabis Sativa plant

Fig 1.5

In addition to a reliable source of locally grown industrial hemp, hempcrete products also require lime. There are a range of US companies producing lime mixes designed as additives to produce hempcrete. Lime is made from limestone, a carbonate sedimentary rock found across the US. Locally sourced limestone that could be processed locally is an ideal option as it would also reduce transportation costs and carbon emissions. The viability of local limestone and its processing into lime for use in hempcrete will be explored in this project.

To make hempcrete, hemp's woody core is combined with water and a lime mix, which acts as a mineral binder to coat the hemp hurd. The hempcrete produced in this process creates a naturally antimicrobial and antifungal mixture, a simulated "concrete-like" material, and a product that has a range of construction uses. Today, very little hempcrete product development is being undertaken for use in any sector of the construction industry in the United States, primarily because of the recent restrictions on hemp cultivation. However, we maintain that hempcrete is an innovative product with many useful construction properties and maintaining its use as an alternate, affordable, healthier building product will produce a multitude of beneficial outcomes.

Families, especially children, living in affordable housing are often subjected to poor living conditions. Creating alternate products and building systems made from locally grown and sourced hemp and lime materials will contribute to improved health outcomes for children and families living in affordable housing. Families living in affordable housing are often excluded from important conversations about their futures as it relates to their health, housing, and other critical issues. In all of our work and in this project, we focus on amplifying and embodying the voices of local community members. By making it a priority to work with local community members, we gain valuable insight into how to make the most of the strengths and resources of rural community members so that those critical local voices will also guide and inform the process.

Construction and finish materials currently used in affordable housing are often the cheapest and least healthy on the market. We have conducted case study research[7] in five different geographic locations in the US where affordable housing developers, their teams, and architects are working to push the boundaries of current construction practices and consider healthier material alternatives. But alternate products that are healthier, affordable, and appropriate for use in affordable housing are limited. Discovering a viable, sustainable, insulating hempcrete wall system as an alternative to current walls is intriguing and worth exploring.

It is difficult to innovate in the US affordable housing sector. Land costs are high, and funding for affordable housing is complicated as owners and developers must draw from multiple sources of both private and government funds to construct their projects. Each fund has its own restrictions and constraints. Managing the funding process requires intensive oversight, adding to the "soft" costs of projects, which can be equivalent to the hard costs of construction. Yet the supply of better construction materials is limited and often expensive. How can we contribute to change in affordable housing by creating a new system of viable materials production? A new agriculturally based system with new models of production will create new opportunities in agriculture for farmers, as well as provide new training opportunities for workers, setting into motion the production of new materials and new jobs in construction. Not only will we be able to design and construct better affordable houses, we will also create new value chains for rural communities.

Collaborators

Healthy Materials Lab has identified a collaborative relationship with McEnroe Organic Farm, which planted six acres of hemp in the summer of 2018 to test its viability in the upstate New York region. The McEnroe family has been farming in the Hudson valley since the 1870s. Today the farm has been certified organic by the Northeast Organic Farming Association of New York for over twenty-five years. For more than twenty years, McEnroe's soil blends and compost have been used by other organic growers, regional farms, commercial landscapers, municipal parks, and home gardens and for green rooftops. The composting operation receives manure, leaves, and food waste, all of which are organically converted to a high-quality compost soil amendment for use on the farm to ensure a rich and biodiverse organic farm and for sale throughout the northeast region. Rural communities face many challenges as the value of agricultural produce fluctuates. The McEnroe farm has identified through their production of organic produce products that can be sold to yield a higher return. Expanding their products to include the cultivation of hemp to make better building materials based on agricultural materials is a logical next step for this innovative producer. Access to land to grow hemp, as well as land to prototype the walls for the houses, is an important next step for this project. In our study we will involve local community partners in a range of locations, including a local design strategist who has been working with farmers with the goal of creating a decentralized, regenerative supply chain creating regional networks of farms and new small-scale production centers. We will also work with colleagues from Arizona State University's Biodesign Center for Environmental Health Engineering, who will use a range of testing protocols to evaluate the air and particulate quality of the new construction.

Alison Mears

Alison Mears, AIA LEED AP, is Director of the Healthy Materials Lab at Parsons School of Design, New York. She is a Principal Investigator of the Healthy Affordable Materials Project. HAMP is a three-year, $7.5 million grant to detoxify the interior environments of affordable housing units (the grant was renewed April 2018). Her research focuses on developing a range of strategies that disrupt the building supply chain in affordable housing to incorporate human health. Previously Dean of the School of Design Strategies and Director of the Bachelor of Fine Arts Architectural Design and Interior Design programs at Parsons. Alison teaches in Parsons Architectural Design program and interdisciplinary design studios.

Jonsara Ruth

Jonsara Ruth is Design Director at Healthy Materials Lab, Founding Director of the MFA Interior Design Program, and Associate Professor at Parsons School of Design. Central to her work is listening to and learning from diverse perspectives and studying human experience, behavior, and health as principal motivations for design. Material curiosities drive her research. Jonsara is a designer and artist and founded Salty Labs, a collaborative design studio, to improve environmental health while creating viscerally designed spaces, events, and furniture.

Irshaad Malloy

Irshaad is a third-year graduate student in the Master of Architecture program at Parsons School of Design. She received her Bachelor of Science in Architecture from Kent State University in August 2015 and remained in the area to work with a firm designing affordable housing for the following two years. She has specific interest in the organic environment's influence on architecture, as well as the ways in which cultures and cultural diversity impact architectural design. Through her work Irshaad aims to contribute to the thoughtful intentionality that becomes healthy and affordable living environments.

Mariana Gonzalez

Mariana Gonzalez is a graduate of the Master of Fine Arts Transdisciplinary Design program at Parsons School of Design. Her academic background is Innovation and Design Engineering, while her professional experience is product engineering, project management, and graphic design. She is interested in exploring the role of designers in environmental and social challenges and how designers can create awareness and engagement and allow consumers and other designers to make ethical and responsible choices by facilitating information flow in a meaningful way.

tina lê

tina lê was born in Tiohtià:ke/Mooniyaang (Montreal) on unceded and contested land to the Kanien'kehá:ka and Anishinaabe Nations. They are double-majoring in Art History-Studio Arts and Philosophy at Concordia University. Their research-creation explores the antinomy of absence and presence, invisible labor, diasporic debt, and alternative modes of drawing as extensions of the body through language, fibres and textiles, video, performance, and sound art. Invested in collaborative approaches, their practice delves into personhood, intersubjectivity, agency, and responsibility to investigate what it means to exist in an increasingly fraught and globalized world.

Erich McEnroe

Erich McEnroe is one of the operators of the McEnroe Organic Farm in Millerton, New York. The McEnroe farm is completely organic, which, as they boast on their website, entails "using methods that preserve the environment and avoid most synthetic materials, such as pesticides and antibiotics." [1] Organic certification comes from the United States Department of Agriculture (USDA) as a way to ensure proper standards and practices are used within farming." Interested in the potential of growing industrial hemp, Erich has been in partnership with Healthy Materials Lab and is a vital participant who will provide agricultural expertise on the specifics of growing and harvesting industrial hemp.

Lou Grasso

Lou Grasso of the Urban Mining Company works in Westchester, New York, in developing/mining high-performance pozzolans. Pozzolan is a finely ground material that, when added to materials such as concrete, provides quick and long-lasting added durability. The Urban Mining Company specifically utilizes recycled glass ground into fine powder as its main product, Pozzotive. Lou brings a lifetime of experience in the concrete industry particularly block making to the project.

Rolf Halden

Rolf is a Professor in the School of Sustainable Engineering and the Built Environment and Founding Director of the Biodesign Institute's Center for Environmental Security and the Biodesign CES Mass Spectrometry Facility at Arizona State University, where he also holds affiliate appointments in the School of Biological and Health Systems Engineering and the Barrett Honors College. He has twenty years of experience in environmental monitoring, human health assessment, and sustainability science. Rolf has authored 150 peer-reviewed articles, reports, and patents, a book on emerging contaminants, as well as over 300 presentations at national and international symposia. Rolf was a co-founding member of the Center for Water and Health at Johns Hopkins University, where he maintains an adjunct faculty appointment in the Department of Environmental Health Sciences. Rolf received his MS in Biology from the Technical University of Braunschweig, Germany, and his MS and PhD in Civil/Environmental Engineering from the University of Minnesota.

Background

Access to better building materials used in both new construction and renovation projects is a significant challenge. This guide compiles information to provide readers with the necessary knowledge to begin developing and working with products created from industrial hemp such as hempcrete. Hempcrete is a better alternative to other traditional wall systems, having good insulation and fire-resistant properties and a low carbon footprint. Addressing the history of industrial hemp, this guide provides information and references traditional practices and case studies to illustrate the range of possible uses of industrial hemp. Best agricultural practices are recommended, in addition to an introduction to the range of new hemp building materials, wall sections and construction techniques. Additionally, this guide portrays a clearer picture of the specific potential economic benefits of a burgeoning hemp industry based in the United States.

In the US, Cannabis was classified as a Schedule I narcotic, an illegal, psychotropic drug with "the highest potential for abuse."[8] This classification referred to cannabis as a genus, extending the prohibition to all species of cannabis. This included industrial hemp, despite its lack of addictive qualities and its beneficial uses as a building material. The 2014 Farm Bill approved hemp activities destined for research and pilot programs in order to determine whether its legalization would be beneficial.[9]

In December 2018, the Agriculture Improvement Act, otherwise known as the 2018 Farm Bill, reclassed hemp from the Schedule I category to an agricultural commodity.

Fig 1.6 Villa di Gioia by Pedone, Italy

This lifted the previous Farm Bill's limitations, legalizing the cultivation, production, and commerce of industrial hemp across the US, regardless of state laws. This applies to Indigenous Nations as well, theoretically supporting their right to self-determination as a sovereign nation. Some Nations, such as the Menominee Nation in Wisconsin, had approved and were growing industrial hemp prior to 2018. Since Wisconsin had not yet developed a pilot program, the Menominee farmers were, in 2016, met with federal suppression. The recently inaugurated bill should prevent any further recurrences of suppression.[10] That being said, each state retains authority in regulating the "cultivation and processing of hemp . . . as they see fit."[11]

As we consider the current benefits of agricultural crops like hemp, we forefront the historical and present practices that disenfranchise people. Our intention is to learn from the past and not perpetuate injustices on any peoples. The colonial introduction of the European strain of hemp and other crops to the Americas launched centuries of economic dominance of colonized lands, peoples, and resources as well as 400 years of slavery in the US. Colonists appropriated farmable land and extracted resources without a recognition of the rights of either Indigenous or African American peoples. The emergence of botany is intertwined with the history of colonialism, especially where the Americas is concerned. "Colonial botany—the study, naming, cultivation, and marketing of plants in colonial contexts—was born of and supported European voyages, conquests, global trade, and scientific exploration."[12] Indeed, this enterprise yielded important financial gains for colonizing countries. On expeditions to uncharted lands, naturalists acquired, whether illegally or not, valuable plants for their respective countries and monarchs, as well as "personal and corporate profits."[13] Where colonialism was a race between countries to riches taken from foreign territories, it coincided with the contact of new plants that served practical and economic ends. For example, antimalarials were highly sought after for colonization efforts in tropical environments during the Enlightenment era. Eighteenth century French explorer Charles-Maine de La Condamine gathered Peruvian bark seedlings in an effort to undermine Spain's monopoly on this medication. Botany, as a lucrative and useful science, was therefore instrumental to colonialism; in providing colonizers with sails, hemp specifically played a key role in the conquest of the Americas.

Today, industrial hemp is being used in hempcrete in one-off residential construction at small scales using imported or occasionally locally produced hemp products. In order to scale the use and production of industrial hemp based products, the United States must begin to develop an infrastructure to create equitable local systems of production and support the use of hemp in construction.

Our research indicates that hemp is being successfully grown and used to produce construction materials in small- and medium-scale residential and commercial construction in Europe.

Based on these findings, we have established new partnerships with architects and producers in Europe to learn from their experience. This has enabled us to leverage their knowledge, consider adoption in the US, and propose potential scaling for use in multifamily residential structures. Hempcrete performs differently compared to other building products, which means that it may be necessary to change building code requirements to support the larger-scale adoption of this product.

By adapting and advancing current European practices, the US is capable of becoming a key actor in the advancement of the hemp industry and a leader in the construction of healthy and affordable housing. The product of the hemp crop combined with locally available lime would create new, innovative products to construct affordable and healthier housing.

Our work is predominantly focused on residents living in underserved communities within the United States who are often forced to deal with the worst interior and exterior environments. Residents of fenceline communities, or housing located next to industry or other potential sources

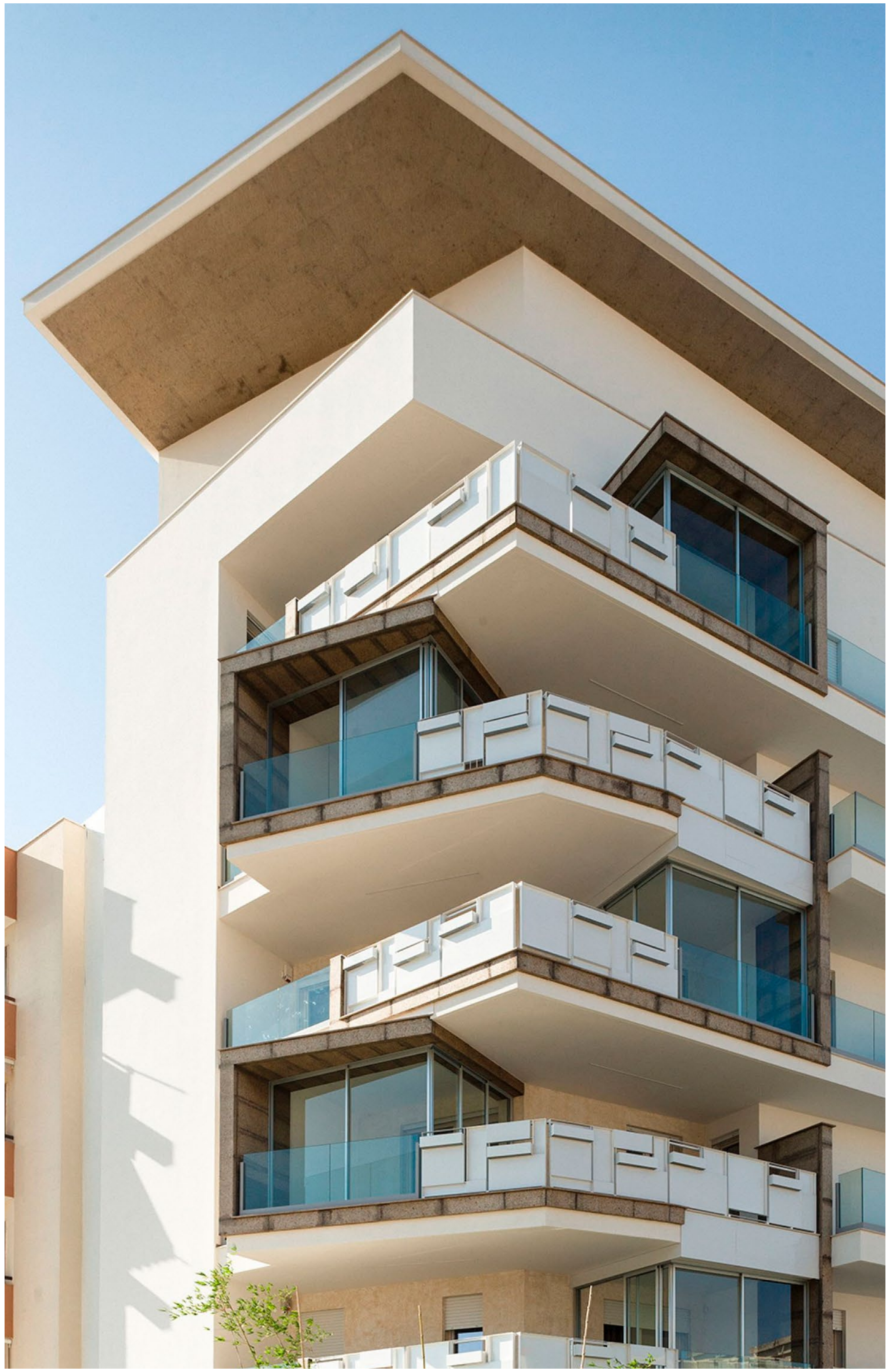


Fig 1.7 Casa di Luce by Pedone Working, Italy

of air, water, and noise pollution, are particularly at risk. Affordable housing in these areas could utilize hempcrete as an alternative material, to create healthy and breathable housing.

It is possible to improve building products and make better choices about affordable, healthier materials as part of a complementary and holistic health approach, minimizing the health gap of low-wealth communities. Access to better building materials used in affordable housing for both new construction and renovation projects will result in reduced or completely eliminated exposure to harmful chemicals rife in the building industry. By targeting the affordable housing market and increasing access to lower-cost and less harmful building products, this project has the ability to revolutionize the entire construction industry and contribute to a virtuous cycle of innovation. Petrochemical

Petrochemical Industry, Human and Environmental Health

The twenty-first century is marred by rapid change and catastrophic global environmental problems. In October 2018, the United Nations' Intergovernmental Panel on Climate Change (IPCC) urged countries to restrict the average global warming to 1.5 °C (2.7 °F) above preindustrial levels. Our excessive consumer habits rely on substantial energy consumption, forcing corporations and governments to consider all sources of petroleum, including fracking, to extract oil and gas. Fracking has transformed the US energy production and now occurs in over twenty-one states. Fracking is environmentally destructive, polluting water sources, destroying forests, and infringing on indigenous territories. Climate change is not just an environmental issue, it is also a sociopolitical issue for the disenfranchised and Indigenous peoples that directly affects their livelihood. Winona LaDuke, Anishinaabe rural development economist and hemp farmer from the Makwa Dodaem (Bear Clan) Mississippi Band of the White Earth Reservation in Minnesota, advocates for climate justice and Indigenous rights. She says that the "[Anishinaabeg] Seven Generations and Seventh Fire prophecies tell us we are in a time when we have a choice between two paths. One path is well worn, scorched and leads to our destruction. The other path is new, green and leads to Mino-Bimaadiziwin (the good life). We must choose to walk the new path."[14]

Petroleum is a finite fossil fuel that takes on the form of crude oil, natural gas, and bitumen, which is present in tar sands. It is also processed into a derivative known as a petrochemical, which includes methane, ethylene, propylene, butane, butadiene, and BTX (benzene, toluene, xylene). The rampant extraction and burning of petroleum for fuel and energy in and of themselves are extremely polluting, not to mention the oil spills that contaminate the water. The process of obtaining petroleum emits large quantities of CO2, ash, nitrogen, and sulfur. These chemicals contribute to smog, pollution, and acid rain. An excess of carbon in the atmosphere leads to rising temperatures,[15] thereby worsening the climate crisis. Currently, our daily worldwide oil consumption is 95 million barrels. 12% of that, or 11.4 million barrels, is allotted to the petrochemical industry.[16] [17]

Petroleum has infiltrated every aspect of our daily lives: It is found in our detergents, phones, food preservatives, pesticides, and even the building materials that constitute both our work and home environments. We have grown overly reliant on petrochemicals and are in constant contact with them.Through this codependency, we are contributing to the destruction of the earth and its ecosystems, which by extension inevitably leads to the destruction of our own health. In the last year, the US has become the largest producer of petrochemicals. "Between 2011 and 2017, the U.S. added roughly 14 million tons of petrochemicals production capacity, [which] according to IHS Markit, [is] just under the amount built in the Middle East. But this year marked a turning point: through 2020, the US is expected to add another 14 million tons of production capacity, more than double the amount slated to come online in the Middle East."[18] The construction industry contributes to 14% of the petrochemical industry consumption, or 1.5 million barrels per day.

The US Gulf Coast has become the center of global petrochemical growth with production predominantly located in flood-prone areas.

Fig 1.8 Old Oil Refinery Station at Gas Work Park, Seattle, United States

During the Houston flooding in 2017, chemicals from multiple production sites overflowed into the water and soil. The flooding affected many underserved residential communities that qualify as fenceline communities, which are disproportionately represented by families living in poverty, the working class and/or people of color. The multitude of pollutants produced by chemical plants has several expected, as well as unexpected, consequences. Women, children, the elderly, and pregnant women are more susceptible to contracting asthma, cancer, and developmental and reproductive health issues that may result from exposure to toxic chemicals present in exterior and interior constructed settings. Explosions and other on-site accidents may also be caused by these industrial facilities. However, because of the lack of affordable housing alternatives, thousands of families are forced to remain in these fenceline communities. Beyond the dangers of day-to-day living in proximity to chemical plants, the petrochemicals that are the raw materials of building products are problematic because of their pervasiveness, their toxicity, and their long lifespan when they are installed in the built environment.

In the US today, most of the 85,000[19] chemicals in common use are not regulated. The Toxic Substances Control Act of 1976 (TSCA) is the only US law regulating toxic chemicals. It “grandfathered” in 62,000 existing chemicals that were already in use in 1976, as they were assumed to be “safe unless proven otherwise.” Of these, approximately 250 chemicals have been tested. Five chemicals have been (partially) restricted under the law, including asbestos, PCBs, dioxins, chlorofluorocarbons, and hexavalent chromium. Because there are no regulations in place, there is no required minimum for testing regarding the safety or potential toxicity of these chemicals and their effect on human health. Harmful synthetic chemicals are used in a wide range of products, including those in the construction industry.

There is effectively no governmental legislation in place to protect consumers from the harmful effects of chemicals in building products.

Petrochemical emissions span a products life cycle, releasing toxic chemicals from the point of initial extraction as a raw material and processing to its end of use and inevitable disposal. The omnipresence of such toxic chemicals in all construction materials, including those used in affordable housing, exacerbates the potential to harm already vulnerable populations. Substandard housing aggravates the risk of exposure or subjects residents to a new host of exposures resulting from poor plumbing, inadequate heating, leaky roofs, pests, and more. Health impacts can include infectious and chronic diseases, asthma, and lead poisoning. These have real health and economic impacts. Lead exposure has been estimated to cost approximately $95 million per year in treatment or disability, including loss of work time or time away from school, and these costs are expected to increase as we factor in the potential for future loss of earnings.

The Construction Industry

With the global population exceeding 7.7 billion people in 2019, both developing and developed countries are expanding their urban infrastructures. Over the past few decades, this accelerated worldwide development has drastically increased the number of construction projects and the demand for a wide range of building materials including steel, cement, and other ingredients used in concrete. This has resulted in global shortages of the finite raw materials required to produce building products and a consequent inflation of their prices.
Concrete is a mixture of rock aggregates, water, and cement, which acts as the binder. It was estimated in 2010 that three tons of concrete is produced per person every year. Roughly 7.5 tons of cement is required to produce 1 ton of concrete; that’s a yearly consumption of 22.5 tons of cement multiplied by the world’s population. One ton of cement emits one ton of carbon dioxide. Therefore, on a global scale, the cement industry releases 22.5 tons of CO_2 per person each year.[20] The construction industry needs to reduce the consumption of concrete to reduce these CO_2 emissions. The IPCC’s report delineates how to meet the 1.5°C (2.7°F) warming

Fig 1.9 Holly Refining Co, Wood Cross, United States

Fig 1.10 Holly Refining Co, Wood Cross, United States

limit: reforestation is of utmost importance, as is revolutionizing our technology and the way we use land. Indeed, we must adopt electric modes of transportation and implement carbon capture technology anywhere we can.[21]

> **"Architecture and Urbanism play a significant role in the consumption and distribution of resources in space. The design of the built environment plays a vital role in achieving equitable and sustainable consumption. Carbon emissions directly depend on how we design our cities and buildings. In order to sustain ourselves through the climate change crises, we need to design our buildings and cities with sustainable and equitable carbon footprints."** [22]
>
> **—Vandana (Van) Baweja (School of Architecture)**

There is an increasing demand to reduce the cost of constructing buildings and speed up the process. This leads to the use of cheaper materials.There is, however, also a demand for better performance characteristics to meet new energy efficiency and other requirements. Petrochemicals are cheap to make and can enhance materials. As such, the construction industry has grown to rely on a host of petrochemical-derived products that contain a range of toxic chemicals. These hazardous products are often not as resilient, long lived, or benign as more traditional building products and are made from chemicals that are largely untested. The highest growth area in construction materials today is in polymeric materials—plastics, rubbers, thermoplastics, adhesives, foams, paints, and sealants. Common building products such as insulation foams are laden with toxic flame retardants and adhesives and material finishes contain polyurethanes, one of the most toxic and carcinogenic chemicals in use.[23] Some scientists recommend that we should "decrease the hazards and risks from chemicals associated with plastic production and plastic products, reduction measures, substitution, or phase out of the most hazardous chemicals, and maybe even of some polymers (if risk assessments conclude high risk), are important."

Finding alternatives to common building products like foam insulations and the cement used in concrete is imperative. Sustainable and healthy substitutions can be used in both construction and renovation projects. Alternate products would reduce residents' exposure to a host of health issues in the built environment by decreasing or eliminating the use of toxic chemicals in building products. And alternates will yield immense benefits, including diminishing our carbon footprint.

The Agriculture and Textiles Industry

To ensure consistent and significant crop yields, agriculture has become highly dependent on fertilizers and pesticides, almost all of which are produced from petrochemicals or petroleum. In addition, farming machines are critical to agricultural production, and they run on gasoline. As a result, agriculture is one of the largest consumers of petroleum-based products.

Some crops use more water and petroleum-based products than others. For example, conventional cotton uses about 16% of the world's insecticides and 7% of pesticides. Currently, common alternatives to cotton are petrochemical-based synthetic textiles such as polyester, which make up 60% of our clothing. Though they require less water and pesticides, these synthetic textiles are inadequate substitutions: when accounting for the petroleum involved in the production, polyester releases three times more carbon dioxide than cotton does. Microfibers are made from polyester fibers; microfibers are roughly one nanometer in size in comparison to a human hair at 100 nanometers. Prevalent in many everyday items, these fibers are released into the environment when we do our laundry. As much as 700,000 microfibers break away from one piece of synthetic textile during a single wash. Given their microscopic size, it is increasingly difficult to prevent their entry into our oceans and beaches. Over time, they build up in concentration and are ingested by sea creatures. Moving along the food chain, microfibers inevitably find their way into our own bodies via the food we eat.[24] These petrochemical-based alternatives therefore harm the environment as well as our health. However, hemp fibers would provide viable alternatives to cotton fibers, and hemp as a crop is a less energy- and water-intensive crop.

Climate scientists predict a 3°C (5.4°F) average increase in temperature by 2100. We have until 2030 to make fundamental changes to avoid an irreversible catastrophe that would expose hundreds of millions of people to extreme heat, poverty, drought, and floods. Respecting the 1.5°C increase set for 2030 would still result in the destruction of 70 to 90% of the coral reefs, preferable to total extinction at 2°C (3.6°F) warming. The latter scenario would decimate marine life,[25] ensuring the catastrophic loss of our unique ecosystems and depletion of natural resources that is already underway. Historical collapses in civilizations have been caused by deforestation and habitat destruction as well as soil fertility losses. That list has since grown to include issues we currently face, namely human-caused climate change, buildup of toxic chemicals in the environment, energy shortages, and full human utilization of the Earth's photosynthetic capacity.[26] Life as we know it is at stake; in order to survive, we must adopt sustainable practices.

Fig 1.11 The ubiquitous plastic bag, an example of how petroleum has infiltrated every aspect of our lives.

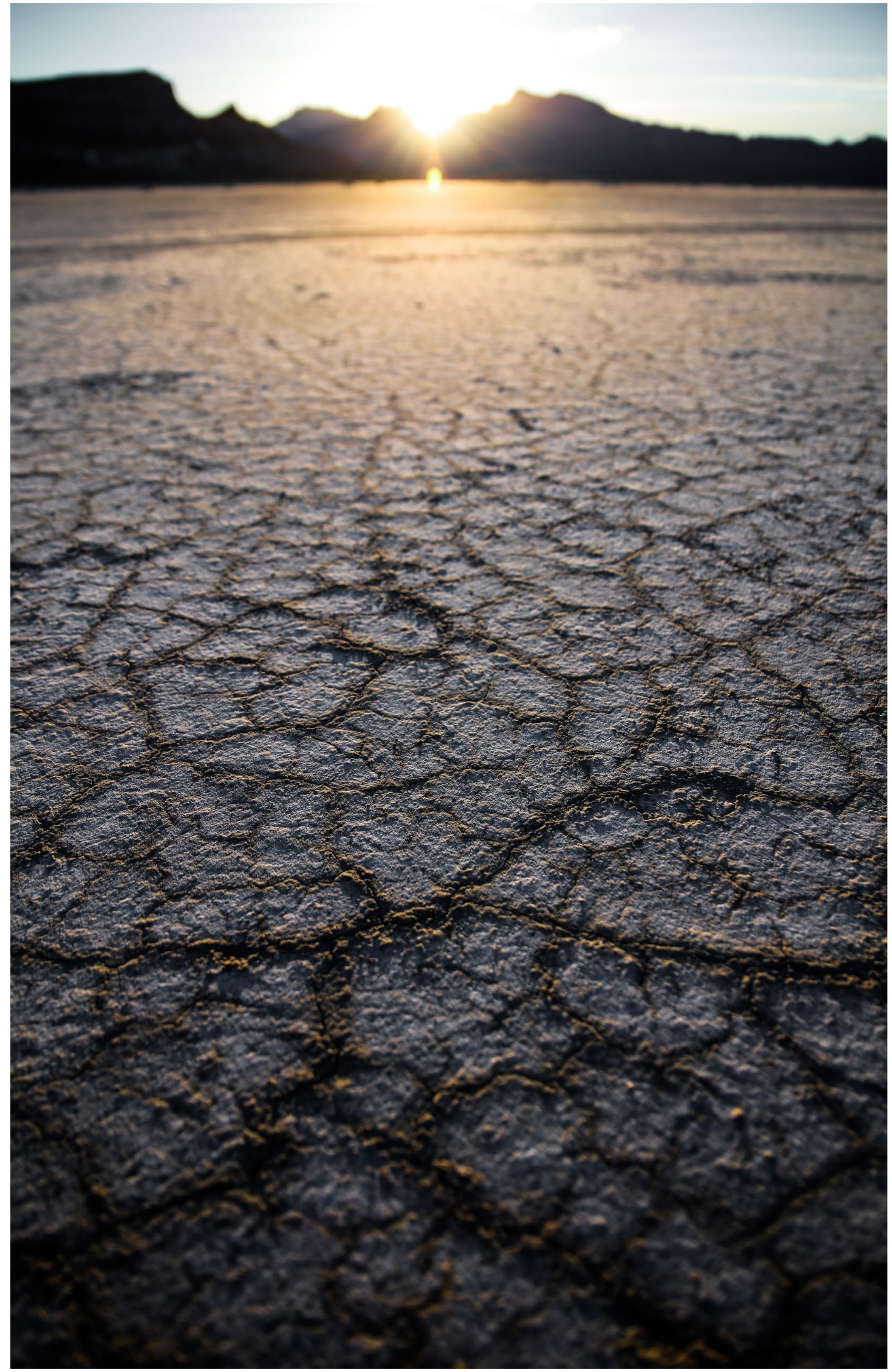
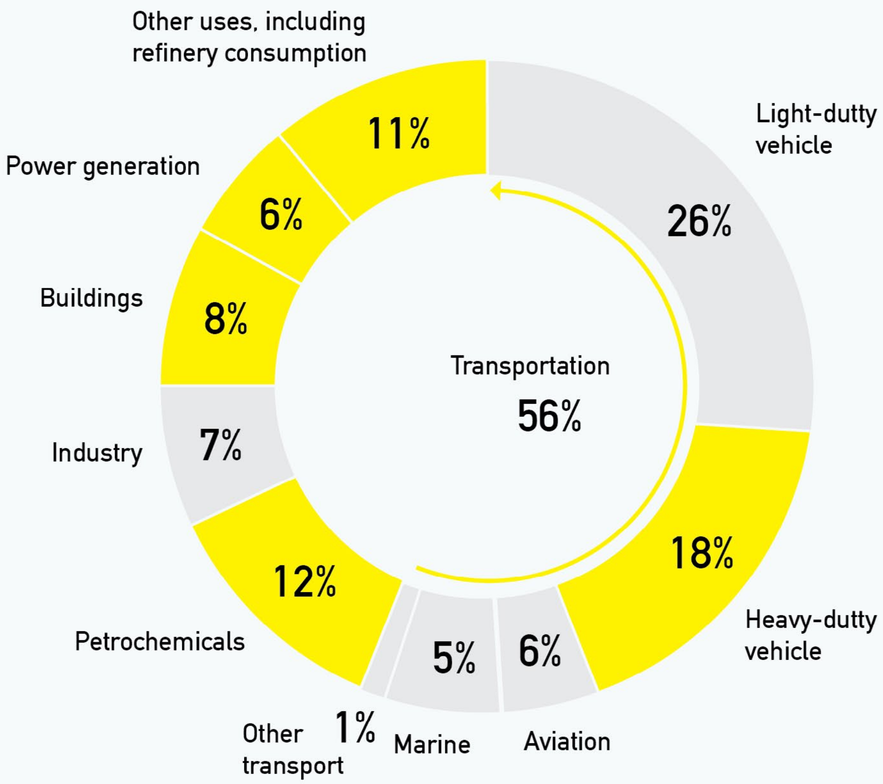


Fig 1.12 Extreme heat and drought, some of the effects of climate change we are starting to see.

World Oil Demand

The use of hemp and lime in the building industry can impact different sectors where oil is used. If hemp-based products replace petrochemical products, emissions created by areas like power generation, buildings, heavy-duty vehicle or petrochemicals would be reduced significantly.



Areas where the use of Hempcrete would reduce emissions

Diagram 1.1

Petrochemically based vs hemp based products

A comparison between the environmental impacts of petroleum and hemp based construction products. Petroleum based products have multiple negative environmental impacts while comparable hemp based products reduce energy consumption and sequester carbon dioxide.

Petrochemically Based	Hemp Based
40% of green house gas emissions are produced by the building industry	**110 kg** of CO2 are sequestred in one cubic meter of hempcrete
7.6 million barrels of oil are used to heat homes per day in the United States	**50-80%** energy conservation for heating + cooling hemp structures
1.5 million of barrels per day are used by the construction industry	One hectare of industrial hemp can absorb **22 tonnes** of CO2
16% of pesticides and **7%** of insectizides are used by conventional cotton	**0** fertilizers or insectizides are required by Hemp.
170 Million tons of building related waste were generated in 2003.	**0%** on-site waste
233% More frequent smoke signatures caused by synthetic furniture and construction materials.	**100%** non-combustible with a 2-hour fire rating

Introduction to Hemp + Lime

As cement in concrete becomes more expensive and rare, and as the climate crisis turns more dire, it is no longer tenable to use this highly polluting material in such massive quantities. Indeed, competition for the diminishing natural resources on the planet will only increase as populations and the global economy grow. With the exhaustion of such resources, finding healthier and more sustainable resources is of vital importance. We can do our part to mitigate imminent damage by meeting current needs without compromising those of future generations. This, however, must happen now.

Often promoted as a miracle crop for its carbon-negative cultivation, industrial hemp is a non-psychoactive form of Cannabis Sativa L. Hemp is an agricultural plant that does not need insecticides or pesticides to flourish. While cotton production can be water intensive, hemp does not require additional water during its typical growing season. Hemp can be made into diverse products such as food, paper, canvas, textiles, and construction materials. Moreover, its ecological cultivation and use is a solution that subscribes to IPCC's push for reforestation efforts and carbon-capture technology implementations.[27]

Hemp photosynthesizes carbon dioxide more efHemp photosynthesizes carbon dioxide more efficiently than trees do. One ton of hemp absorbs 1.63 tons of CO2. Though one tree can absorb up to forty-eight tons of CO2, it takes decades to grow and requires a lot more acreage than hemp does.[28] Hemp reaches maturity within one hundred days and can thrive in various environmental conditions.[29] It can also be harvested twice a year, meaning that its carbon sequestration rate is doubled. Since it can be made into paper, this plant can help protect our forests as we focus on reforestation projects. Therefore, with hemp we can plant new trees, preserve the ones we already have, and significantly reduce our carbon footprint.

"Sustainability comprises three pillars of social, environmental, and economic aspects. The Petrochemical industry has a great interrelated complex impact on social and economic development of societies and adverse impact on almost all environmental aspects and resource depletion in many countries, which makes sustainability a crucial issue for petrochemical industries."[30]

Once mixed with lime, hemp produces hempcrete, a building material that continues to sequester CO2 throughout its entire life cycle. This contributes to a new virtuous cycle of housing construction capable of producing viable and benign material options that can replace current building products. It can be used to create blocks or panels that would replace other exterior cladding materials. Because of its thermal properties, hempcrete can also replace petrochemically based insulation products. Using industrial hemp in affordable and healthy housing encourages the design, development, and production of new bio-based products with hemp and lime as their primary ingredients. Additionally, hempcrete can be reused at the end of its life and broken down and recast as new hempcrete. "Sustainable Materials Management (SMM), the use and reuse of materials in the most productive and sustainable way over their entire life cycles, can help the US address its material and resource needs in the built environment while remaining competitive in the global economy." Hempcrete is a viable and sustainable alternative product in the construc

Fig 1.13 Crushing hemp and line blocks for reuse

Fig 1.14 Hemp hurd and lime binder

tion industry that could be used in affordable housing and beyond. This revolutionary material gives us a fighting chance against the climate crisis we face. Indeed, opting for hempcrete undercuts the prevalence of materials that destroy the human and environmental health. It has the potential to help save our planet.

Contextualizing Hemp in Colonial America

A renewed interest in "forgotten crops" like hemp is vital in considering alternatives to petrochemical-based building products. Increased use of a simple material like hemp can help mitigate and even suspend the accumulation of toxic chemicals in the biosphere. With recent changes to legislation, hemp has resurfaced in the general public as an agricultural crop. This is especially true in the US, where the hemp industry is now burgeoning after the passage of the 2018 Farm Bill. This industry, however, requires land. In the context of the US, a consideration of land requires an understanding of the history and legacy of colonialism, genocide, and 400 years of African American slavery. Agricultural cultivation in the US is taking place on unceded Indigenous territories and conducted with the labor of enslaved peoples.

Colonialism is the seizure and settlement of foreign land as a means of expanding a nation's dominion. This is achieved for economic dominance of colonised lands, peoples, and resources.[31] In this process countries enforce their doctrines and practices on the colonized and thus also gain sociopolitical supremacy.[32] European powers began colonizing other countries in the fifteenth century. Colonies provided land that they could farm and extract resources from as well as access to other valuable commodities. However, landowners needed cheap labor, and colonists turned to Africa to obtain laborers. Within several decades of being brought to the American colonies, Africans were stripped of human rights and enslaved as chattel, an enslavement that lasted more than two centuries. In 1865 the Third Amendment to the Constitution outlawed slavery and promised previously enslaved peoples "40 acres and a mule." That order was rescinded and the land returned to its former colonial owners. Racism and discrimination continues to today. African American citizens in the US today still bear the scars of this history, and the discussion of reparations are now a part of the dialogue to attempt to compensate the descendants of slaves for their ancestors past labor and suffering.

Colonists found the Americas to be an ideal environment for "European agriculture and ways of life."[33]

They "were interested in establishing permanent settlements on the land, clearing it for agricultural purposes, and taking advantage of the timber, fish and other resources to meet their own needs or to supply markets elsewhere. They were determined not to be frustrated or delayed unduly by those who claimed title to the land and used it in the Aboriginal way. In something of a return to earlier notions of the 'civilized' and 'savage' uses of land, Aboriginal people came to be regarded as impediments to productive development."[34]

The acquisition of land in the Americas was realized primarily through unfair treaties "negotiated under duress or facilitated with bribes [that] were often violated soon after ratification, despite the language of perpetuity. Nonetheless, they presume a nation-to-nation relationship, which still informs US Indian policy today. Less well-

Fig 1.15 These cotton hoers use to work from 6 a.m. to 7 p.m. for $1.00, Mississippi, 1937

Fig 1.16

known are the two other tools of dispossession: federal legislation and executive order."[35] There was little to no regard for Indigenous peoples; Europe was more concerned with accruing wealth and power. The Americas were densely populated by Indigenous Nations and deemed "worthless [by colonizers] without an increase in the size and 'civilization' of the workforce."[36] This provided a convenient solution for colonizing countries to capitalize on their poorest citizens by forcing them to work the land as indentured servants or slaves. Meanwhile, Indigenous Nations were barred from their traditional territories and relocated far from their homes in areas selected by colonists.[37] This advantaged "[their pursuit of] an economic development program increasingly incompatible with the rights and ways of life of the Aboriginal peoples on whose lands this new economic activity was to take place. To justify their actions, the non-Aboriginal settler society was well served by a belief system that judged Aboriginal people to be inferior. Based originally on religious and philosophical grounds, this sense of cultural and moral superiority would be buttressed by additional, pseudo-scientific theories, developed during the nineteenth century, that rested ultimately on ethnocentric and racist premises."[38]

The conquest of 1.5 billion acres that now forms the United States was accomplished through treaties that qualified as "legal fiction." This was crafted by settlers in favour of their expansionist agenda at the expense of Indigenous peoples. The cession of their territories were vaguely delineated by colonists:"They traced watersheds that no 19th century surveyor could determine with any precision; they extended to foothills (exactly where they were located was anyone's guess); and they took direct paths to mountain tops that could not be accurately identified. Sometimes it was easier for federal officials to describe not the cession itself but the reduced tract reserved for the indigenous nation. In 1823, for example, the Seminoles relinquished 'all claim or title which they may have to the whole territory of Florida' in exchange for a much smaller, clearly delineated area where they were to be 'concentrated and confined.'"[39]

According to history hemp cultivation in North America today is taking place on unceded Indigenous land.

Similar to the land rights and mineral rights movements, we need to understand the historical and ongoing events that lead to the continued disenfranchisement of Indigenous peoples and Nations, in this particular case through the agricultural use of contested land. Many peoples have been advocating, cultivating, and/or using hemp long before its legalization and current interest.

The hemp industry has the potential to dramatically reinvigorate Indigenous economies and societies. However, these benefits could also be reaped at their expense.

As such, we must work with Indigenous Nations to empower, support, and amplify their voices in the drive for self-determination, sovereignty, and land rights. For this to be, we must familiarize ourselves with the ways in which colonial history influences and seeps into the present.

Over 50 million people migrated to Turtle Island, or the Americas, roughly 12,000 years ago. Saulteaux artist and curator Robert Houle writes, "By 1492, when 'America' was ostensibly 'discovered,' there were untold numbers of indigenous societies, untold numbers of languages and dialects, architecture to rival any, imperial city states with astronomical observatories and solar calendars, a mathematical concept of zero, an extensive knowledge of natural medicine and the healing arts, highly developed oral traditions, and above all, a spiritual comprehension of the universe, a sense of the natural and supernatural, and a profound sense of the sacred. This was part of humanity's long, inexorable ascent to civilization, on an earth possessed of honour, dignity, and generosity of spirit."[40]

Fig 1.17 Participants in the 14th annual Crazy Horse Ride, South Dakota.

When Christopher Columbus reached the continent in 1492, there were approximately 10 million Indigenous people living on territories now known as the United States of America. By 1900, that number had dropped to less than 300,000. This staggering annihilation of Indigenous lives was due to a colonialism rooted in their genocide, facilitated by the willful spreading of diseases such as syphilis and smallpox, military massacres, discriminatory legislations, and cultural assimilation via residential schools.[41] Indigenous families today are still being separated against their consent; with 300 children forcibly removed from their communities per year, South Dakota is the biggest present-day perpetrator.[42]

Colonial projects are justified by the racist creation of the civilized and barbaric binary, the effects of which are still palpable today. In her book The Myth of the Savage, Métis historian Olive P. Dickason explains how "'civilized' is usually applied to societies possessing a state structure and an advanced technology [whereas 'savage'] is applied to societies at an early stage of technology, a stage at which they are believed to be dominated by the laws of nature."[43] Colonizers applied the latter categorization to both Indigenous peoples and African American slaves. They were and continue to be conceptualized as foils to progress, associated to a timeless primitivism and defunct past. This manifests as stereotypes of the infantile and violent barbarian, especially in textual and visual representation. In contrast to a people defined as "naked both in mind and body, and destitute of laws, of arts, of ideas and almost of language,"[44] colonizers fashioned themselves as innovators at the "threshold of greater things to come."[45]

***Colonists willfully ignored* "the fact that, in the fifteenth century, Indigenous peoples of the Americas had a greater variety of societies than Europe."** [46]

Maps are a spatial and imagined structuring of information, a representation and production of colonial knowledge. The 10 million Indigenous peoples constituting over 600 Nations already had their own understanding of their territories. In reorganizing Indigenous land and displacing bodies, maps are a metaphorical and physical exertion of political control communicating the colonial narrative and authority. They disfigure Indigenous experiences in relation to their histories, land, and languages, so as to restructure it all in accordance to a Eurocentric and patriarchal ideology. Inseparable to projects of conquest and nation-building, colonial maps painted the land as terra nullius, or nobody's land, a land with no people, and implied it was free for the taking. This rendered Indigenous peoples and cultures that had long been established as constituents of the natural landscape which necessitated "taming."[47] For example, Indigenous peoples were removed from their families and forced into residential schools where they were forbidden to speak in their mother tongues, given Christian names, and severed from their cultural heritage informing their identities. This was done under the guise of civilizing them.[48] Numerous reports and testimonies attest to the manual, emotional, mental, physical, and sexual abuse that took place within these religious schools.[49] Thus, colonialism, in spite of its genocidal modus operandi, was justified in bestowing the "gift" of civilisation upon Indigenous Nations they massacred and conceived as inferior. This places colonizers in a position of superiority, thereby self-legitimizing their domination over Indigenous peoples.

The process of European military conquest, monetization, and restructuring of the Americas was made possible only through the enslavement of Indigenous and African peoples: "The colonial economy depended on slavery, many well-to-do households functioned only because of slavery, early colonial legal codes were devised to justify slavery and the Pequot War and King Philip's War were fought in large measure to perpetuate slavery."[50] As we consider the benefits of agricultural crops like hemp, it is important to forefront the practices that have historically and continue to disenfranchise people.

Fig 1.18

INDUSTRIAL HEMP

Hemp and Its Uses

Cannabis, one of almost 200 species in the Cannabaceae family, has many names.[51] Cannabis is divided into three subspecies: cannabis ruderalis, cannabis indica, and cannabis sativa. Globally, indica and sativa are the most commonly grown variations of the cannabis plant, while cannabis ruderalis is a variation found predominantly in Eastern Europe and Russia. The three major types of cannabis possess varying properties and physical characteristics. Carl Linnaeus, a Swedish botanist born in the early 1700s, developed taxonomy—the science of identifying, naming, and classifying organisms—still used today. Cannabis sativa L. is the formal notation for this species, where the "L" references Linnaeus' classification. Over time, there has been significant cross-breeding of the three cannabis variations resulting in a wide range of seed types. While pure seed variations of indica, sativa, and ruderalis still exist, many seed types used in current agricultural practices share characteristics with the three plant species.

Industrial hemp utilizes the cannabis sativa variety, which is the variation we will refer to when speaking about hempcrete. Cannabis sativa should be the predominant plant type chosen for use in hempcrete production for several reasons. Cannabis ruderalis only occurs naturally in a small portion of the world and has proven ineffective for industrial hemp production.[52] Cannabis indica is confined to the psychoactive form of cannabis; the term "marijuana" refers to cannabis indica, as well as the psychoactive form of the sativa plant. Indica and sativa are part of the same Cannabaceae family and share many characteristics. In fact, these similarities were used to support the criminalization of the cannabis plant as a whole in the United States. Despite legislative setbacks, cannabis sativa is the most viable plant for building materials: its potential to grow tall and sturdy stalks yields a strong woody core. When dried and processed, it mixes well with lime and water to produce hempcrete

Varieties of Hemp

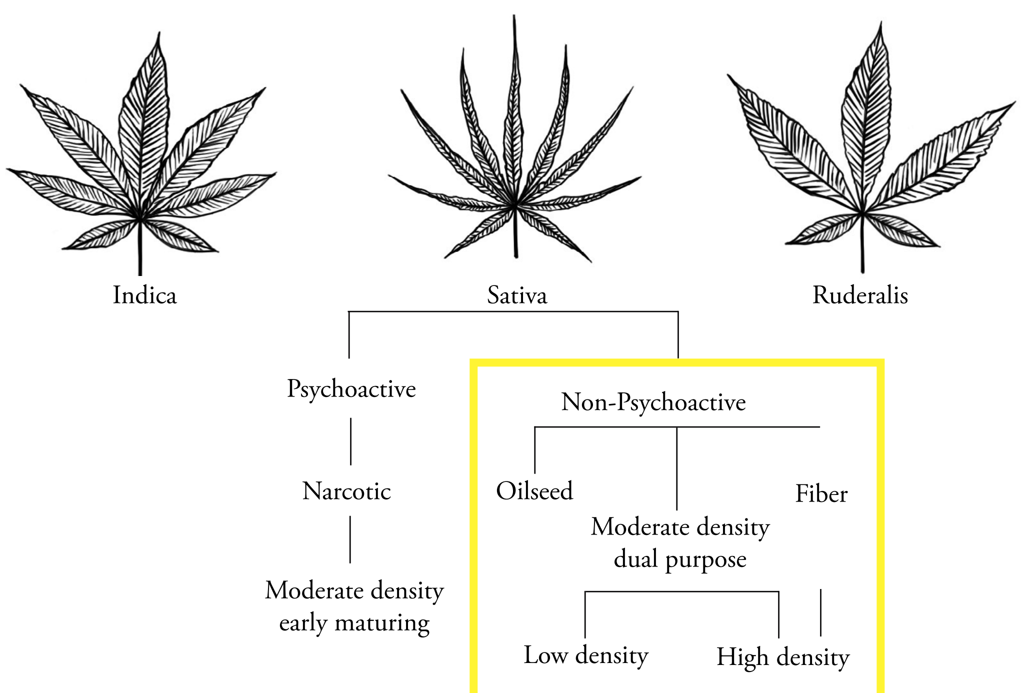


Diagram 2.1 Varieties of Hemp

Fig 2.1 A leaf of Cannabis Sativa grows in the **McEnroe Farm,** located in Millerton, New York

Fig 2.2
Cannabis Sativa Flowers at **McEnroe Farm**

History of Use

Historically, hemp has been a significant and highly useful crop. Over 200 hemp by-products are currently in use and as far back as 8000 BCE, there is evidence of hemp being grown and utilized in various Asian regions of the world.[53] Early uses of hemp included pottery, textiles, fiber for ropes and paper, mortars and plasters, and as a food source. Of the 200 or more products made from hemp today, many are still produced using ancient or traditional techniques. In recent history, the United States has experienced a significant disruption and setback in the cultivation and use of hemp. However, there is an established body of knowledge about the uses of industrial hemp that is accessible and will enable the United States to recover past practices and propose new uses for the crop.

Over 200 hemp by-products are currently in use and as far back as 8000 BCE, there is evidence of hemp being grown and utilized in various Asian regions of the world.

Since the Middle Ages, hemp has been an important source of revenue in Europe[54] prized for its diverse uses as a textile and source of nutrition; commonly made into rope, sails, and riggings, it produced essential materials for maritime colonizers. France sold large quantities of hemp to other countries like England and Spain. By the sixteenth century, France had accumulated much of the continent's wealth through revenue derived from its wheat and hemp exports.[55]

Hemp, or a local hemplike plant, had been cultivated and used by many Indigenous Nations long before colonizers reached the Americas. In 1605, French colonist Samuel de Champlain recorded that the Wampanoag and Nauset Nations were cultivating hemp and wearing hemp-derived textiles.[56] Jacques Cartier, another French colonist, also encountered Indigenous peoples in Acadia using hemp. Some sources claim that this was a misidentification.[57] This commonly occurred with Apocynum Cannabium, a plant indigenous to North America that is referred to as Indian hemp or dogbane hemp.[58] Similar to cannabis sativa's non-psychoactive strain, it was used for textiles, food and medicine by many Indigenous Nations for thousands of years. It also possesses carbon sequestering properties. Its common names in fact refer to its likeness to hemp from the cannabis family. Interestingly, the latter "is sometimes called Indian hemp."[59]

Sources say that "the European variety of hemp did not grow wild in the New World."[60] Additionally, the 1619 law demanded that all American farmers grow both English and Indian hemp.[61] Indian hemp is often considered as hemp, even if it does not come from the cannabis family. Nevertheless, Samuel de Champlain was given European hemp seeds to bring over to the Americas. France believed that "they could still make a profit in hemp if they could persuade the colonists who were settling in New France to cultivate cannabis as a crop."[62] When England acquired New France in 1763, they continued the promotion of hemp as an agricultural plant with incentives and gave out free hemp bushels to colonists. Hemp cultivation in the Americas presented an economic opportunity aligned with the colonial agenda.

The timeline of industrial hemp production in the US indicates the range of uses that prevailed at different points in the country's history. Prior to the Marijuana Tax Act of 1937, the growing of hemp in the States was widespread, and it was legally required that American farmers in the 1700s grew hemp. Hemp was an important crop used to create paper products, including the paper for the Declaration of Independence, and textiles. The Marijuana Tax Act of 1937 presented to congress by the Federal Bureau of Narcotics, led by Harry J. Anslinger, placed a tax on the sale of cannabis products and discouraged the production of hemp.[63] To push this act through congress, Anslinger, who previously headed the Department of Prohibition (of alcohol), relied on insufficient data to regulate and restrict cannabis production and usage. "The desire to present a solid front when the Department appeared before the committees of Congress caused the officials to ignore anything qualifying or minimizing the evils of marijuana."[64] Historians point to the cessation of the Department of Prohibition under

Fig 2.3 Historic Hemp Rope Production

Fig 2.4 Historic Hemp fiber production

Anslinger's leadership and his desire to continue to remain a government employee as the reason for his attention being redirected from alcohol to marijuana.[65] Viewed as a trusted government official, Anslinger was not only able to influence the drug policies of America, much of which are still intact today, but he also influenced international drug policies.

By 1942, the United States Department of Agriculture created a program and short film known as "Hemp for Victory," which led to the production of over 150,000 acres of hemp to support the war efforts.[66] Prior to the start of World War II, the US relied on fibers from the Philippines and East Indies and India. Once the war began, however, both the Philippines and East Indies were under the control of Japan, making access to previously imported fibers impossible. The importation of jute from India became limited during this time, as well.[67] While the Marijuana Tax Act remained in place, the US government allowed for tax exemption for a number of American farmers who chose to grow hemp. Post World War II, the growth of hemp in the states declined until it essentially ceased. By 1970, the Controlled Substances Act effectively sealed the fate of Cannabis growth in the United States by declaring the plant a Schedule I narcotic.[68]

Historic Uses of Hemp

12,000 B.C.- 1776

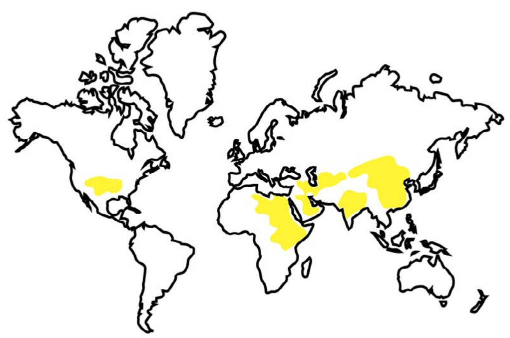
Origins of use

The common hemp plant, Cannabis Sativa, is one of the earliest recorded domestically grown plants, with evidence of its cultivation since the Neolitic times. It is tought that the plant originated in China.

Spread

Cultivation gradually spread westwards through India and into the MiddleEast, Africa and the Mediterranean, where hemp formed an essential part of the livelihood and culture of each people who grew it.

Apocynym cannabium indigenous to north america used for textiles, food and medicine.

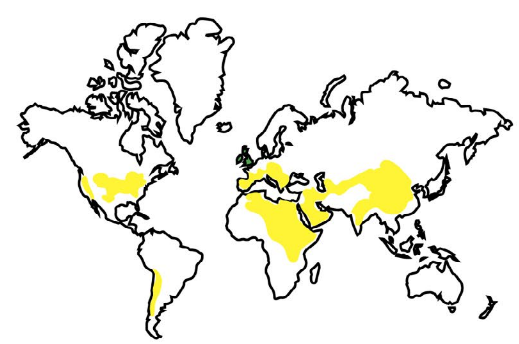


Use in Europe

It is believed that hemp made it to Europe in approximately 1,200 BC. During the middle ages, hemp became an important crop of enormous economic and social value supplying much of the world's need for food and fiber.

Use in America

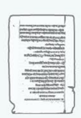
Hemp might have been cultivated in America before the Europeans arrived. When the Puritans arrived, hemp had reached the continent. California, Kentucky New York, New England, Virginia, Massachusetts, Louisiana, and Missouri were some of many states where hemp was grown.



Neolithic Times (12,000-6,500 BC) — **2700 BC** — **1200 BC** — **1545**

Hemp has been found in ancient pottery

The Chinese used it to make clothes, shoes, ropes, and an early form of paper.

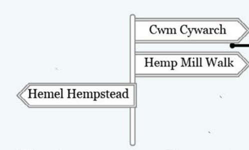


The word Canvas derives from cannabis *-a fabric made from Hemp,* and as a pulp from which to make paper.

Egyptian and Greek records the importance of the hemp plant to lifestyle andexpansion of these civilizations

The Saxons incorporated it into their medical treatments

Kings of England promoted the cultivation of hemp for everyday uses such as linen and rope, and it contributed to their supremacy in military sailcloth and rigging.

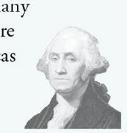


Translates- *The steep-walled mountain basin in which hemp is grown*

The importance of hemp in British and Irish society through the ages is reflected in place names accross the land.

Henry VIII passed a law making it compulsory for farmers to grow hemp (1509-1547)

Hemp, or a local hemplike plant, was cultivated and used by many Indigenous Nations long before colonizers reached the Americas



Washington predicted that hemp could be a more profitable crop than tobacco and grew it on his farm (1760)

The first American flag made by Betsy Ross was made from industrial hemp (1776)

Diagram 2.2

Historic Uses of Hemp

1928- 2018

Prohibition of Cannabis

Due to the psychoactive effect, hemp growth and possesion was outlawed in most western countries. However, the influence of petroleum based companies played a crucial role in the stablishment of these laws.

World War II 'Hemp for Victory'

The 1942 Japanese invasion of the Philippines cut the U.S. off from their major source of imported hemp. The U.S. government lifted restrictions to meet the demand for supplies of hemp for rope and canvas.

Illegal Crop Once Again

After World War II, the prohibition was immediately re-instituted and industrial hemp was once again an "illegal crop."

Re-embracing use of Industrial Hemp

Netherlands was the first country to introduce an official policy of tolerating the possesion of small amounts of the drug without prosecution

1928 — **1942** — **1945** — **1990**

Hemp growth and possession started to be outlawed in most western countries (1928)

The Marihuana Tax Act of 1937- a U.S. act that placed a tax on the sale of cannabis, was influenced by powerful synthetic fiber companies who saw hemp as a big threat to their businesses.

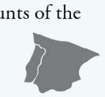
Henry Ford Prototyped a car manufactured and fueled with hemp (1941)

Hemp for Victory is a black and white government film, which aim was to explain the uses of hemp and encourage farmers to grow as much as possible.

In 1942, farmers, at the request of the government, planted 26,000 acres of hemp seed. The goal for 1943 was to plant 50,000 acres of seeds of hemp.

The prohibition was immediately re-instituted and industrial hemp was once again an "illegal crop."

Netherlands, the first country to introduce an official policy of allowing the possesion of small amounts of the drug. (1972)



Spain, Portugal, The Czech Republic and Switzerland have followed Netherlands example in decriminalizing the possesion and use of small amounts of the drug.

Canadian Government provided legislation allowing for the planting and processing of industrial hemp (1998)

Industrial Hemp is Legal again in US (2018)

Diagram 2.2

Cannabis Sativa: Industrial Hemp

Often promoted as a miracle crop, industrial hemp is a non-psychoactive form of Cannabis Sativa L.   Industrial hemp's range of uses and potential advantages makes it a valuable addition to agriculture with the potential to create a new revenue stream for farmers. The plant itself is composed of the stalk, bast fibers, hurd, flowers, and leaves. Hemp has a plethora of uses ranging from hemp seed powder to paper, textiles, and building products. The end use of the plant is determined by how the hemp is seeded and grown in order to maximize postharvest utility.

Cannabis sativa varies in chemical properties and requires constant inspections to ensure seed varieties used to produce industrial hemp have THC levels that never exceed 0.3%. From a governmental standpoint, hemp poses the most significant threat when it crosses over the threshold from industrial hemp to a narcotic and, thus, from a legal to an illegal product and practice. Tetrahydrocannabinol, or THC, is the psychoactive chemical present in cannabis plants and is what defines cannabis as a narcotic. This chemical exists in the makeup of each cannabis plant as an inverse of another chemical called cannabidiol, or CBD. In other words, the higher the THC content, the lower the CBD levels and vice versa. This is significant because as CBD continues to find beneficial uses in the medical profession, high THC levels are almost entirely associated with cannabis as a narcotic.

Beyond THC and CBD content, cannabis sativa possesses a number of other qualities that differentiate it from indica strains. When seeded into open fields, sativa has the potential to grow tall and sturdy stalks, which lead to strong fibers and hemp shiv, also known as hurd. It is the woody core, the hurd, that is utilized, occasionally with the bast fibers, to create hempcrete.

Fig 2.5 First Cannabis Sativa field **The McEnroe Farm, June, 2018.**

North American Hemp and Sociopolitical Context of Climate Crisis

Climate change ravages marginalized communities the most because of their limited or nonexistent access to basic resources and state support. Indigenous peoples are among the first harmed due to their deep connectivity to the land and the historic ongoing systematic oppression.[69] The ongoing destruction of their territories directly endangers their livelihood. As such, they have no choice but to defend their land.

It is agreed upon between "Indigenous activists, scholars, and leaders [...] that climate change is, in many ways, an issue of indigenous peoples' human rights, and that by returning stewardship of natural resources to the historic caretakers of mother earth, we can help to mitigate negative effects".[70]

At over 370 million spread across seventy countries, Indigenous people currently make up 5% of the world's population.[71] Each Indigenous individual, community, and Nation has a unique connection to their land, its resources, and its ecosystems. Their territories are essential to their culture, identity, and survival.[72] As custodians of the land, they fight to protect 80% of total global diversity.[73] Studies assert that Indigenous lifestyles are sustainable and conducive to environmental health: indeed, "forests managed by indigenous peoples have been preserved more efficiently than protected forests."[74] However, for the past thirty-three years, the International Work Group for Indigenous Affairs (IWGIA) has documented the increasing discrimination and violence against Indigenous individuals and Nations. This is evident through legislative and physical acts such as arbitrary incarceration, unfair treaties, disappearances, and murders. Indigenous activists defending their identities and biodiversity are particularly at risk.[75] Victoria Tauli-Corpuz is Kankana-ey Igorot, an Indigenous Nation in the Northern Philippines. As the UN Special Rapporteur on the rights of Indigenous peoples, she asserted in 2018 that "a crucial underlying cause of the current intensified attacks is the lack of respect for indigenous peoples' collective land rights and the failure to provide indigenous communities with secure land tenure, as this in turn undermines their ability to effectively defend their lands, territories and resources from the damage caused by large-scale projects."[76]

There are 573 Nations in the US that are federally recognized as sovereign governments.[77] However, the IWGIA emphasizes that settler "state authorities are the most common perpetrators of violations against Indigenous rights defenders even though they bear the primary responsibility for ensuring their protection."[78] Such governments will initiate resource extraction or development projects that infringe on Indigenous territories against their consent. This violates their sovereignty, contaminates their water, desecrates sacred burial grounds, and displaces communities without any compensation. When Indigenous rights defenders protest such institutional transgressions, they are met with military violence. Protests at the Oceti Sakowin Camp (Standing Rock) with the Dakota Access Pipeline protests in 2016 or the Unist'ot'en Camp with the Coastal GasLink/TransCanada Pipeline in 2019 were both met with violence. While settler states vindicate their encroachment for the sake of "public safety and interest," protestors are framed as regressive and anti-modern[79]—a modern version of the civilized and barbaric dichotomy that justifies armed responses and the ongoing suppression of Indigenous sovereignty and land rights. Settler states infantilize protestors and assume a paternalistic role where they act as judge, jury, and executioner.

In 2016, 85% of the Navajo and Fort Berthold's economies were based on fossil fuels. Winona LaDuke explains that many Indigenous Nations have been forced into this industry with fracking leases that are destroying their land. In addition

Fig 2.6 Bureau of Indian Affairs and the Drug Enforcement Administration Fresno Area Surveillance Team and local sheriffs eradicate illicit marijuana on Pit River tribal lands, 2015

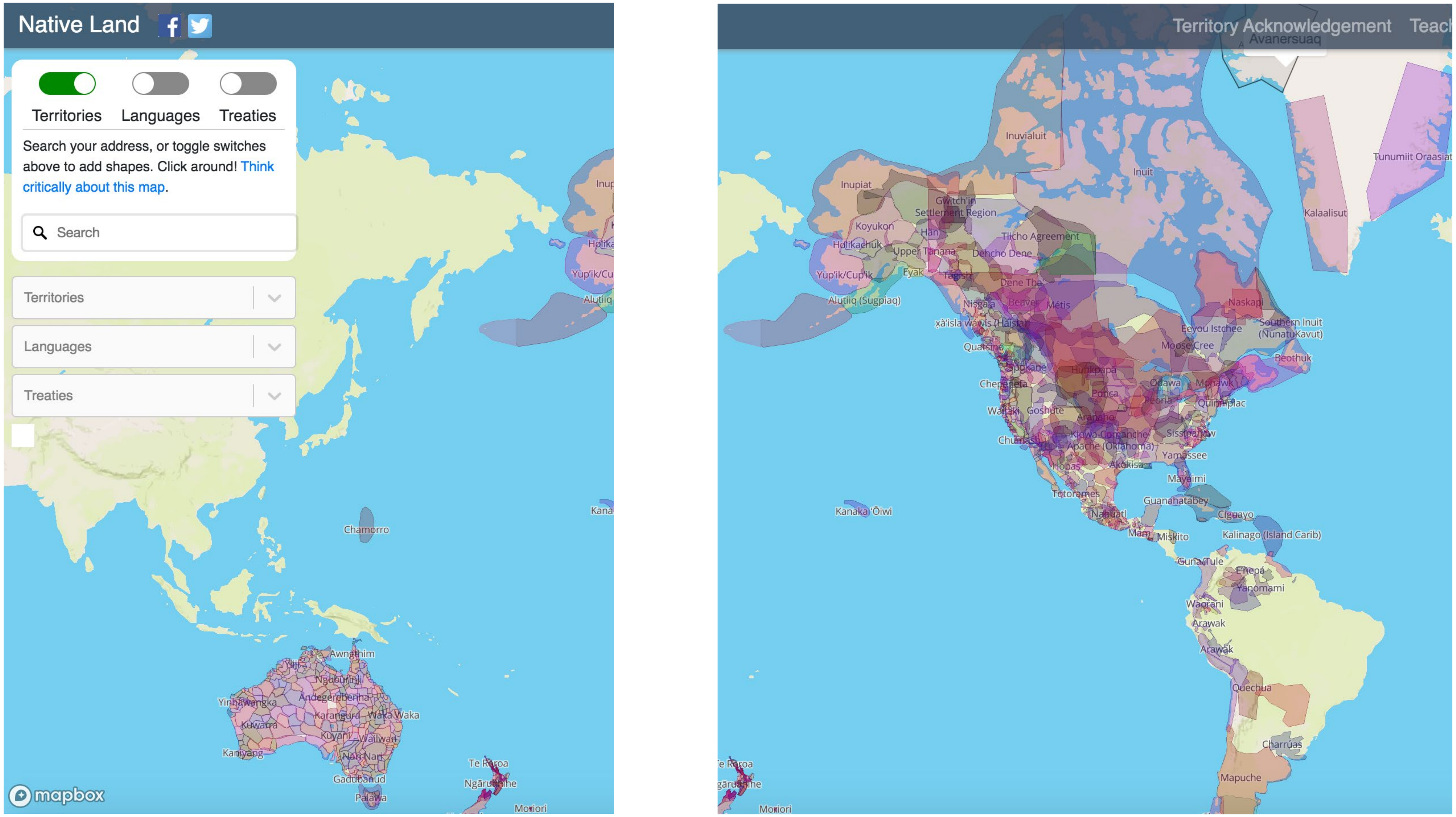


Fig 2.6 Indigenous territories in the americas in Precolonial times, source http://native-land.ca/

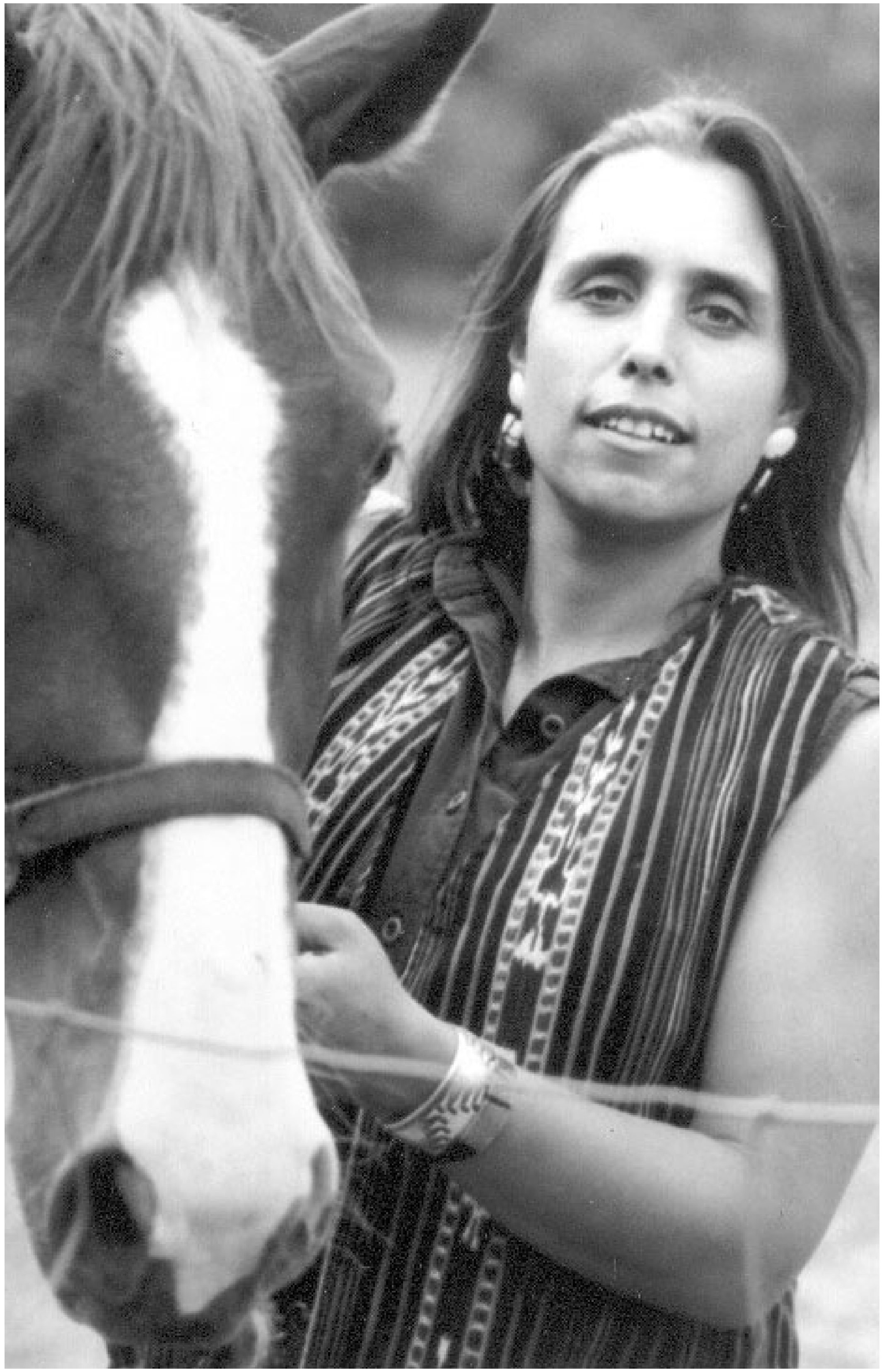


Fig 2.7 Winona LaDuke, director of the Indigenous environmentalist non-profit organization Honor the Earth.

to air and water pollution, fracking also increases the potential for oil spills, which can harm the soil and surrounding vegetation. With a traumatic genocide that spans centuries, performative efforts towards (re)concilliation and mediocre support for issues such as mental health, crumbling infrastructure, mass unemployment, and a lack of access to resources like food and water, Indigenous Nations are doing their best to survive. Deprived of the means to thrive, some have been left with no recourse but to sign up for fracking leases. Nations tell themselves that "things haven't been going too well for us, so we're going to sign a few more of these leases, because, after all, nothing has ever worked out well for us. And so, we're going to get a little bit of money."[80] As the director for Indigenous environmentalism nonprofit organization Honor the Earth, LaDuke is advocating for a regenerative economy wherein Indigenous Nations participate and flourish.[81] She proposes that the hemp industry can surpass and replace Indigenous gambling revenues for the Nations that have such an industry. She emphasizes how this sustainable and durable alternative is advantageous for its important "health and environmental benefits."[82]

Hemp is valued as "the most complete food source and the strongest natural fiber on earth." *[83]*

Alex White Plume of the Oglala Lakota Nation has been cultivating and selling hemp since 1968. The Lakota Nation has legalized Wahupta Ska Pejuta, or hemp, on the Pine Ridge Reservation since the 1851 Ft. Laramie Treaty. Despite its local, legal status, White Plume's farm was plundered in 2000 by the Drug Enforcement Administration (DEA). Charging in with machine guns and helicopters, they confiscated his hemp and cost taxpayers over $200,000. White Plume continued to grow hemp as an assertion of Indigenous sovereignty and self-determination; the government, however, destroyed his crops in 2001 and threatened him with an injunction the year after that. They decreed that he would be jailed without trial or jury for so much as touching hemp. Had the settler state honored their recognition of the Oglala Lakota as a sovereign government, White Plume estimated that he could have brought in $16,000 for his community from 160 acres of hemp.

Marcus Grignon, a Menominee hemp farmer and longtime advocate, was inspired by Alex White Plume. The Menominee Nation began working with the federal government to negotiate hemp cultivation on Menominee territory in March 2015. Discussions went smoothly until the DEA raided Grignon's farm without warning and destroyed his crops in October. Since Grignon's cultivation efforts were suppressed, he focused on education. In a document dating from the nineteenth century, he found that his Nation had a word for hemp as well, shä'nap, and that they used to weave baskets out of it. He noted that knowledge relating to shä'nap agronomy was lost due to assimilation and repression. Grignon asserts that hemp is a solution to a number of issues. Not only is it a sustainable way of resisting the exploitative and coerced dependence on the fossil fuel industry, but since hemp can revitalize their land, this industry can also revitalize Indigenous knowledge, cultural heritage and relationships to ancestral territories.[84] Murial Youngbear, a Meskwaki involved in the economic development of hemp agronomy in Indigenous Nations, views hemp as a way "communities . . . [can] be a place people run to, not from."[85] However, Indigenous Nations' autonomy and ability to thrive undermines the state's and corporation's ability to exploit them and prey on their land and resources.

Oloah, a long-time hemp Oglala Lakota farmer from the Pine Ridge Reservation, spoke at NoCo, the largest hemp convention, in April 2019. She remarked that this is a dangerous time for Indigenous peoples. As hemp has proven to be a lucrative business, powerful outside interests are looking to sink their teeth into the industry; wanting to acquire land, they threaten to displace Indigenous communities and further disregard their land rights. This would also extinguish the potential hemp possesses to revitalize their cultures and territories. Oloah talks about Lakota term wašícu, which can be understood as "fat-taker." She explains that "wašícu is taker of the best part of the meat, takes the best part for [themselves]." This term is used to refer to the white man, but she explains that it can extend to people of all ethnicities. She paraphrases LaDuke in saying that the hemp industry is currently being led by white men. She is wary of the hemp industry becoming one of wašícu, of fat-takers, as that is the mentality that led to their historical and ongoing oppression.[86] Oloah reminds us that we are on stolen land. Therefore, settlers, regardless of colour, are "illegally growing and living on stolen land, and that brings guilt, [but nevertheless,] we're here about being neighbors and to discuss healing aspects for self and earth, for a mother we all share."[87] She leaves hemp actors with critical questions of re-evaluation: "Are you here as a fat-taker? Are you willing to share knowledge?"[88]

As we consider the farming of hemp, we must wrestle with these questions of stolen land and a long history of racism and discrimination. These complex issues cannot be ignored or tabled. They must be understood and confronted, and we must adopt new antiracist strategies.

Current Landscape and the 2018 U.S. Farm Bill

Since the passage of the 2018 Farm Bill, the hemp industry is "projected to grow 18.3% each year over the next decade."[89] In 2018, it generated a revenue of $1.1 billion, which greatly revitalized the agronomy sector, helping American farmers thrive and creating demand for seed suppliers as well as hemp processors and manufacturers. This figure is expected to reach $2.6 billion by 2022 and will create thousands of jobs for "accountants, lawyers, compliance officers, government regulators, IT specialists, financial and insurance experts, transporters, researchers and lab technicians, marketers, CFOs, CEOs and various retail employees." By February 2019, hemp cultivation was authorized in forty-one states covering an estimated total of 78,176 acres.[90] Demand for hemp is skyrocketing; it is a fast-growing market with great potential to alleviate global warming and revolutionize the construction industry, but its rapid expansion is not without ramifications. There are legislative, financial, and agricultural issues to consider and resolve if this is to be a viable industry.

There are two entities that regulate the hemp industry. The USDA regulates all things agricultural, whereas the Food and Drug Administration (FDA) is responsible for hemp-based products. Both federal agencies have failed to release clear and concise guidelines, leading to numerous complications and litigations.

States and Indigenous Nations must submit their production and regulation plans to the USDA for review and approval before cultivation can commence. The Flandreau Santee Sioux Nation, who have had plans to grow hemp on their land since 2015, sued the USDA in June 2019. They submitted their application to regulate hemp agronomy on their land in March 2019. As per the 2018 Farm Bill, the USDA has a sixty-day period to review and approve it, yet they failed to do so. At the time of their submission, the Flandreau Santee Sioux Nation notified the USDA that they had already invested money, expecting to plant their first crop in 2019. However, the USDA has yet to clarify what the legal process of growing entails; until it establishes the proper procedures and requirements, the agency claims it cannot approve any plans. Court records reveal that though the USDA has received plans for seven states and eight Nations, refusing a total of fifteen proposals. They claim that the government shutdown from December through January delayed their process; they expect to have regulations sorted by fall 2019. The Flandreau Santee Sioux Nation asserts that "delay in approval of the tribal plan and unlawfully withholding tribal authority curtails receipt of the tribal revenue from hemp production at grave cost to tribal members, putting tribal members' health, safety, and welfare at risk".[91]

As farmers across the country grow hemp, there is a fear of cross-pollination between hemp and marijuana crops. For example, Oregon's marijuana surplus has led to a 50% price decrease. Since it is federally illegal to sell marijuana, marijuana farmers cannot seek bankruptcy protection nor apply for bank loans. Their marijuana market is also limited to Oregon as opposed to hemp, which is legal on a national and international level. As such, they are curbing their marijuana production and look toward diversification in order to limit their losses. As a sustainable, low-maintenance, and economically valuable

Fig 2.8 Monhave Green facility in Monhave Valley, Arizona, an indoor grow operation facility where medical marijuana is harvested, trimmed and packaged.

Fig 2.9 Cody Lewis employee of Monhave Green's Choice Cannabis checks and waters marijuana plant

plant, many view industrial hemp as a solution.[92] However, farmers may lack the knowledge to cultivate large acres of hemp. The widespread cultivation of hemp leads to the inevitable cross-contamination of different cannabis species. Indeed, pollen can travel between three to thirty miles. For the best yield, marijuana agronomy relies on unpollinated female plants, whereas hemp agronomy includes both male and female plants to account for the different products derived from the plant. The cross-pollination would be disastrous for both marijuana and hemp growers; contaminated marijuana crops will have lower THC levels, therefore resulting in a loss of revenue. Upon contamination, medical marijuana loses its usage and thus is completely worthless. The issues arising from cross-pollination must be tackled both at a state and interstate level, since pollen can travel across borders. Until that has been resolved, Oregon marijuana farmers are left with the option to move indoors. Indeed, their crops are limited to one acre, whereas industrial hemp can easily take up a few hundred acres. Many producers are reluctant to change their operations; establishing the required structures and facilities for indoor cultivation will be expensive. What's more, their crops still won't be safeguarded from cross-pollination as the pollen may still bypass their infrastructures. As for hemp, contaminated crops would contain above the 0.3% per dry body weight legal limit of THC. This would result in the destruction of the crops as mandated by the 2018 Farm Bill.[93] It can also lead to prosecutions against hemp farmers since growing hemp with THC levels above 0.3% is illegal.[94]

Medical marijuana farmers of the Santa Cruz County in Arizona have demanded a minimum distance of ten miles between marijuana and hemp farms. Officials don't think that zoning is the appropriate measure; they refused the proposed buffer on the basis that it would thwart the potential to grow crops on thousands of acres of land and therefore infringe on private property rights. The USDA claims this to be a local issue and, for that reason, is refusing to weigh in. If there are no regulations developed around cross-pollination issues, then it is only a matter of time before both crop variations are destroyed.[95] This will lead to million-dollar losses, and civil lawsuits are likely to arise, exemplified in the Jack Hempicine LLC v. Leo Mulkey Inc. case in 2018.[96]

Fig 2.10 CBD was offered at a Florida coffee shop in 2018. Some local governments are cracking down on its sales.

CBD in food and supplements is not legal, even if such products are available on the market. This leads to confusion, as there is a discrepancy between legality and availability. The FDA is currently prioritizing the pursuit of those erroneously claiming that their products may treat health issues such as cancer or AIDS.[97] Since no legal action is being taken over products that do not boast aggressive health benefits, many CBD products remain in a legal limbo.

In Texas, two GM Tobacco stores, which sell CBD, were raided in March 2019 by police officers. They confiscated roughly $50,000 worth of products, including thirty pounds of smokable hemp, which they misidentified as marijuana. They also seized money from both the stores' register and safe. Even though the stores' hemp respects the THC limit, the police are not trained to distinguish marijuana from hemp. Their lab does not check the percentage of THC, but only for the presence or absence of THC.[98] Currently, there are no national guidelines regarding how to evaluate THC content. Joe Crinkley, from MCR Labs in Massachusetts, says that "there is variability from plant to plant in how it's going to test."[99]

Without any standardized process, the people involved in the hemp industry risk immense monetary losses and/or prosecution.

Though Texas legalized hemp in June 2019, it is unclear when the bill will take effect.[100] Whatever the case, authorities must at the very least ensure that their technology is current with federal law. For this to be, they must know how to differentiate hemp from marijuana and implement a procedure to test for quantity of THC. The latter must be included in the USDA's standard guidelines to eliminate confusion.[101]

Idaho State Police (IPS) seized 7,000 pounds of industrial hemp in January 2019 and arrested the driver. The shipment came from Oregon and was to be delivered to Big Sky Scientific, a hemp manufacturing company in Colorado. The driver faces drug trafficking charges and is pleading not guilty. His trial is set for October 2019, and if he is convicted he could spend five to fifteen years in prison.[102] Big Sky sued the Idaho police and is currently awaiting hearing. Until then, the 7,000 pounds of hemp remain in the ISP's custody. The USDA has responded to the case, maintaining the delineations of the recent farm Bill: though states and Nations do possess the authority to regulate and prevent hemp cultivation on their territory, they cannot intercept interstate hemp shipments.[103] The USDA's memo is not legally binding, and IPS argues that the 2018 Agriculture Act is not in effect until it has been updated in print.[104] In fact, Elijah Watkins, an Idahoan attorney representing Big Sky, says that the state does not acknowledge industrial hemp as an agricultural commodity. In their state, anything that contains THC is considered to be a controlled Substance I.[105] State laws conflicting with federal ones present an immense problem for the hemp industry. As per the Supremacy Clause in the US Constitution, Watkins affirms that federal legislation overrides all—that it is, in fact, supreme.[106] However, lawyer Sam Mendez, who oversaw the Cannabis Law and Policy Project at the University of Washington, notes that both the IPS and Big Sky, backed by the USDA, have valid arguments.[107] Parallelly, if Idaho can stand its ground against the federal government and have its opinion respected, then the same should apply to Indigenous Nations. Any inconsistency denotes prejudice and discrimination.

When hemp was still illegal at a federal level, banks refused to lend their services to the industry. Even though that has changed, banks remain conservative.[108] Without clear USDA regulations, these financial institutions are unwilling to deal with individual liability and incompatibilities between state and federal policies.[109] Therefore, legal hemp businesses and other actors within the industry are forced to take out personal loans. By doing so, they assume all the risks as they have little to no protection or insurance. Without banks, all of their transactions, such as paying vendors, employees, and taxes, must be carried out in cash. They are thus more vulnerable to "burglaries, extortions, robberies and other violent crimes because they require immediate access to large sums of cash and often have no safe place to store it."[110] Additionally, there is a 15% penalty on paying taxes in cash. It is clear that the hemp industry requires the cooperation of financial institutions to continue growing. However, banks are confused about the legality of hemp as well as its differences from marijuana. This necessitates USDA's clarifications.

Despite these complications, the USDA has announced that the official guidelines will be released in August 2019. This will come just in time for the 2020 growing season. The agency's regulations will "address land usage, standards for testing, disposal, law enforcement compliance, inspections, and certification for both products and industry workers."[111] It is a step toward a viable hemp industry, which will hopefully influence other countries to do the same.

International and Indigenous Models of Hemp Production

It is useful to consider and evaluate the status of hemp growing in other countries to understand how others are addressing legal issues and also building new knowledge about hemp production. Currently Ethiopia faces legal hurdles in regards to hemp cultivation. Their cannabis industry was valued at $10 billion by American company New Frontier Data for its potential to produce both medical cannabis and industrial hemp. This could bring in a valuable source of new revenue for Ethiopia. Hemp textiles could be considered as a viable alternative fiber to cotton in the countries large cotton production industry. However, Amir Aman, the Minister of Health, has said that their "position regarding the growing of cannabis (and hemp) for medicinal purposes in Ethiopia has neither been recognized nor sought after. And no regulatory approval was given. Requests for such investments have been and will continue to be denied."[112]

In Japan there is a campaign to reinstate hemp agronomy specifically for agricultural regeneration and innovation. Japan had a 10,000-year-long history of using hemp with, at one time, eighty active hemp processing factories. Unfortunately, the conflation of hemp and marijuana has led to the country's restrictive policies on the non-psychoactive plant. Medical CBD brand Epidiolex has just been approved for clinical trials, which bodes well for Japanese hemp's comeback. Dr. Harumi Kikuchi, the director of the Hokkaido Industrial Hemp Association who is spearheading the revival movement, hopes to grow 20,000 hectares (roughly 50,000 acres) of hemp in Hokkaido, where it was historically grown.[113] Hemp can also be used in Japan's food and cosmetic industries.

South Africa legalized CBD sales in May 2019 and is the first country on the African continent to do so. In September 2018, they decriminalized Cannabis for personal use, meaning that people are allowed to grow and consume it in their homes.[114] This bodes well for an eventual hemp industry, which could revitalize the South African economy. Indeed, the Department of Trade and Industry (DTI) is researching the potential of hemp use in different sectors. Minister Rob Davies maintains that South Africa can become a key hemp actor in the fast-growing global market. The Cannabis Development Council of South Africa (CDCSA) is working towards creating industrial hemp production guidelines and incentivizing supply chains.[115]

HempMongolia is the first company in Mongolia to obtain permission from the Ministry of Health to cultivate, process, distribute, sell, and ship CBD oils. The company is planning a 20,000 hectare expansion in the eastern part of the country. They are working with Mongolian Innovation Center, a company that focuses on supply chain technology and policy. Together, they are working to "develop a complex industrial processing facilities to turn out hurd for hempcrete, technical fiber, CBD extracts, hemp fiber, nano cellulose, biofuel and hemp foods."[116]

The Marche, a region in eastern Italy, is focusing on the hemp industry for its potential use in construction, textiles, bioplastics, and food sectors. Legislation is underway, and €360,000 has been earmarked to fund local hemp activities and industry expansion over two years. There are plans to research processing technology as well as the hemp-derived construction materials and to make them more resistant to earthquakes.[117]

By February 2019 in Tasmania, Australia, 1,600 hectares (roughly 4,000 acres) of hemp was grown and valued at $4.5 million AUD (about $3.1 million USD). Tasmania has the ideal

Fig 2.11 Multipurpose cropping equipment with technology that uses the entire plant. Designed in New Zealand.

climate for cultivation as well as access to water and experienced growers. The current harvest yield is an average of one ton of hemp per hectare (about 2.5 acres) and occasionally 1.5 tons per hectare. Local companies are trying to meet the growing demand for hemp seeds. If they are unable to meet the demand, farmers will have to buy imported seeds. There are three companies cultivating local hemp seeds, contributing to two-thirds of Austrialian-grown hemp. Stakeholders foresee hemp fields growing to 8,000 hectares (roughly 20,000 acres) in the next few years. The Tasmanian Hemp Association (THA) is currently working with the state government to revise current legislation to authorize the sale of hemp crop residues such as mulch.[118] Legislation was passed August 8, 2019, in Australia's Northern Territory making it the last Australian state or territory to legalize hemp farming and processing. NT's hot dry climate may enable local farmers to plant two crop cycles annually. NT authorities said they want to tap the potential of hemp for fiber and grain, and anticipate that the Territory will be a major provider of planting seeds to the rest of Australia. They said the possibility of two crops per year is a major factor that incentivizes farmers.[119]

New Zealand companies Hemp NZ, Carrfields, and NZ Yarn have partnered to develop technology that uses the entire plant. They have designed a multipurpose cropping equipment where "the harvester front attachments capture seed while leaving the hemp stalks in the field for baling."[120] So far, only the seed is harvested, however the hemp businesses aim to change that. New Zealand's technology, infrastructure, and innovation is up to par to European counterparts, and they are now ready to catch up on the production of industrial hemp.

Canada legalized recreational cannabis in October 2018, and Zaffia Laplante, Métis undergrad at Wilfrid Laurier University, worried about the excessive production of waste this would yield; in 2017, a consumption of fifty-two tons of medical cannabis resulted in 400 tons of waste. She founded Hempergy, championing clean and natural materials to reinvigorate Indigenous economies. With hempcrete and hemp insulation, her startup is tackling current problems in Indigenous housing such as mold and overcrowding. Laplante is currently working on prototyping products as well as accruing seed capital to

Fig 2.12 Alex White Plume stands amid the wild remains of his low-tetrahydrocannabinol hemp crop. Pine Ridge Indian Reservation, South Dakota.

Fig 2.13 Zaffia Laplante, CEO and Founder of Hempergy

expand her company. She has obtained a federal licence to cultivate the plant, but plans to initially source hemp from experienced farmers. She wants to "incorporate [Indigenous communities] throughout the supply chain through employment opportunities, . . . expanding the cooperative development of hemp across Indigenous communities in Canada so they're able to grow and process, harvest hemp itself, and then create their own products."[121] By doing so, Laplante recognizes Canada's Truth and Reconciliation Commission's Call to Action #92, which requires the informed consent of Indigenous peoples before infringing on their land with development projects; to take into consideration Indigenous interests as preceding economic ones; actively integrating Indigenous peoples in the workforce and even more so in industrial projects occurring on their territories; ensuring that non-Indigenous peoples grasp Indigenous histories and cultures, especially those involved in industrial projects situated on Indigenous territories.[122]

An "environmental framework of land (or wilderness) as separate from people is an inherently colonial mindset that pits environmentalists not only against labor but also Indigenous people whose lifeways are inseparable from land."[123]

Hemp is garnering attention for many reasons, one of which is its undeniable ecological benefits in the face of the climate crisis we face, from regenerating the soil to sequestering carbon. That being said, to engage in climate justice work necessarily involves Indigenous Nations and how they are disproportionately affected by global warming as well as resource extraction projects. It commits us to knowing, rather than simply acknowledging, whose land we occupy. Indeed, we must learn about the Nation(s)—even the ones that might not be '"federally recognized"—that still or no longer inhabit the area and about the history and reasons for their specific disenfranchisement and dispossession. It is equally about knowing where we came from, how our family history has led us on stolen land, and how this shapes our relationship to the territory and Indigenous communities. Often Nations are deprived of the very resources we steal from their territories. It is thus essential to inform ourselves about where our water, heat, and electricity is sourced from; these come as a

"profit from extraction on Native lands [that] is rarely returned to the community that has paid the cost in destruction of lands and sacred sites, damage to health, and the devastation of local economies and lifeways."[124]

Indigenous Action ascertains that "direct action is really the best and may be the only way to learn what it is to be an accomplice. We're in a fight, so be ready for confrontation and consequence."[125] It is not enough to say that we support them yet remain idle in the face of the ongoing and global injustice they face. We must, as accomplices, act in solidarity with Indigenous peoples in their drive towards liberation. This can be done by way of financial reparations and donations, building relationships with communities receptive to it, participating in protests, listening to what Indigenous peoples and communities have to say, and using one's privilege to hold space for their voices. These, to the best of one's abilities, ought to be practiced simultaneously along with other acts, as this is a general list.

The hemp industry is evolving rapidly, and the biggest hurdle for development is current legislation. There must be consistent practices that remove unnecessary laws that constrain farmers, processors, and businesses. Governments must also ensure that such frameworks are respected. Once that has been demonstrated, financial institutions will cooperate and support the development of the hemp industry. Governmental agencies must recognize the sovereignty of Indigenous people and some Nations who have legalized, used, cultivated, and advocated for hemp long before its current popularity and yet were nevertheless met with federal suppression.

Hemp, as an agricultural plant, necessitates land and can be used to combat climate change. Hemp therefore implicates Indigenous Nations and environmental stewardship. We must acknowledge and educate ourselves on the history of violence and colonialism that has been built on the continued disregard for their human, sovereignty, and land rights. We must concede that their disenfranchisement is due to a willful systematic oppression that subsists to this day. More importantly, we, as settlers must also recognize the ways in which we profit from their marginalization at varying degrees. Meaningful reconciliatory work can be achieved in the hemp industry that could improve circumstances in which Indigenous peoples have been put in. That, however, is contingent on how we act now while the industry is still being established. If we can ensure the involvement of Indigenous peoples and communities in the hemp supply chain and seek their informed consent and opinions, then hemp could truly become a sustainable and equitable industry that promotes regenerative economies. For this to be, we must reevaluate our intentions and the repercussions of our actions. We must hold each other accountable and reflect on Oloah's words: are we here as wašícu, as fat takers, and are we willing to share?

GROWING HEMP

Benefits
Challenges
Cultivation
Economic Viability

Challenges

- Lack of clear guidelines from the USDA.
- Acquisition of seed is more difficult for hemp than traditional crops.
- Insufficient precipitation during the early growing periods can result in short, weak stalks.
- American farmers will be in competition with more experienced countries.
- There is little infrastructure in place to support the manufacturing and selling of hemp products in the United States.
- Specialized machinery for hemp is expensive and uncommon in the US.
- Risk of cross-contamination with marijuana crops compromising harvest and investment.

Benefits

- Carbon-negative process.
- Does not require fertilizers.
- Considered a regenerative crop—hemp improves the nutrient quality of the soil for
- future crops.
- Few natural pests and if seeded correctly will have no need for herbicides.
- Can produce a range of products from seed powder to paper to building elements.
- Potential to offer higher profits than traditional crops.
- State incentive programs offer funding.

Comparison of Hemp Varieties

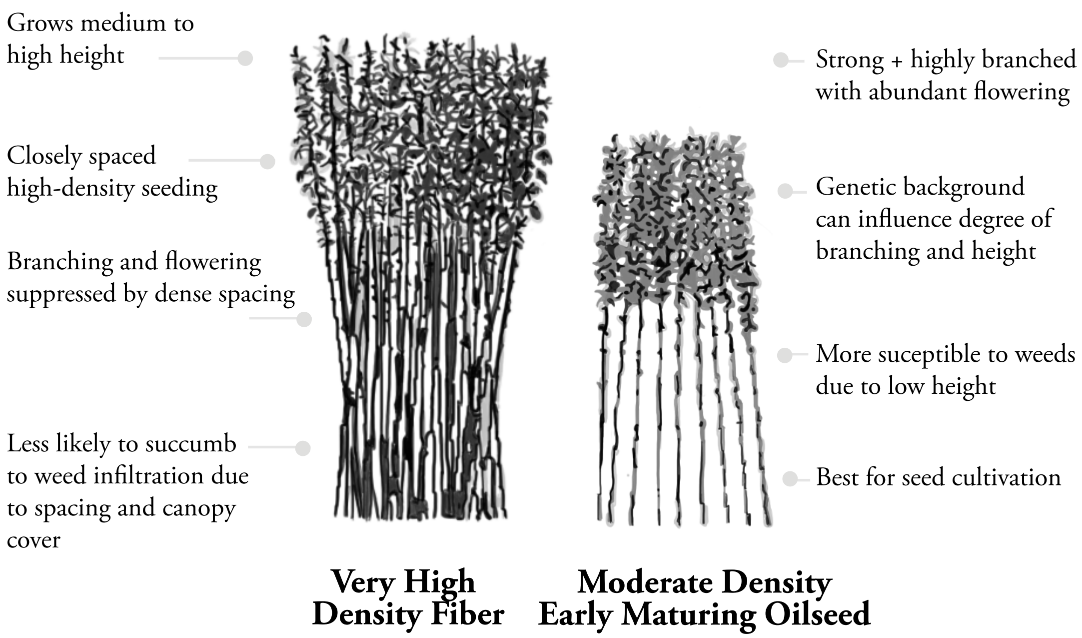


Diagram 3.1 Comparison of hemp varieties

Fig 3.1

Fig 3.2
Leo Pedone at **Pedone Architects Bisceglie, Italy**

Cultivation

Germination

Cannabis can be grown in a variety of ways that ensure it reaches its performative goals once harvested. The desired products that will be derived from the hemp plant will determine the different methods of sowing seeds, water and sunlight requirements, and soil properties. Germination of hemp seed is considered relatively straightforward in comparison to other crops, but precipitation is required early in the growing period. Outside of water demands, hemp requires minimal field preparation and can grow in a wide range of soils, temperatures, and moisture levels. Additionally, growing hemp, when seeded correctly, requires little to no pest management.

Soil Qualities:

- Well-drained, non-compact soil.
- Fertile, loam soil.
- Soil temperature of 50°F is adequate.
- Soil pH of 7–7.5; minimum pH of 6.0.

Best Practices

- Best planted after the last frost of the season although seeds can survive a light frost.
- Between 12–15 inches of precipitation prescribed for an entire growing period, with the majority of moisture intake occurring during the germination period.
- Ideal seeding depth of 1/2-1 inch—No deeper than 1 inch.
- Typically planted in rows spaced 6–7 inches; close seeding spaces suppress weed growth.
- Can be cross-pollinated by the wind, which can lead to contamination.
- For fiber and hurd production, growing periods should be limited to 4–5 weeks.

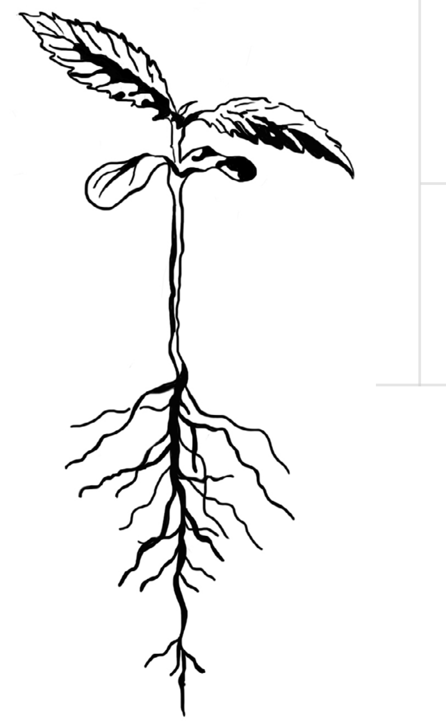


Diagram 3.2 Hemp Seed Germination seasonal growth

Fig 3.3
Cannabis Sativa plant at **Casa di Luce Puglia, Italy**

Plant Gender[126]

The gender of hemp plants act as an indicator for a multitude of processes relating to the harvesting of hemp seed and fiber. Female, male, and hermaphroditic varieties of hemp operate in different manners. While the male plant produces an abundance of flowers, the female plant grows to create a number of calices to be fertilized by the male. Although strong fiber can be obtained from both the male and female plants, oilseeds can only be obtained from the female because the male does not produce seeds at all. Additionally, given the primary role of the male plant to pollinate its female counterpart, it should be noted that once the flowering period comes to an end, the male plant begins to die. This allows for a shorter window for harvesting male plants. Male plants should typically be harvested within four to five weeks following germination. The harvest of female plants can technically occur at a later point, but it is often done at the same time as male plants. Hermaphroditic plants, artificially manufactured, combine some of the major benefits of both the male and female plants, including the ability to produce oilseed and fiber in the way that the female plant does, as well as the ability to self-fertilize, eliminating the need for the male plant.

Male

- Ideal use for fiber production of a finer grade than produced by female plants.
- Do not produce seeds.
- Begins to die shortly after flowering.
- Flowering occurs along the length of the stalk.
- Tiny recemes (short flower stalks) grow at the base of the plant.

Female

- Ideal for both seed and fiber production.
- Outlasts male plants following flowering.
- Produces a blend of tiny pistils and calices; the calices contain the ovules.
- The calyx is the location of seed production after fertilization.

Hermaphroditic

- Can self-fertilize.
- Can be used for both oilseed and fiber production.
- Artificially manufactured.

Morphological Timeline of Hemp Cultivation

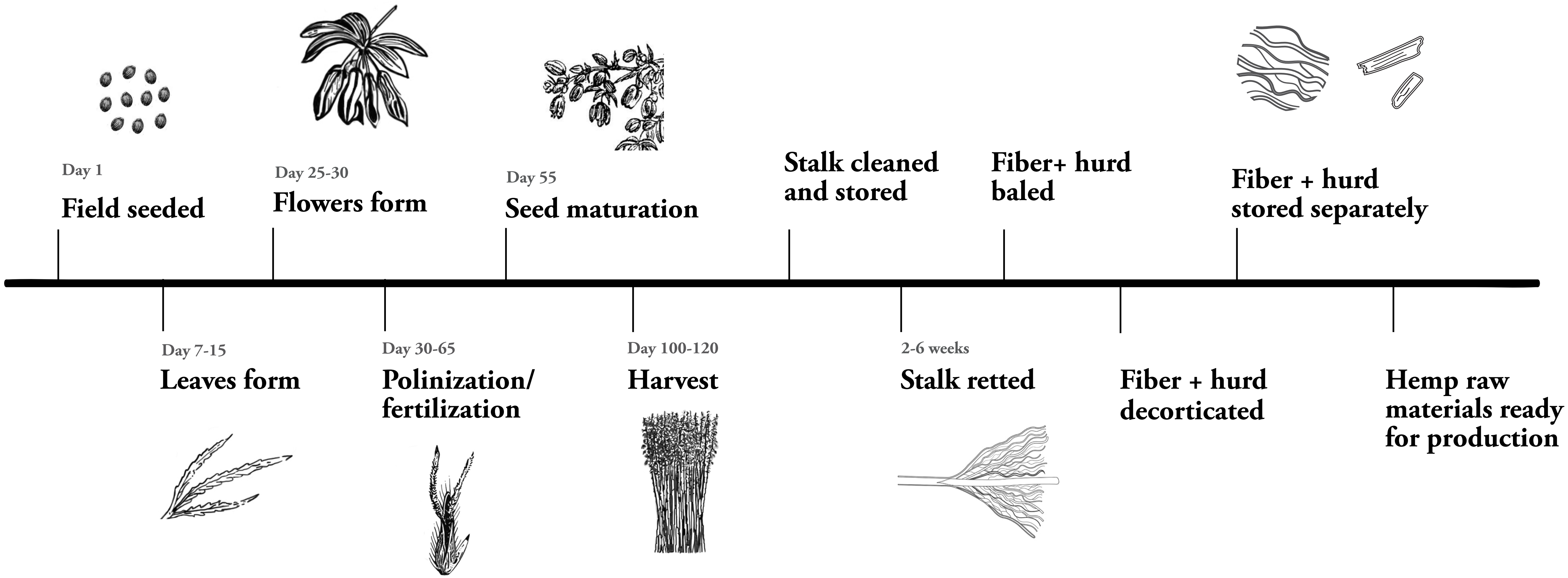
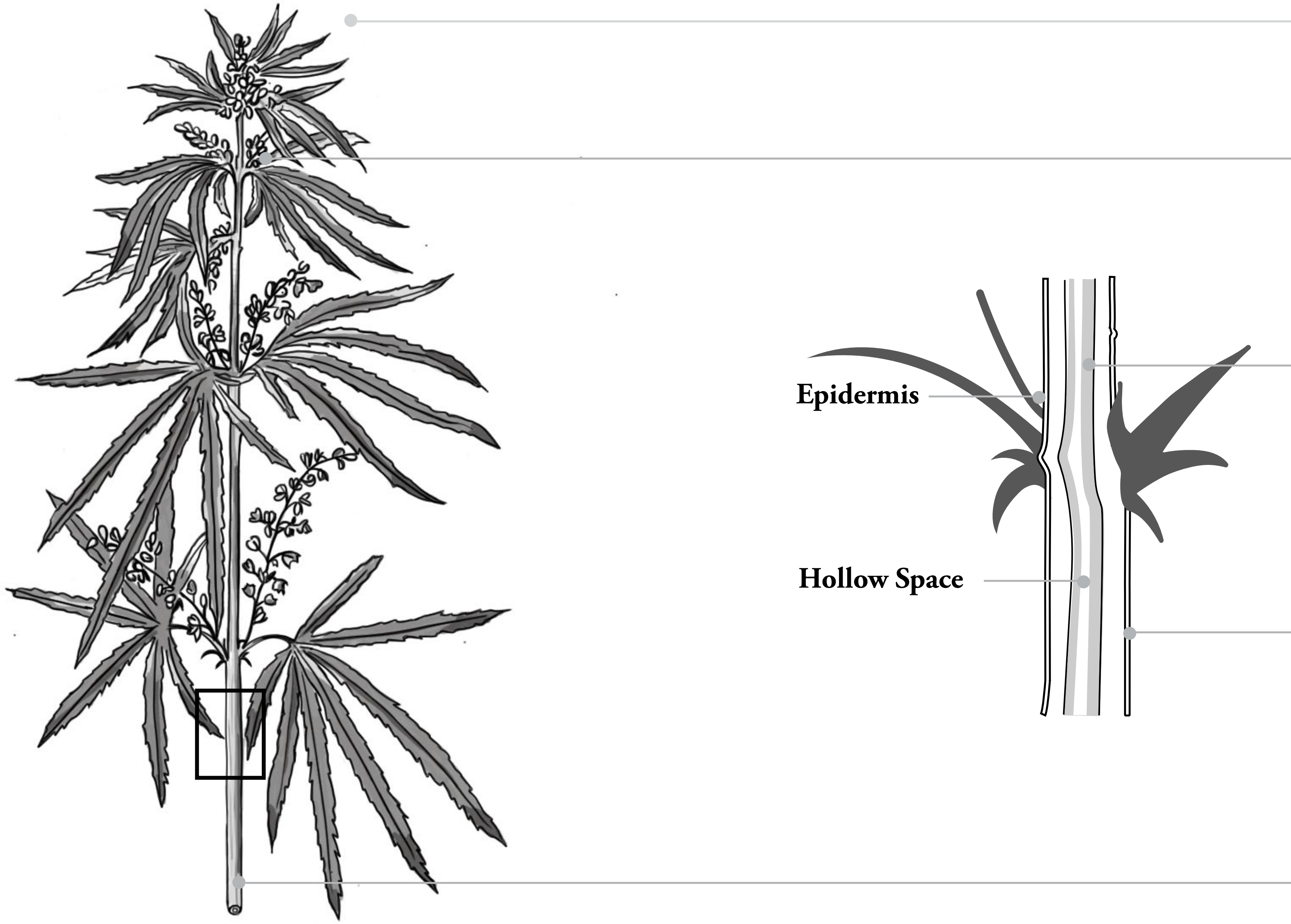
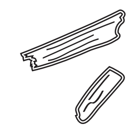


Diagram 2.3

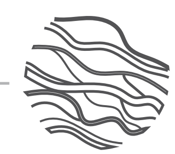


Flowers+Seeds
Psychoactive plant-generally

Seed
- Protein Source
- Fuel
- Lubricants
- Ink



Hurd
- Mulch
- Chemical Abso
- Fiberboard
- Insulation



Fiber
- Netting
- Canvas
- Carpet
- Biocomposites
- Clothes

Stalk
- Biofuel/Ethanol
- Paper Products
- Cardboard
- Filters

Diagram 2.4

Harvest

In comparison to many traditional crops including corn and soybeans, industrial hemp has one of the shortest turnaround times from seeding to harvest. Approximately four months in total, industrial hemp is best harvested once stalks begin to change color, indicating the start of a rotting process known as retting. Retting, which is a process that can be tailored to the desired products, should be factored into the total harvesting time for hemp.

At the point of harvesting, stalks can reach heights of up to sixteen feet, growing at a rate of four inches per day or up to twelve inches per week. Additionally, since growing hemp is not a common practice in the United States, most US farmers are not equipped with the machinery to properly harvest hemp. With this in mind, American farmers are tasked with acquiring the proper machinery prior to harvest.

Best Cultivation Practices

- Best harvested between 70 and 90 days after seeding.
- Acquire and become familiar with machinery prior to harvest.
- Ill-suited machinery will break down when attempting to harvest hemp.
- Consideration of a combine harvestor to cut and collect the seed separate from the stalk.
- Determine best-suited retting method.

Harvesting for Fiber and Hurd

- Harvest typically between 11 and 12 weeks post-seeding.
- Harvesting hurd and fiber go hand in hand; strong stalks will contain healthy fiber and hurd.
- Cut as whole stalks.
- Cutting at base while leaving roots in the soil can improve nutrient content for future crops.
- Cutting stalks at the top removes seeds so both seeds and fiber can be harvested simultaneously.

Retting

Retting is the process of "rotting" away the pectin of the hemp plant, which acts as a naturally occurring adhesive between the fibers and the stalk of the plant. The result is the sloughing off of the outer part of the stem and the loosening of the hurd from the phloem fibers. Retting will occur naturally when hemp is left in place but can also be manually performed and sped up with the aid of additional energy or chemicals. There are six common retting methods that can be used by farmers to prepare fiber and hurd for manufacturers. Of these six practices, half involve the use of water to "rot" away the outer stalk and two of the remaining practices involve mechanically crushing the stalks or chemically dissolving the pectin for easy separation. The remaining process, known as winter retting, has the longest duration of retting time but is the most passive retting process that can be used.

When considering natural retting processes, the determining factor is time. Water is used to passively rett stalks either through the humidity of the environment or by submerging stalks into pools of water. Utilizing this method, retting can take several weeks to complete. The addition of energy to heat water to warmer temperatures helps to speed up the retting process to less than a week.

Fig 3.4

Fig 3.5 Retted and baled hurd and fiber

Methods

1. Dew retting/Field Retting:

- Utilizes environmental moisture, sun and fungi to break down fibers.
- Environment should be humid, but, not excessively moist
- Typically takes between 2-3 weeks to ret.
- Change to either a gray or golden color can indicate the retting process is complete most economical and least labor intensive.

2. Water Retting /Dam Retting:

- Bacteria breaks down plant pectin as stalks are immersed in natural bodies of water.
- Can take between 2-4 weeks typically, but, best judged if ready by testing how easily the stalk separates from itself.
- Produces thinner more uniform quality product.
- This process can contaminate the bodies of water in which they soak

3. Warm Water Retting:

- Involves submerging the stalks of industrial hemp in different temperature water to expedite the "rotting" process.
- Depending on the temperature of the water, the stalks can break down as quickly as 3 days or as long as 45 days. The process is as follows:

a. 98.6°F requires 3 days of submersion.
b. 68°F water requires 7–8 days.
c. 53.6°F water requires 15–17 days.
d. 44.6°F water requires 30–45 days.
e. At 41°F retting does not occur because bacteria are inactivated.
f. At 104°F the stalks are destroyed.

4. Chemical Retting

- Artificial chemicals are used to dissolve the pectin and ultimately separate the fibers from the hurd.

5. Mechanical Retting

- Stalks are crushed under using force to the point at which the hurd can be easily separated from the fibers.

6. Winter Retting

- Stalks are cut down and left in the field over the course of the winter. Natural absorption of moisture over an extended amount of time facilitates the separation of the bast fibers from the hurd. This is one of the least labor-intensive retting processes.
- extended amount of time facilitates the separation of the bast fibers from the hurd. This is one of the least labor-intensive retting processes.

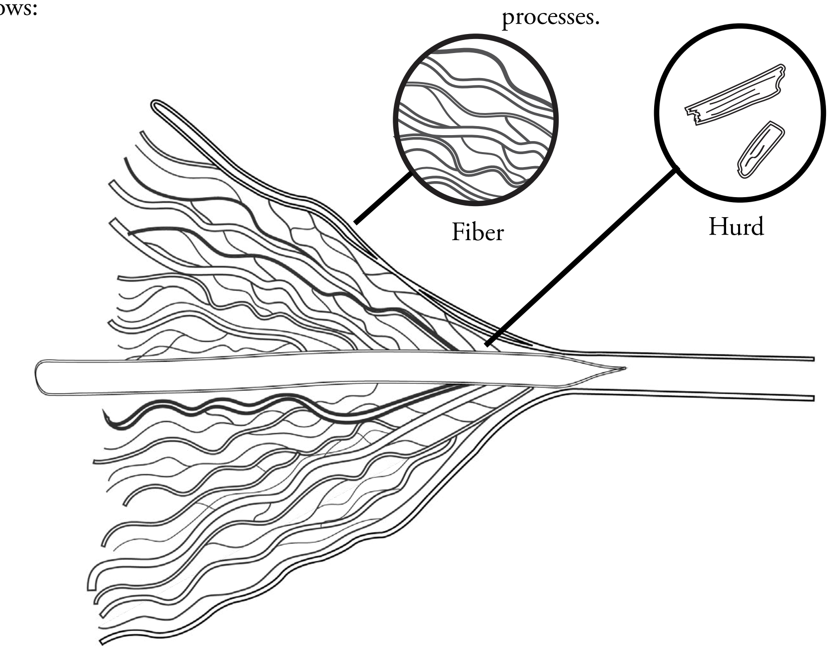


Diagram 3.5 Hemp stalk structure

Minimum and maximun retting duration

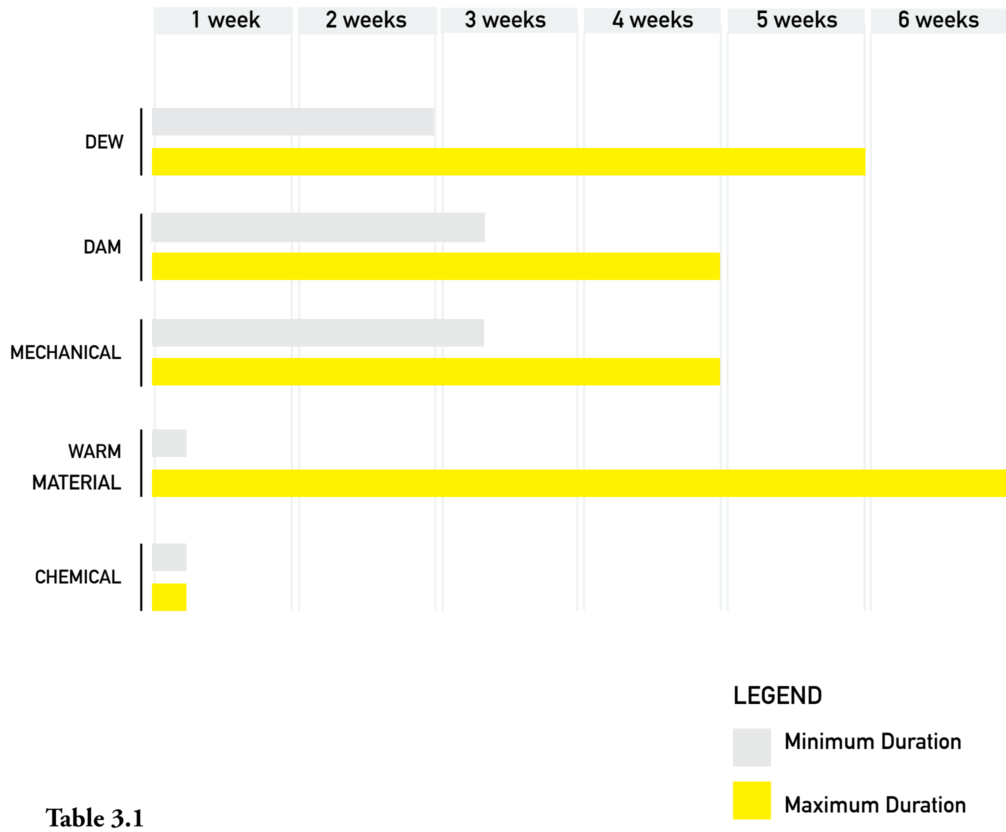


Table 3.1

Post-Harvest Processing

Following harvest, separated hurd, fiber, and seeds will be stored until ready for transportation. It is vital that all components of the hemp are stored in a dry and covered location since each is prone to water intake. Fiber is often baled and elevated above ground on platforms or pallets. Hurds and seeds can be packaged in bins or bags to await shipping.

Fig 3.6 Retted and baled hemp, Kentucky

Introduction
Industrial Hemp
Growing Hemp
Lime
Hempcrete
Products & Production
Construction
Case Studies
References

Economic Viability-Growing Hemp in New York

Some of the most popular crops grown today in the United States include corn, soybeans, hay, and haylage. Across the country American farmers are seeing an increase in the total cost of production for some of these crops and a decrease in profit. Some factors that play into the decrease in total revenue include cash rents, property taxes, and government regulation and change in policies. With the various fluctuations that continue to occur, it is becoming increasingly difficult for American farmers to make a profit with traditionally grown crops.

Implementation of policies like the Federal Agriculture Improvement and Reform Act of 1996, also known as the 1996 US Farm Bill, put a strain on farmers' ability to turn a profit by removing acreage restrictions on program crops and instituting production flexibility contract payments that are not linked to commodity grain prices.[127] With the introduction of fixed contract payments and the cessation of deficiency payments that occurred prior to the Farm Bill to counter-balance low grain prices, farmers incurred a higher risk than previously.[128] "The decline in grain prices increased the financial pressure on many farmers, prompting government officials to enact emergency assistance programs to aid them."[129]

The United States has experienced a number of other factors causing the fluctuation of total cost and revenue. In Minnesota, for example, the southwest, south-central, and southeast regions between the years of 2015 and 2017 experienced above average corn yields; however, negative profit margins continued to persist for corn on cash-rented land.[130] In 2018, the Midwest saw a $9 profit for corn and soybeans as the total revenue per acre was $673 compared to the average total cost of $664 per acre to produce.[131] Between 2008 and 2016, Illinois experienced property taxes growing at a rate of 9.6 percent per year. This resulted in property taxes more than doubling by 2016. Due to these kinds of circumstances, farmers will continue to look for ways to increase profits to avoid just breaking even during harvest season.[132]

According to the 2018/2019 State Agriculture Overview of New York State, there are almost 7 million acres dedicated to agricultural production. Of the 33,400 farm operations in upstate/rural New York, the majority are dedicated to livestock, hay, and haylage and corn, both grain and silage. In total, crop production of hay products and corn products has a value of $1.25 trillion combined. A closer look will show that the value of production of hay and haylage, including alfalfa, totals $827,542,000. Corn, with the majority of acres harvested for grain, totals $420,476,000.[133] Experiencing a slight increase between 2017 and present day, corn has increased in value of production from $398,578,000 by approximately $20 million. This increase can be misleading as corn has generally been decreasing in value, which is evident in the Census of Agriculture of New York: Table 2. Market Value of Agricultural Products Sold Including Landlord's Share, Food Marketing Practices, and Value-Added Products: 2017 and 2012.[134] With 6,732 farm operations producing corn, the value of production was $620,793,000 in 2012, decreasing by more than $220 million with over 1,300 farm operations ceasing to produce corn. Simply put, corn is becoming an unreliable source of income for farms in rural New York. The introduction of a new crop with its own revenue potential and a multitude of uses after growth is enticing.

As described earlier Industrial hemp has been historically grown in the US but first reduced then ceased production because of regulations after World War II. This does not mean, though, that it cannot regain popularity within rural communities across the country, but it should not be treated as a miracle crop capable of solving all problems plaguing American farmers.

Today, France is the largest producer of industrial hemp, focusing primarily on fiber growth.[135] The United States domestic markets for industrial hemp, though, are primarily supplied by Canada and China with sales of hemp-based products totaling over $688 million in 2016.[136] With the desire to begin growing industrial hemp at a larger scale in the United States comes the current period of adaptation and experimentation.

There are several hemp seed cultivars used worldwide to grow industrial hemp, with a number of new cultivars testing below 0.3 percent THC

Fig 3.7 Field retting hemp

added every year.[137] Of the existing commercially available cultivars from Europe and Canada, many are being bred to enhance production of oil, fiber, or both. The problem the United States faces currently is the lack of yield testing.[138] Occuring only in recent years, testing in New York State has resulted in over 2,300 pounds per acre for the highest yielding cultivar in the highest yielding trial. This amount confirms the state's potential for industrial hemp growth.[139]

In addition, the selection of certain cultivars can have a high yield across a multitude of categories i.e. fiber and oil. In other words, multipurpose cultivars exist that are capable of producing oil with a high CBD content, as well as strong fiber and therefore plentiful hurd.[140] As it is becoming harder to predict the revenue generated by certain commonly grown crops, one crop with multiple potentials can provide the safety farmers are seeking. While it may be hard to predict as of now, precise seed selection can be the difference between breaking even and turning a profit. Reported in the 2017 Industrial Hemp Trials for New York State Grain and Fiber Production, "Eletta Campana" was twenty-eight percent bast fiber while "Carmagnola" was 24 percent bast fiber, equivalent to a difference of over 550 lbs. of bast fiber per acre."[141]

While the potential for growing and profiting from industrial hemp seems positive, it is not without its own concerns. Industrial hemp is often lauded as a crop that can sustain itself through the growing season without fertilizers. This has been reported by a multitude of sources, but there are other factors that can impact yield.[142] To clarify, field crop history is worth taking into account when considering the use of fertilizers. Crops grown prior to industrial hemp can severely affect nutrient content of the soil and therefore reduce yield. The necessity for fertilizer can be best determined by a soil test and is worthwhile for all farmers to do prior to seeding their fields. The Canadian Hemp Trade Alliance encourages new industrial hemp farmers to begin with a limited quantity of acres, at or below 300 acres/121 hectares in the first year to gain a better understanding of how to manage growing this particular crop.[143] In summation, the great economic potential of growing industrial hemp on American soil is not without risk and should be met with excitement and experimentation as well as caution.


Fig 3.8 Harvesting corn, Kentucky


Fig 3.9 Field retting hemp, Kentucky

Cost of Production of Hemp Compared to Corn

	Industrial Hemp (Dryland)	Industrial Hemp (Irrigated)	Corn
Yield per Acre (lb)	1073.9	1679	10360
Operating (Variable) Costs (USD)	$214.74	$219.42	$118.47
Capital Costs (USD)	$71.10	$91.10	$120.47
Total costs of production (USD)	$285.84	$310.52	$238.95
Price (per lb)	$0.53	$0.53	$0.07
Gross Returns	$562.23	$714.85	$217.02
Gross Margin	$276.39	$404.33	$-21.93

Many farmers are hopeful that the multiple benefits of hemp including increased revenue can help support and rebuild agricultural communities in the U.S.

Notes:

1. Data in the United States Dollar (USD), acres (ac), or pounds (lbs).
2. Acres cropped were 103 (Hemp-Dryland), 133 (Hemp-Irrigated), and 280 (Corn). Data included in the table is recalculated for 100 acres cropped.
3. Data is studied for the year 2015. More recent information for corn, which was available for the year 2017, is provided separately.
4. Canadian studies refer to operating costs as variable costs. Additionally, allocated overhead are referred to as capital costs.
5. The division of dryland to irrigated corn growth is 89% to 11% respectively.
6. Gross margin is gross return minus the cost of production. This is a close approximation of the profits to be made by growing either crop.

Table 3.2

LIME

Why Lime
- History of Use
- Types of Limestone
- Limestone Regions in the World

Extraction
Processes
Lime Cycle

Fig 4.1
Limestone quarry at
Puglia, Italy

Why Lime?

Many architects and designers are interested in alternatives to toxic synthetic petrochemically derived building products and aspire to construct homes out of natural, nontoxic building materials to create healthier, habitable spaces. By combining hemp hurd with lime, we create hempcrete that can provide a number of benefits to both the inhabitants of spaces and the immediate environment. Lime, also referred to as quicklime, acts as a binder in a hempcrete mixture. Etymological terms such as calce (Italian), kalk (Dutch), and lime (English) refer directly to the description and use of lime as a glue. With a chemical makeup of CaO (calcium oxide), lime, when mixed with hemp, binds itself to the silica of hemp hurds. Due to its high pH balance, lime acts as a natural combatant against mold and fungus and, in addition, is an antimicrobial material.[144] As an antifungal material, lime, effectively coats every piece of hurd in the mixing process and in humid climates prevents mold from accumulating on or within various surfaces.

With the success of antimicrobial materials in medicine, the building industry is looking to incorporate similar technologies in building. Extensive research is being done currently to understand the viability of both organic and inorganic antimicrobial mixtures used to create mortars and their effectiveness at reducing the ability of microorganisms to survive on a range of surfaces (e.g. door handles, countertops, bathrooms, etc.). One study notes that the use of biocide and fungicide agents in a concrete with polypropylene fibers inhibited the presence of such pathogens as *Escherichia coli*, *Staphylococcus aureus*, and *Aspergillus niger*.[145] The use of inorganic biocides and fungicides is problematic and linked to

Fig 4.2 Lime preparation

Fig 4.3 Limestone quarry at Højerup, Denmark

public health concerns. Global Market Insights notes that "growing environmental and regulatory concerns with regards to use of halogenated compounds such as bromine and chlorine are expected to hamper growth and affect biocides market price trend."[146] It is likely that markets will shift their focus from inorganic biocides to organic biocides and fungicides like lime, which is an organic form of both.

A combination of hemp and lime has positive and some negative environmental implications and supports carbon sequestration. Limestone undergoes a number of steps between quarrying the stone and actual use in construction. Following extraction, the limestone is brought to a kiln in which it is heated to temperatures ranging from 900°C-1000°C (1652°F to 1832°F)[147] as the first step in its conversion to lime. As the limestone is heated, it completes a process known as calcination, which is defined as the partial decomposition of limestone and the release of CO_2, transforming $CaCO_3$ (limestone) to CaO (lime).[148] This transformation also accounts for the change in color of limestone to a chalky white. Given what we know today about the presence of greenhouse gases in our atmosphere and its effects on global temperatures, industries are looking to make major strides to reduce the release of CO_2 into the environment. While technology is being developed to capture CO_2 directly following the calcining process, this is an essential first step in this industry. In addition, the building industry is also capable of reducing the amount of greenhouse gases via sequestration through the use of hempcrete

Carbonation is the process by which lime is transformed back into limestone in the Lime Cycle.

Acting as the reverse process to calcination, in carbonation CO_2 is sequestered from the environment allowing the transformation of CaO back to $CaCO_3$.

Through this process, the presence of a lime binder in hempcrete effectively reduces and even counteracts the release of CO_2 into the environment during the carbonation process.

History of Use

Limestone is classified as a rock containing no less than 50%, by weight, calcium carbonate in the form of calcite. Limestone is a common rock abundant in many locations, typically found buried deep beneath soils and adjacent to bodies of water. Limestone has been in constant human use for the last 6,000 years and is an important material in building construction. It is the intention of this guide to highlight the role limestone plays in hempcrete production and its multiple benefits including carbon sequestration and its host of benefits for the inhabitants of a structure.

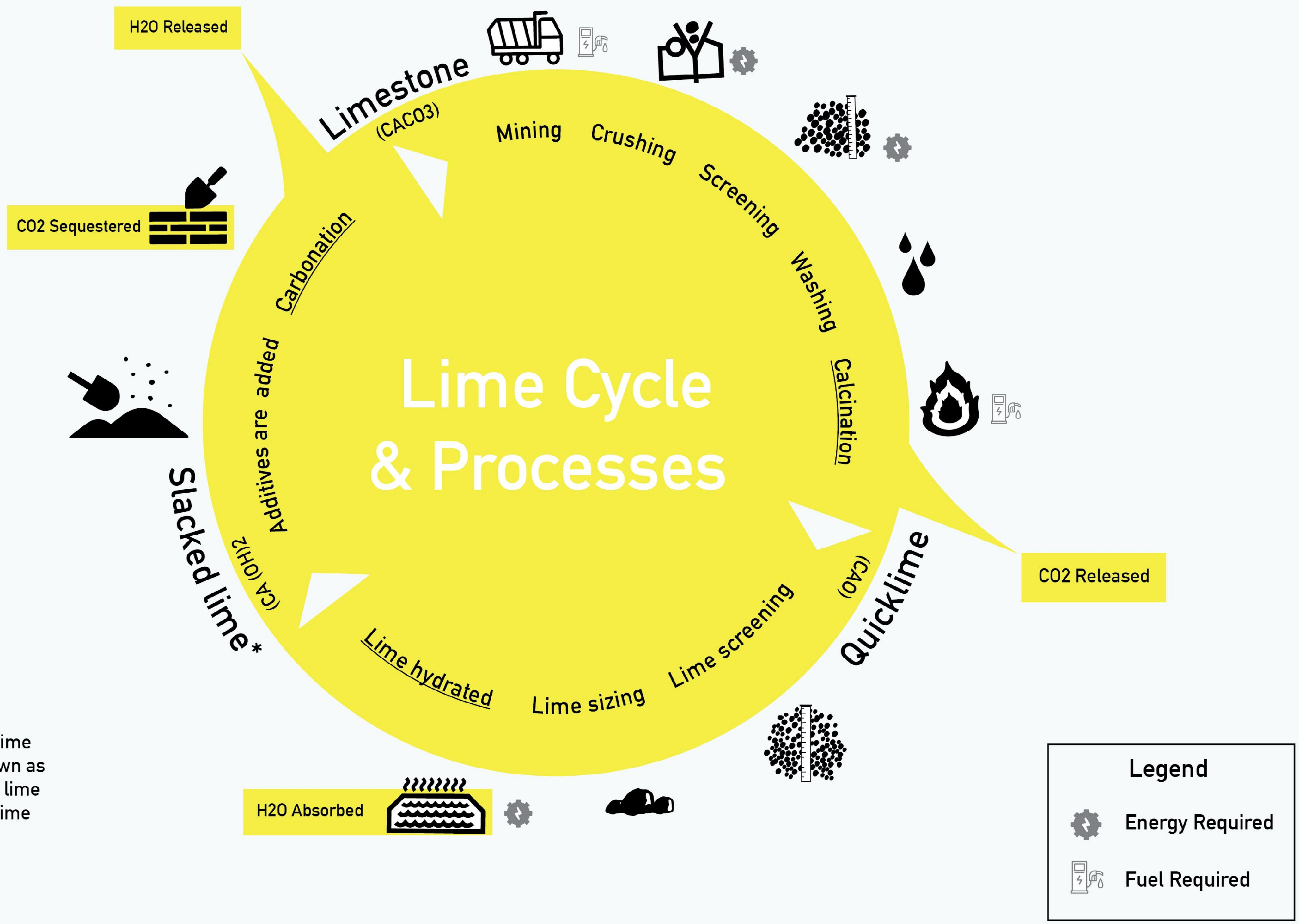
Ancient Egyptians fired limestone to create lime for use in pottery and used both limestone and lime to create extraordinary architectural constructions such as the pyramids of Giza. The pyramids were constructed on foundations of limestone and constructed of limestone blocks that were finished with Tura limestone from a nearby quarry to provide a white and shining finish.[149] Additionally, the mortar used between the massive blocks of limestone was a gypsum-based matrix with additives including limestone and mud brick.[150]

Roman concrete utilized quicklime, a burned form of limestone combined with water and volcanic ash "combined with fist-size chunks of bricks or volcanic rocks called tuff, and then packed into place to form structures like walls or vaults."[151] In Ancient Roman architecture, the volcanic ash additive mixed with the lime cement provided additional strength to the mix and has allowed structures such as the Pantheon and the Colosseum to remain standing to this day.

These construction techniques declined during the European Middle Ages, but traditional practices with limestone continued to be used elsewhere. In the state of Rajasthan in India, the geography of the region came to define the local limestone-based architecture. Jaisalmer, a city in Rajasthan, displays a rich history of locally sourced yellow limestone used as early as 1156 AD to construct forts and temples. Today lime is used for "interior floorings, wall claddings, monuments, cobble stones and for decorative purposes."[152] Other Rajasthani cities such as Jaipur and Jodhpur have earned new names referencing the role of limestone in their architectural

Fig 4.4 Lime paint over cow dung plaster in desert village homes, Jaisalmer, India

Lime Cycle



*Slaked lime also known as hydrated lime or putty lime

Diagram 4.1 Lime Cycle & Processes

styles. Referred to as the "Pink City" and the "Blue City," respectively, Jaipur received its name after painting the entire city with calcium oxide, a pink paint, while Jodhpur became known as the Blue City from its predominant use of blue lime plaster on the majority of buildings located in the city.[153154]

The geological existence of limestone in an area, its type and color, and its distance from the surface has heavily influenced societies throughout the course of human history. Though it is a common mineral, it is the local practices developed to incorporate the use of limestone into a culture that make limestone special. Today there are a number of limestone quarries currently in operation in the United States. Lime is an essential ingredient of cement, a critical component of concrete for construction. Because it is heavy and construction activities are local, the location of limestone quarries are important. As the US Geology Survey notes, "Although limestone is common in many parts of the United States, it is critically absent from some."[155] The use of limestone is so critical to various building processes that not using it is rarely an option. The majority of cost to the producer is the transportation of the limestone from quarry to factory.[156] Additionally, the process by which limestone is fired to produce quicklime, lime putty, etc. is known to release carbon dioxide into the atmosphere. Weaved so deeply into common construction practices, there is clearly a need to reduce or absorb CO2 emissions in lime production. If we cannot remove the need for lime from limestone, then we need to find ways to counteract some of its more problematic negative climate impacts through the use of hempcrete and plant, soil, and other CO2 sequestration.

Fig 4.5 Amer Palace, Jaipur, Rajashthan, India

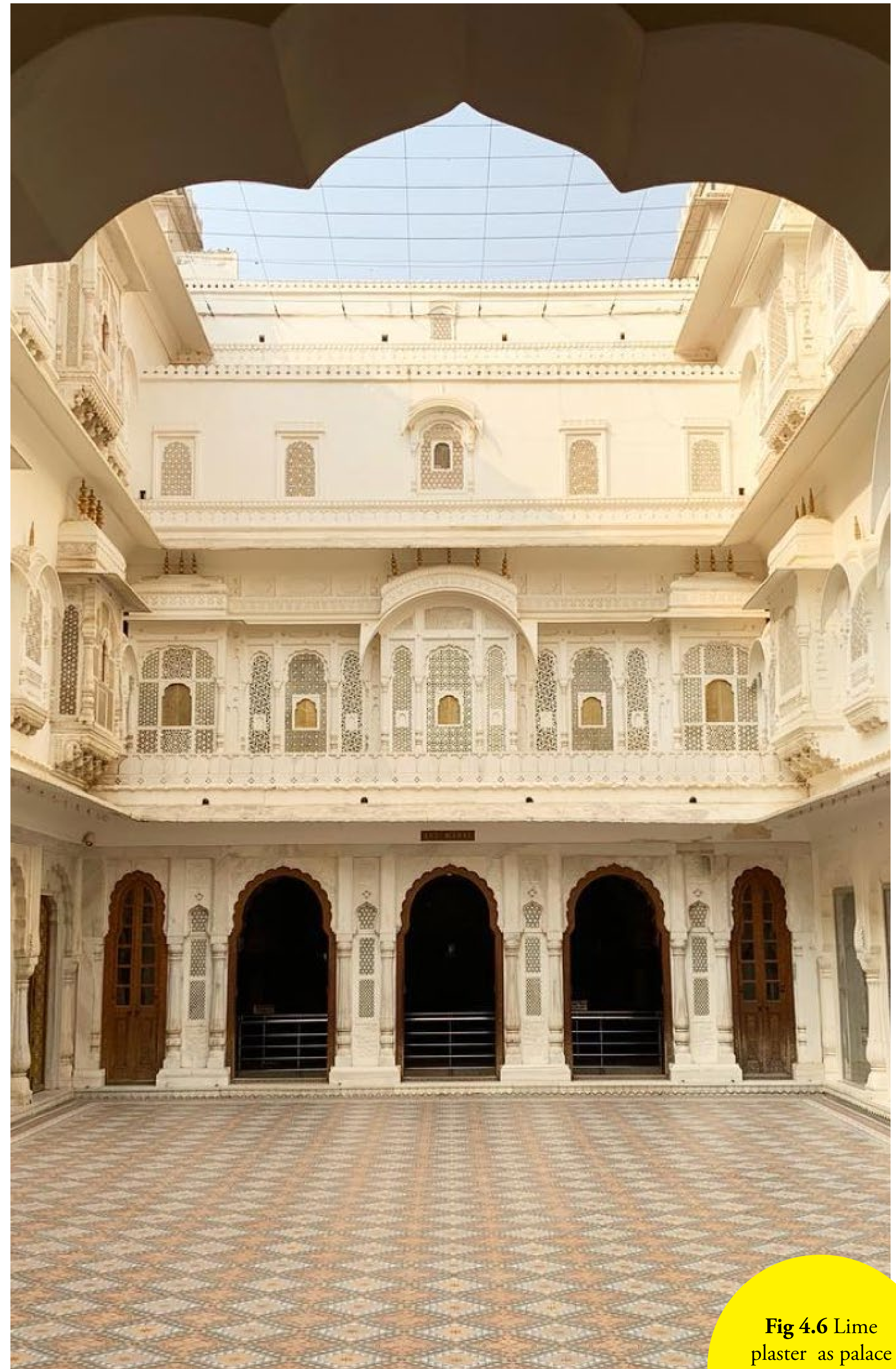


Fig 4.6 Lime plaster as palace facade at **Junagarh Palace**

Brief Survey of Global Lime Applications in Buildings

Diagram 4.2 Brief Survey of Global Applications in Buildings

Fig 4.7

Types of Limestone

Limestone is a naturally occurring mineral found in many regions around the world. Classified as either a chemical sedimentary rock or a biological limestone, the location and method in which limestone is formed indicates qualities that will later be used to evaluate limestone among manufacturers. Chemical sedimentary rocks, formed as a result of the direct precipitation, include types like travertine, recognizable by its banded striations. Biological limestone occurs as a result of the accumulation of organic skeletal matter.[157] Biological limestone such as biosparites are limestone deposits that were once located at the bottom of bodies of water and have since been made accessible for human use by receding waters and rising lands.

Quarries of biological limestone within the United States are located around various bodies of water. The US Great Lakes region are surrounded by dolomitic limestone deposits. When dolomite, a mineral, is found adjacent to limestone it changes the chemical property of limestone. Some regard dolomitic limestone as the highest quality of limestone available. Dolomitic limes create mortars with high strength.

Defined both by the way in which the limestone has formed, as well as, the extent to which the limestone has been crushed in the processing phase, the granular size of the limestone determines the texture of the resulting products. There are four different classifications of grain size for limestone. The four classifications include: micro-grained (less than 4 um); fine-grained (4 to 60 um); medium-grained (60 to 200 um); and coarse-grained (over 200 um to approximately 1000 um). With the use of additives such as clay, native soil and specific minerals, many companies experiment with different combinations of lime to create mixtures that best suit their range of building needs.

Fig 4.8 Different granular sizes of crushed limestone

Limestone Regions in The World

Designed by Hannah Nestel for Circle of Blue
Source: Williams PW and Y.T. Fong, World map of Carbonate Rock Outcrops V3.0, 2006 revision

Diagram 4.3 Limestone Regions in the World

Extraction

The process of transforming limestone into usable products is referred to as the Lime Cycle. The lime cycle is a chemical process that entails extracting the limestone from the ground, cooking the limestone in a kiln until it becomes lime, combining the lime with water to allow soaking to occur, and producing a lime putty that, if desired, can be transformed back into limestone.

To begin, extraction is the process by which limestone is quarried from the Earth. Limestone found at higher altitudes, typically appearing darker in color, is often pulled from the adjacent land and dropped into deep pits. This process utilizes gravity to break the limestone into more manageable fragments. Limestone that is located at lower altitudes, appearing lighter in color, is mechanically broken down at ground level. Limestone found near mountains (higher altitude) has the advantage of using a sustainable energy force (gravity) to do the work that otherwise would be done mechanically at lower altitudes by machinery.

Fig 4.9 Limestone Quarry, Puglia, Italy

Fig 4.10 Lime Processing

Fig 4.11 Gruppo Unicalce, Puglia

Unicalce SPA
Puglia, Italy

Processes

If there is a production facility in proximity, limestone can be processed at the same location where it is sourced. Limestone is broken up and distributed between kilns. It is important to note that limestone at this point in the chemical process is safe to touch; once limestone is baked in kilns, however, it becomes caustic and dangerous to handle. Baking limestone entails heating the limestone to extremely high temperatures ranging from 1652°F to 1832°F. This process releases levels of carbon dioxide into the atmosphere considered detrimental to the health of the environment and all species that inhabit it. The process is nevertheless necessary: it transforms limestone (chemical makeup) into lime (chemical makeup). The process colors the lime a chalky white and halves its original weight.

The lime is then soaked in a pool of water in a process known as slaking. Slaking involves adding fragments of lime to pools of water and allowing the lime to carbonate the water. In other words, the water dissolves the carbon dioxide present in the lime. This process should be done slowly, adding a moderate amount of lime to the pool each time so as to not promote too violent a chemical reaction. The water experiences a noticeable rise in temperature—just short of reaching the boiling point. As slaking occurs, the once-solid lime becomes the consistency of a thick liquid. The duration of time the lime is allowed to cook at these high temperatures is crucial. Experienced lime workers are instrumental to ensure the lime is evenly processed and not overcooked. Once the lime has fully completed the slaking process, the resulting substance, lime putty, is safe to touch and can be used to create a multitude of products.

Fig 4.12 Slaking process to create putty at Unicalce SPA, **Puglia, Italy**

The Virtuous Cycle of Hemp + Lime Products

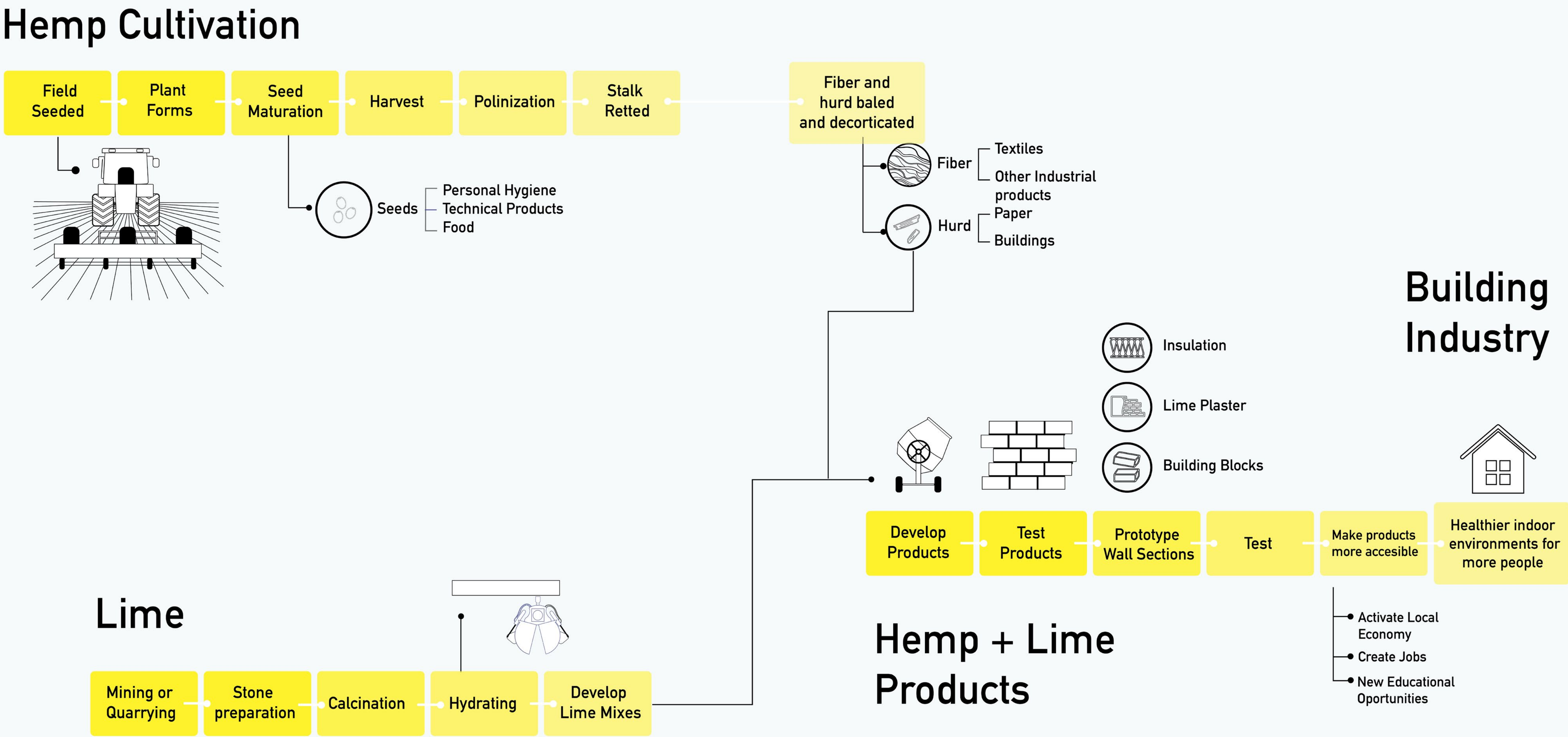


Diagram 4.4 The Virtuous Cycle of Hemp + Lime products

HEMP + LIME PRODUCTION

What is Hemp + Lime Production?
- Why Hemp + Lime? (Potential) Impact
- Properties
- Uses
- Benefits

What is Hemp + Lime Production?

Hemp + Lime is composed of a mixture created by combining, in specific ratios, the woody core of industrial hemp, referred to as hurd or shiv, with lime that acts as a mineral binder. When mixed together a chemical reaction occurs as the lime, combined with water, coats the hemp hurd and hardens it over time to a solid form.[158] Hempcrete, as it is currently used in the construction industry, is an excellent insulation material and is capable of sequestering carbon dioxide from the immediate environment. As a mixture containing lime, hempcrete is antifungal and antimicrobial, effectively reducing the health risks from airborne bacteria. Additionally, hempcrete boasts a plethora of architectural benefits such as flame retardance, improved acoustical qualities, and breathability.

Why Hemp + Lime? (Potential) Impact

The classification of cannabis as a Schedule I narcotic significantly hindered the United States' involvement in the global hemp industry. Disadvantaged by this setback, American farmers have been forced to catch up to their European, Asian, and Canadian counterparts. Despite facing a multitude of complications, hemp has persevered as an important and lucrative agricultural crop in the face of less promising alternatives.

For example, corn, a major crop grown in the United States, has been widely cultivated. In 2014, it was estimated that farmers located in New York grew approximately 1.15 million acres of corn annually. In the last thirty years or so, there have been wide fluctuations in the number of acres of corn grown and the economic value of corn. As acreage and value increased, new industries developed such as ethanol and various grain-storage industries as well as a number of industries specific to upstate New York.[159] In more recent years, though, many American farmers have struggled to do more than break even when they plant corn as returns plummet.[160] While global warming is a critical concern, the production of corn—with over 97 million acres in the United States—emits over 5.6 million tons of nitrogen due to the use of chemical fertilizers.[161] American farmers and traditional landowners are looking for alternatives to grow new crops with greater financial benefits and fewer negative environmental impacts than corn.

Hemp boasts many impressive qualities when assessing its potential as an agricultural crop. Growing industrial hemp from the cannabis sativa plant can be more lucrative for some farmers than corn.

When seeded correctly, hemp requires few to no herbicides, has few natural predators, and no prescribed pesticides.[162] The process of growing hemp improves the soil quality of the land by adding nutrients to the soil and makes an important contribution to regenerative soils as it also builds and binds soils, increasing its CO2 sequestration rates. Industrial hemp, when grown, provides sustainable alternatives to common products.[163] For American farmers, there are still many challenges that must be tackled early on to ensure profitable harvests. Without access to hemp seeds or specialized hemp harvesting equipment in the United States, farmers have a number of hurdles to overcome before they are able to reap the many benefits that growing hemp provides.

The construction industry in the United States faces a similar number of challenges as American farmers in realizing profit margins in the global hemp industry. When industrial hemp is

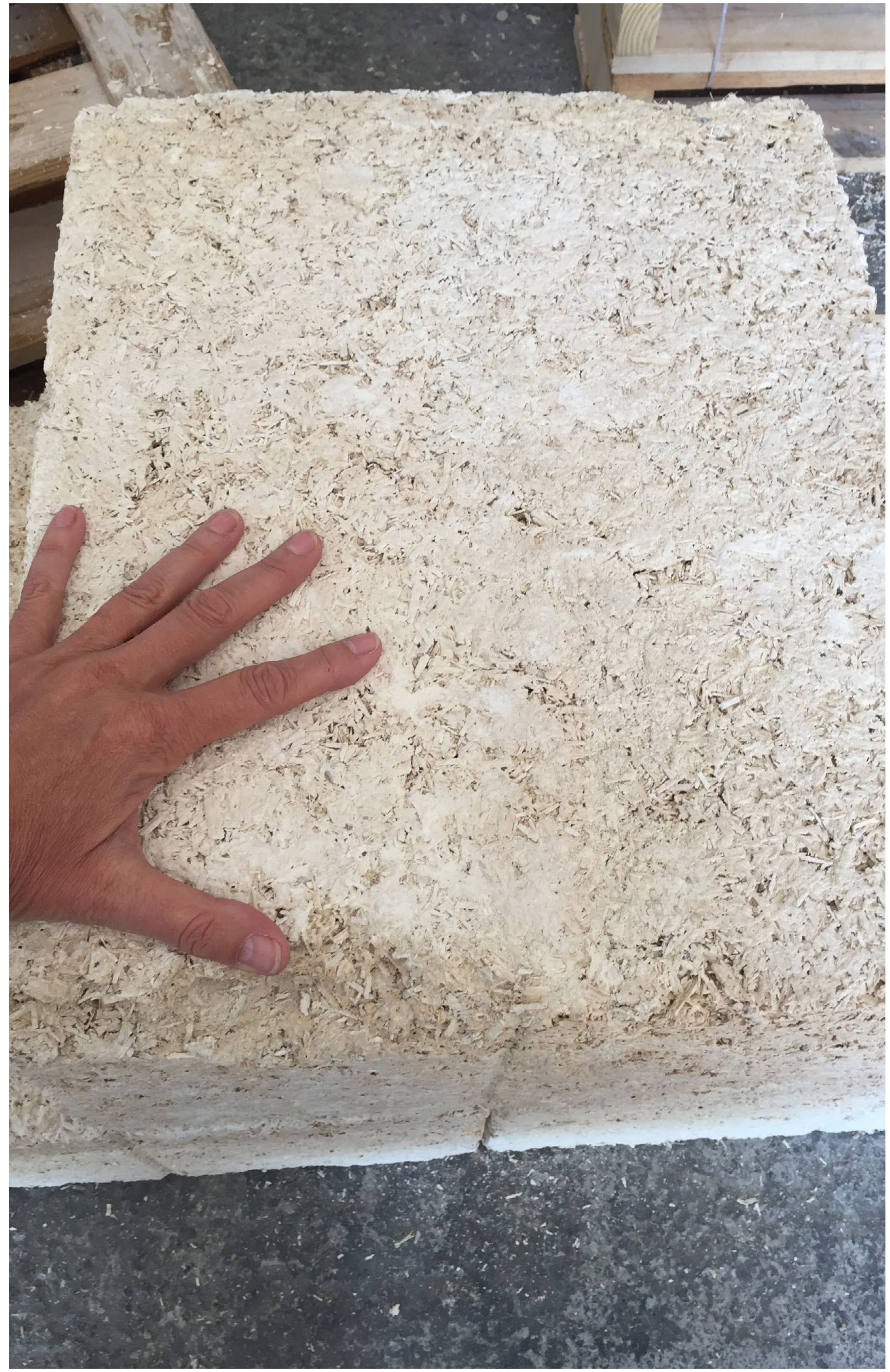


Fig 5.1 Hempcrete Block at Pedone Architects Materials Yard

integrat ed as hempcrete into the building industry, it can produce interiors with superior temperature and moisture control that are highly resistant to mold and rot, have effective acoustics, and act as active carbon-negative structures. Additionally, being an organic material, hempcrete is saved from the landfill as it can be recycled and reused at the end of life.

Properties

Hempcrete is approximately 1/8th the weight of concrete and when incorporated into traditional wall sections has the potential to transform the composition of typical wall construction.[164] Most walls in residential construction are composed of a number of different products. There is an exterior cladding product that may need to be finished (wood clapboard needs to be painted, for example), there is a wood or steel structural frame and bracing to support the wall, a vapor barrier, insulation, an interior gypsum board and painted finish with additional local details to waterproof window/doors, heads, and sills. In a hempcrete construction, the typical materials are reduced to a wood frame, hempcrete panels or blocks, an interior and exterior plastered hempcrete finish, and additional local details to waterproof window/doors, heads, and sills.

With the ability to reduce the number of materials used in a typical wall makeup, hempcrete has the potential to become the predominant material in walls by utilizing its many beneficial properties.

As the predominant material in a wall construction, hempcrete refines the air quality, temperature, and acoustic properties of a space. A versatile material, hempcrete can be made into rigid panels or blocks, as well as produced as bulk or blown-in insulation. While no longer considered hempcrete, a combination of hemp and lime can be used in other contexts at different proportions to create some of the supplemental layers, like lime-hemp plaster used in a hempcrete wall construction. In construction, hempcrete promotes natural/organic wall compositions.

In the years since the second industrial revolution—which marks the start of the chemical industry and petroleum refining and distribution—technology and innovation has incorporated untested chemicals to transform building materials and consumer products.

These products can affect human health not only during their usage, but also through their processing, manufacturing, and all stages of the life cycle.

Chemicals are released from common products, migrate through the environment, and find their way into our bodies. The effects of toxic exposures can depend on a variety of factors, including bodily predispositions, routes of intake, chemical properties, and biological factors. In the landfill, they may release toxic substances into groundwater and surrounding soil. Plastics, for example, are also more combustible and dangerous than natural materials. When combined, these synthetic building materials increase flammability and smoke risk, putting both occupants and first responders at risk of exposure. It is also important to take into account the carbon emissions resulting from both the manufacturing and transportation to and from far locations of synthetic materials, specifically, those used as insulating building products.[165]

Hemp does not cause further degradation of the environment during its cultivation or in use as hempcrete or at the end of its life. The negative impacts on the environment are limited to the production of lime. At the end of life, hempcrete can be reused unlike other products, whereas there are significant costs associated with the disposal of more traditional toxic building materials, some of which like highly fluorinated chemicals (e.g. used to provide stain resistance and nonstick chemicals) have lives measured in geologic time.

Hempcrete has significant thermal properties. In construction hempcrete has the ability to passively regulate internal temperatures, which allows residents to reduce the energy consumed during a building's lifetime. By increasing overall thermal performance, less energy is required to heat and cool buildings in warmer and cooler climates, reducing the use of fuels that contribute to carbon emissions.[166] The building industry could minimize its reliance on fossil fuels and reduce the carbon footprint of the construction industry[167] if hempcrete were used in construction and made from locally sourced raw materials from a renewable source.

By transforming typical construction one structure at a time, hempcrete could transform the construction industry indirectly, slowly severing its dependence on the cement used in concrete. The production of cement has traditionally and continuously been used as a binding material throughout history. Itspervasiveness has caused it to be the largest source of emissions through its process of decomposing carbonates.[168] As the understanding of hempcrete and its many benefits in housing construction become more widespread, cement production could stabilize or decrease as more hempcrete is incorporated into new projects. The cement industry is responsible for 8 percent of global CO2 emissions (Le Quéré et al., 2016, 2017; IPCC, 2006). Additional benefits of Hempcrete occur at a much smaller scale. The use of lime in a hempcrete mix ensures that it will be antimicrobial and antifungal.

Uses

Hempcrete has many possible product applica-
Hempcrete has many possible product applications within a single construction, and products are created typically based on the hemp-to-lime ratio. As an insulation material, Hempcrete can be formed into blocks, placed or packed into a wall, floor, or roof construction. A floor can be finished with hempcrete over insulation with the addition of a higher lime-to-hemp ratio. It can be formed into a hemp insulation of soft bats and placed within structural wall studs. As a product it can be formed into a variety of different shapes as hempcrete blocks or panels, formed and cast based on the structural dimensions of typical wood framing for easy installation. Hempcrete block thickness can also be designed to meet local energy codes requirements and R-values. Hempcrete can be used to frame out openings such as doors and windows with precast hempcrete lintels and jambs. Hempcrete can be used as an exterior and interior wall finish. On the exterior the mixture provides a waterproof layer, though it cannot come into contact with the ground. These different applications are the result of altering the ratio of hurd to lime to water. The more lime the harder the product, the less lime the softer the product.

There are numerous current opportunities to explore product development based on local construction needs, including the dimensional considerations of the US market.

Benefits

The largest benefit of hempcrete is one that not only affects the immediate environment hempcrete is placed in, but the world as a whole, from hemp cultivation to building demolition.

Fig 5.2 Pedone Architects

Fig 5.3 A range of hemp and lime products at Pedone Architects

Hempcrete in construction has the power of carbon sequestration, similar to hemp during cultivation. In cultivation hemp can absorb atmospheric CO2 supporting carbon sequestration via photosynthesis, similar to other plants.[169] Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide, which has been released into the environment through various chemical processes. As hempcrete, the plant material is locked into the buildings fabric, preventing the re-release of carbon back into the atmosphere for the lifespan of a building.[170] This collection of CO2 could contribute to an overall decrease of greenhouse gas in our environment helping to lower the global temperature.

In addition, a simple change to a fundamental building product used in the wall of a typical building is innovative, and combined with the use of intelligent design will result in housing, including affordable housing, that will eliminate exposure to toxicity from other typical building materials. For example, common, inexpensive foam insulation products (like polystyrene or polyisocyanurate) may contain brominated flame retardants, known carcinogens and endocrine disruptors. Bisphenols and phthalates found in vinyl products like flooring and caulking are linked to asthma. By using products based on hempcrete we would still have highly energy efficient buildings but reduce the quantity and range of products made from synthetic chemicals typically used in affordable housing construction and reduce overall toxic exposure. This change is beneficial to the entire building ecosystem.

PRODUCTS & PRODUCTION

Introduction

Hempcrete has a number of applications in both new builds and renovation projects. Dependent on the requirements that must be met, hempcrete can be mixed in various proportions as well as applied in a range of thicknesses to reach desired insulation ratings.

In construction hemp+lime (sometime called hempcrete) can be applied in the following locations: walls, attics or lofts, within floor structures, and in plaster finishes.

The location in the building where hempcrete will be placed will determine the proportions at which the hemp hurd, lime binder, and water are mixed.

Flooring, for example, requires a denser mix, while hempcrete mixtures located in exterior walls benefit from a less compact mix with a multitude of air pockets. Using the same ingredients as hempcrete, one can also make a hemp-lime plaster in which the proportions shift from high hurd content and a fractional amount of lime binder (for hempcrete) to high lime content and minimal hemp for plaster. Water, additionally, becomes a major factor not only for creating the perfect mixture, but also for ensuring the mixture dries in a timely manner.

When considering the production of hemp products, one looks to manufacturers' preferred methods to determine best practices. As a versatile material, the basic mixture of hemp hurd, lime, and water is used across a number of manufacturers to create products such as rigid panels, compact blocks, bulk or blown-in insulation, or used to create plaster-like products. This section will explore the best practices and products that can be used in a typical wood-framed construction.

Fig 6.1

Fig 6.2

Manufacturing Processes & Techniques

Following harvest and a potentially lengthy retting and drying process, hemp hurd is shipped to various manufacturers. Once received, the hemp hurd typically undergoes a number of processes to ready it for the market. The desired final product determines the amount of handling that needs to occur. Producing bags of dry hemp to be mixed on site is the most straightforward approach for using hempcrete if it is to be cast in place or used as a render or finish. Generally speaking, once the hemp hurd is dried it is ready to be packaged. Companies such as IsoHemp sell packaged hemp hurd in 25kg bags. Sold separately, but recommended to purchase at the same time, is a prepackaged lime binder comprised of aerated limestone and hydraulic lime. The proportions of the aerated limestone and hydraulic lime in prepackaged products is considered to be proprietary. Given the information included in the lime section of this book, it should be understood that as a binder lime has a wide range of suitable varieties. There are a number of manufacturers to look to for lime products with a wide spectrum of mix-ins and additives to choose from. Since utilizing dry mixes of hurd and lime requires the most work to be done on site, manufacturing prepackaged bags of each is the extent to which manufacturers are involved in this particular method.

The process of making precast blocks or prefabricated panels is more involved.

Typically speaking, the method for producing units of hempcrete involves four steps. These steps include mixing, moulding, curing, and palletisation.[171]

Mixing hemp hurd, a lime binder and water are mixed at larger quantities at the manufacturer's facility.

Moulding involves placing the wet hempcrete mixtures in molds of specific dimensions and compacting or securing the mixture in a special press. The location in which the hempcrete will sit, as well as the span of each unit, will determine the widths at which the presses hold each mold in place. IsoHemp, when creating hempcrete blocks, places presses at distances to accommodate the creation of molds between 6 and 30 centimeters wide. To create larger spanning panels of hempcrete obviously requires more space and substantially more curing time

Curing allows for hempcrete blocks and panels to harden to a final state. Each unit is removed from its mold and sent to a temporary storage area via conveyor belts. From this point on, the blocks and panels are left to harden in a covered area with exposure to the outside air to the point that they can be handled without falling apart. While manufacturers can vary, companies such as IsoHemp do not utilize any additional heat or energy during the curing process, allowing the units of hempcrete to naturally air dry.

Palletisation, the final step in manufacturing hempcrete blocks and panels is referred to as "palletisation."[172] Palletisation, simply put, refers to the process of placing all units on pallets to await shipment to construction sites. Seemingly straightforward, the difficulty in this step comes from knowing when the correct time is not only to transfer the units to pallets, but additionally how long the units should remain on the pallets until fully hardened. Once again, open-air drying for periods between 6 and 10 weeks depending on the dimensions.

Fig 6.3 Isohemp lime binder

Fig 6.4 Isohemp blocks

Fig 6.5

Accessory Components

Utilizing hempcrete blocks or panels in construction requires the assistance of certain accessory components. While construction methods can widely vary, for the purpose of this publication, we will consider wood frame construction and complementary practices and components, as it is typical in residential construction and works well with lime mortars.

Hempcrete becomes the largest component of a wall structure and requires the assistance of several components including: a natural mortar, hempcrete lintels, metal brackets, and angle irons for spanning openings, fasteners, connecting brackets, and screws.[173]

The use of a lime-based mortar is significant in a structure like this to ensure that the entire construction is natural and nontoxic. Several commonly used adhesives such as polymer-modified mortars often incorporate the use of latex and/or various emulsions that are potentially harmful when released back into the environment. Lime mortars are used to adhere hempcrete blocks and panels to one another in thicknesses of approximately 3mm.[174] Using limestone-based mortars, which benefit from the high plasticity of lime with tools as simple as a mortar comb or trowel, can seal the spaces between hempcrete blocks and panels with little to no negative environmental impact.

Another major accessory component used in conjunction with hempcrete products is the hempcrete lintel. Several manufacturers—including PedoneWorking, a construction and design company located in Italy—produce a product that incorporates the traditional construction of a lintel into a natural design utilizing hempcrete. Reinforced with a concrete core, the lintel is wrapped on two to three sides with hempcrete. Able to span both door and window openings, these hempcrete lintels can be used with the aid of brackets, particularly in two-sided lintels. Brackets act as supplementary supports either used in addition to hempcrete lintels or used in their absence. Metal brackets are ideal for interior renovations when minimal space is available and minimal intervention is desired. Lastly, construction using hempcrete will also incorporate fasteners. Fastener types can be chosen using the expertise of the construction company in employ as long as they are sufficient to tie the hempcrete blocks back to the structural system of the building. Because hempcrete does not act as a structural element, it is necessary to anchor it to a structure so that each component, instead of acting independently, acts as one architectural element. While there are a number of recommended components associated with hempcrete construction, the number of components is still significantly less than the components used in a typical wood frame wall construction in the US.

Fig 6.6 Typical hemp+lime interior wall section

Fig 6.7 Isohemp hemp+lime walls and concrete structure

Fig 6.8 Fasteners

Products

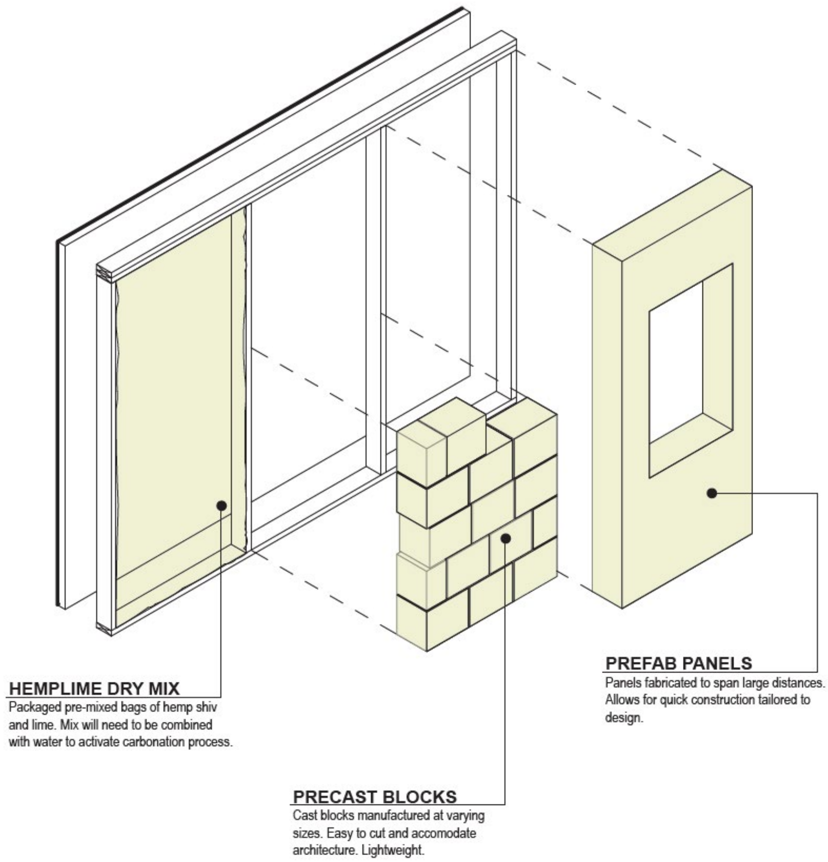


Diagram 6.1 Hemp and Lime Wall Systems

Wall System

There are three major hempcrete applications for construction: on-site mixes, precast hempcrete blocks, and prefabricated hempcrete panels. This guide will focus primarily on the production and use of hempcrete blocks due to the flexibility in construction provided by the creation of modular units. Hempcrete as an insulation material is also a versatile product that can be used in the renovation of existing buildings as well as in providing an alternative insulation product in typical building construction.

Hempcrete Packaged Dry Mix

Mixing hempcrete on-site is one of the more involved methods to incorporate hempcrete into a building construction. Hempcrete manufacturers can provide to site bags ranging between 20 to 25kg of hemp hurd and lime combined or seperate. While the process of mixing seems straightforward, there are many considerations that need to be taken into account when working with hempcrete, especially for the first time.

In general, hempcrete, when mixed on site, is made with concrete pans or mixers. Concrete mixers are sufficient when mixing hempcrete for small projects and can achieve desired results with the use of makeshift tools such as cut wood that can be used to further manipulate the hempcrete to create a consistent mix once removed from the concrete mixer. To begin, the hemp hurd and lime are added to the mixer in proportions suitable for the type of construction currently in process. Secondly, water is added in careful amounts to ensure the mixture will not only achieve the correct density once cured but also allow the mixture to cure in a timely manner. Once appropriate mixes are achieved, the hempcrete is ready to be removed from the concrete mixers and compacted into a building formwork.

As previously stated, the application of hempcrete will determine the ratio at which the three main ingredients that comprise hempcrete are mixed.

For a wall application, the ratio of hurd, lime, and water is typically kept to a 1-to-1.5 to 1.5 ratio or a 1-to-2 to 2 ratio. All hempcrete mixtures are sensitive to both the ratio at which the three elements are mixed, as well as how densely packed the mixture is in any space. The manner in which hempcrete is applied is extremely important when taking into consideration the force at which the components are mixed. The force used to compact hempcrete into a structure can change not only the density but also the insulating ratings of the mixture. Thus, as added security, hempcrete is often used in thicknesses greater than that of typical building constructions in the nine inch to twelve inch range. As a result of the particular nature of the material, the application of hempcrete is something that requires a hands-on approach and personal knowledge of the material.

Depending on its prescribed use (floor, wall, or roof construction), specific mixture ratios are required, however the amount of hemp fiber in these mixtures is often estimated or at least not prescribed in strict measured quantities. Prefabricated blocks, though, help to eliminate some of the guesswork that would typically occur on construction sites. While ratios offer some guidance for hempcrete mixtures, there is a learning curve for working with this particular material.

A secondary element of working with on-site hempcrete mixes is the utilization of formwork. Given the general thicknesses of hempcrete walls, additional formwork is required to support hempcrete as it begins to cure in place. Tied to the structural elements of the building, formwork allows the hempcrete to extend beyond the thicknesses otherwise dictated with the structure, like wood studs in a wall construction. There are various methods one can employ to construct and reuse formwork on site. Slip formwork involves the process of using materials such as plywood boards to form the outer limits of the mass and removing the formwork at the point of shortest curing duration to use the formwork elsewhere. This process, the quickest of all formwork methods, allows for portions of hempcrete construction to dry in place while other portions of the construction are being compacted. Both precast hempcrete blocks and prefabricated panels eliminate the use of formwork on site, at least. Premade units remove the onus of constructing adaptable molds from the construction company and place the onus on the manufacturers.

Precast Hempcrete Blocks

Using some of the same logic as concrete blocks, hempcrete blocks are manufactured by mixing hemp, lime, and water together and casting the mix in desirable dimensions. The use of hempcrete blocks eliminates the unpredictability of hempcrete curing times as they are cast off site and independently of on-site construction. Hempcrete begins as a wet mixture in need of properly allotted drying time, and the use of hempcrete that has been mixed and applied onsite has, in certain cases, slowed or even halted construction due to extensive curing times. Many European countries, for this reason, utilize hempcrete blocks as a way of minimizing the negative potential of curing times from the building equa-

Fig 6.9

Fig 6.10

Fig 6.11 Hemp and lime blocks + mortar, Puglia, Italy

tion and resultantly hastening the construction process. The use of hempcrete blocks ensures that the incorporation of hempcrete into a design does not slow the construction process.

Because using hempcrete in the United States is still considered a new method of construction, the use of hempcrete blocks reduces the amount of time required to become familiar with a new construction material. Shipping hempcrete blocks directly to the construction site eliminates the need for much of the required safety training associated with mixing and compacting wet hempcrete and some of the safety precautions associated with using hydraulic lime on site. There are some comparisons that can be made between hempcrete blocks and concrete blocks, and this can help to bridge the gaps in construction knowledge for those unfamiliar with the material. Hempcrete blocks are laid and tied in a similar fashion to building a wall from concrete blocks. Blocks are placed and coursed between structural members and attached to one another with the use of lime-based mortars. Each course of blocks is staggered, as in a typical masonry system. Hempcrete blocks are lightweight and are both easy to transport by hand and easily cut and manipulated to fit specific conditions.

Hempcrete differs from concrete block construction in the inclusion of organic materials. One needs to take into consideration the fact that hempcrete is an organic element that, when in contact with other organic materials, can undergo chemical change and affect the beneficial properties of the mixture.

Often, concrete is used in underground and foundation construction in hempcrete buildings. Allowing hempcrete to rest on a concrete foundation wall provides the structural integrity needed below ground and the protection from rising moisture above ground. Hempcrete cannot be used in a project absent of adequate structural members. When compared to precast hempcrete panels or poured applications, potential drawbacks to the hempcrete block are that they could impact overall structural density. In comparison to concrete blocks, the use of mortar between hempcrete blocks becomes a cause for concern due to the lack of structural integrity of the blocks themselves. In other words, the adhesive connection between blocks could become a weak point in the wall. However, the thick hempcrete render that is applied to the exterior wall surface helps to stabilize the units, creating a homogeneous strong surface.

There are currently companies working to develop hempcrete building elements that can be considered by code to be structural elements, and a Canadian company, BioFiber, is working towards hempcrete blocks that connect like lego blocks to create a self supporting structural wall.

Prefabricated Wall Systems

Precast hempcrete wall systems provide the quickest installation time of all hempcrete wall assemblies. Cast on or off site, these panelized wall systems can cure separately from the overall building and be set in place when ready. Using this method minimizes drying times of the hempcrete mixture, which has the potential to slow or halt construction on site. Some companies also create standardized panel dimensions to allow for ease of use. The benefits of using precast hempcrete panels include quick assembly times with very little labor requirements and reduced chance of thermal bridging as it fills the entire wall cavity and it is fire-resistant. One of the drawbacks to using precast hemp panels, especially for the United States, is transportation costs for these panels from out-of-country suppliers. This will change as these products become locally produced.

Fig 6.12

Fig 6.13 Prefabricated hemp+lime wall panels, Puglia, Italy

Hemp Insulation

Hemp insulation is a biodegradable, composite material utilizing the fibers of the hemp plant, as opposed to, the hurd. With no chemical binders or potential for VOC off-gassing, hemp insulation is comprised of 88% hemp fibers and 12% polyester fibers bound with a natural adhesive. Together these materials create a vapor-permeable insulation with a U-value of 0.40. The u-value of hemp insulation which classifies it as an effective insulator is comparable to eight inches of fiberglass insulation.

Currently, the drawbacks to using hemp insulation in a project are its cost in comparison to fiberglass and other insulation options and its limited dimensions. At approximately double the cost, hemp insulation is manufactured in semi-rigid sheets and not in rolled form like fiberglass. While typical dimensions of 15-24 inches wide by 48 inches in height can be restrictive for certain projects, hemp insulation can be easily manipulated to fit on-site conditions. In addition, thicknesses of the building material range from 3.5 inches to 8 inches adapting to the depth of the wall frame is it placed. Furthermore, hemp insulation, when saturated with water, only need to be removed and left to dry before being re-installed with no loss of performance. As a natural building material, hemp insulation offers many of the same positive attributes to a project as hemp blocks with even less labor to install.

Hempcrete Plaster + Lime Paint

Building a wall entirely of hemp, lime, and water produces benefits compared to most commonly used building materials in the United States. A hemp-lime wall regulates the moisture content of spaces while preventing mold and mildew. It is the incorporation of additional lime into building materials that enables a hemp-lime mix to be used in typical building elements like exterior walls. Hemp-lime plaster or lime-hemp plaster (both terms can be used interchangeably), is generally comprised of a mixture of hemp fibers,

Fig 6.14 Hemp insulation

Fig 6.15 Masonry block and hemp and lime insulation

high-calcium lime (lime putty), and the optional addition of pozzolans.

Essential to the construction of hempcrete insulated walls, hemp-lime plaster has multiple functions.

Given the often rough texture of dry hempcrete, hemp-lime plaster is typically used to smooth the exterior surfaces of the hempcrete. The proportions of ingredients in hemp-lime plaster, in comparison to hempcrete, varies by increasing the amount of lime in the mixture and substituting hemp hurd for hemp fibers. In addition, the amount of water used varies between hemp components, including hempcrete, hemp-lime plaster, and lime paints/lime washes. Lime paints, which act as the finishing material for hempcrete interior walls, incorporate the most water into the mixture. A combination of lime putty and water, lime paints rely on the water to thin out the lime putty, which would be too thick to spread as a finishing material. The addition of water allows for the paint to be spread with even consistency.

It is difficult to compare water requirements between hempcrete and hemp-lime plaster given the other variations in ingredients. As a smoother textured material, hemp-lime plaster benefits from the switch to hemp fibers instead of hurd, the inclusion of pozzolans that increase the strength of the bond between fibers, and water content, which is most often determined while mixing to achieve a smooth composition. Hemp-lime plaster, when dry, resembles a conventional stucco surface. When finished with lime paint, the entirety of a hempcrete assembly is not only comprised predominantly of organic matter, but it also has the feel of a natural environment with few to no artificial materials. Furthermore, acting as a finishing material, the plaster provides a secondary layer for the hempcrete without jeopardizing its many positive qualities. The lime within the plaster acts as a sealant for the hempcrete as its high plasticity seals the dry hempcrete and protects it from moisture both on the interior and exterior while still enabling the entire wall assembly to breath. It is the inclusion of lime that allows hempcrete to be used as an exterior material without the need for a more traditional rainscreen like brick, for example.

Fig 6.16 Hemp and lime plaster

Fig 6.17 Application of hemp and lime plaster

Safety Precautions

Mixing wet hempcrete on site requires the most extensive safety training of all hempcrete applications. Since hempcrete involves the use of hydrated lime, a caustic material, protective goggles, gloves, and masks are prescribed elements to have available on site.[175] The use of these safety materials reduces the chances of chemical burns to the skin and/or eyes and the harmful inhalation of lime particles into the lungs.

Building Code + Material Specifications

One of the biggest hurdles facing hempcrete and its usage in the United States is the lack of industry knowledge about the material. In Europe, fire testing (one to two hours based on block thickness) has been performed to ensure that hempcrete in wall construction will not contribute flammable materials during a fire. Other tests have been performed to determine the structural properties of hempcrete. While hempcrete does have some minimal structural properties, it is not considered to be a structural material. Hempcrete is an organic mixture, so there are certain inconsistencies that are hard to plan for. A hempcrete wall must be approximately +/- 12" to achieve its desired insulation level. The process of packing hempcrete in place can change its insulation properties. Too compact and the mixture will decrease in R-value, but not compact enough and the potentially oversized construction may increase the price unnecessarily.

CONSTRUCTION

Construction with Hemp
Affordable Housing in Rural Communities

Construction with Hemp and Affordable Housing

Construction with Hemp

Using hemp and lime on exterior walls in construction fundamentally changes building practice. The inclusion of hempcrete leads to an entirely new wall assembly and the elimination of several material layers found in typical wall construction in the United States. Hempcrete eliminates the need for insulation like foam or batt insulation with their added flame retardants, exterior cladding materials, vapor barrier and interior wall boards and finishes. The simplification of the system reduces the complexity of a wall, reduces cost as fewer layers need to be installed, and reduces the amount of embodied carbon in the wall.

In major cities all across the globe, pollution is a real threat. Be it sound, light, or air pollution, as populations continue to grow globally, these forms of pollution are likely to increase outside the urban environment. Global warming, or climate change, is the increase in the average temperature of the Earth's atmosphere caused by the collection of greenhouse gases.[176] Greenhouse gases—including water vapor, carbon dioxide, methane and ozone—are commonly produced from the burning of fossil fuels, which is done to "manufacture products, power our cars and trucks, or to create the energy to heat and cool the homes we live in and the buildings we work in."[177] A significant percentage of these environmentally harmful gases are emitted as a result of human activity that has a disproportionate effect on certain populations. As discussed earlier in this publication, people living in fenceline communities tend to experience poor air quality, high levels of sound pollution, and—for those living in affordable housing—infrequent maintenance of homes, which can result in a plethora of health issues. Architecture has the ability to address some of these issues before they occur. Incorporating industrial hemp into the built environment increases the transparency of material content in the building process and reduces unnecessary chemical content. Additionally, the potential for carbon-storing buildings can help combat climate change.[178]

The two most common exterior residential wall types in the United States are a brick veneer system, where the bricks act as a rainscreen, and a wood clapboard system.

The thickness of both exterior brick walls and wood clapboard can vary depending on the structural components that comprise the wall such as concrete block or wood or metal studs. The structural members within the wall are one of the key elements determining whether the wall will act as a thermal mass that regulates temperature in interiors. If the elements of a wall have low thermal mass, then additional layers of insulation are required. The interdepence of each element in both brick veneer walls and clapboard siding enables the walls to meet state and international building energy codes.

There are no fewer than nine individual elements in a brick or wood siding exterior wall. Each element, when brought together, shields the interior from the elements and keeps the interior dry. In addition to the brick veneer, other elements regulate moisture levels in and through the assembly and provide the strength and structure of the wall. The typical elements that comprise a brick rainscreen wall include brick veneer, brick ties, an air space or air cavity, weep holes, air vents, structural members, plywood sheathing, shelf-angles, insulation, air/moisture barrier, and flashing.

Fig 7.1 Structure using blown hemp+lime

Fig 7.2 Near Ketchum, Italy

Fig 7.3 Blown system for cast in place hemp+lime construction

For an exterior wall using clapboard siding, the typical elements include the wood siding attached using a starter strip and nails, structural members, plywood sheathing, shelf angles, insulation, air/moisture barrier, and flashing. In both cases the interior is finished with gypsum board, primer, and paint.

When a typical wall such as a brick rainscreen is replaced by a hempcrete construction, there is a simplification and significant decrease in number of elements that comprise a wall. This reduction in elements creates transparency of construction. With transparency, there is a clearer focus on easily identified healthy building materials and the potential for simplified deconstruction and reuse.

Utilizing hemp construction has the potential to reduce the number of materials comprising a singular structure, therefore creating a straightforward method of construction and possibly lowering the cost associated with building affordable housing. In a wall construction that uses hemp block, there are few additional construction materials. There are certain elements of typical construction that are transferable in hemp wall assemblies. These items include structural members, as hemp blocks are not considered structural elements, thru-wall flashing, end dams, and mortar.

In comparison to a typical brick wall assembly (see diagram), a hemp wall can reduce the quantity of elements in the construction by at least half.

This includes eliminating the need for a rainscreen and its attachments, including brick and brick ties, an air cavity, an air/moisture barrier, sheathing, and an interior wall covering. The components of a hemp wall are hemp and lime blocks, hemp/lime plaster, and lime paint. Hemp and lime mixtures of different densities and proportions comprise roughly 90% of the wall assembly.

There are conditions specific to hemp construction. For example, given hemp's ability to absorb and moderate moisture in the air, hemp mixtures are required to be elevated above the ground plane. This can be achieved by placing the industrial hemp mix on a foundation wall of concrete blocks or reinforced concrete. In a wall construction using blocks comprised of hurd, lime, and water, what is essentially being created is a thermal mass.

Exterior walls, according to building codes, must meet specific performance requirements. These requirements include moisture control, insulating capabilities, fire resistance, and air-tightness. To perform these tasks, certain building elements are described to meet performance criteria of the code or codes. With hemp construction many of these elements are eliminated because hemp is capable of performing these tasks alone. Elements such as foam insulation, air/moisture barriers, and solid exterior cladding are no longer necessary in hemp construction.

When reviewing the International Building Code (IBC) there are specific code standards that need to be addressed or rewritten to ensure that hempcrete conforms to the code. The following codes need to considered: R703 Exterior Wall Covering and N1104.2 Insulation Materials. In addition, hemp structures must meet specified fire-resistance criteria as it is detailed in Section 703 and 704 of the IBC, with special attention paid to Section 703.5, which deals with the noncombustibility of elementary and composite materials. R703 Exterior Wall Covering dictates the weather-resistance of the building envelope including water, wind-resistant, and flashing to remove any water that penetrates the outermost layer.[179] The use of lime plays an important role when addressing the concerns that need to be met by standard R703. Lime plaster on the exterior face of the hemp and lime mixture is weather and water resistant. The chemical properties and pH levels of lime allow its interaction with water to be one that can moderate moisture levels. Similar to Portland Cement Plaster, Lime plaster eliminates the need for elements such as air cavities and drainage mats, for example, which would facilitate in removing any collection of water beyond the exterior face.[180] With the inclusion of lime in the hemp mixture, a hemp exterior wall is capable of reducing a considerable number of layers. Furthermore, since the lime is able to moderate moisture levels through the assembly, interior to exterior, there is a need to eliminate any barriers that would prohibit this through-wall travel such as plywood sheathing and air/moisture barriers. This is important to note because typical brick or wood clapboard assemblies require air/moisture barriers to perform the exact opposite function of a hemp wall. Since there is no layer in a typical exterior wall assembly that is capable of absorbing moisture, the next best action these walls can perform is to stop the water once it is inside the assembly and redirect it back to the exterior. Hemp assemblies are not only preventative but also proactive in the dynamic handling of water and moisture.

Code standard R402.1.2 Insulation and Fenestration Criteria specifies the minimum R-values a building's thermal envelope must meet by climate zone. An R-value, also known as thermal resistance, is the inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area.[181] The many counties of New York State, for example, range in Climate Zone from 4A to 6A, including many in the 5A climate zone.[182] The required minimum R-Value for these zones for a wood frame wall is R-20.[183] At 14 inches thick, hemp insulation can achieve an R-Value of R-28, which exceeds the minimum value specified in this portion of the code.[184] While typical insulation materials such as foam insulation can exist within exterior walls at much thinner thicknesses, these materials are not only contributing to the increase in greenhouse gases in their manufacture but also prevent the wall from being "breathable." Foam insulations also contain large amounts of toxic flame retardants that migrate into interior spaces.

Exterior walls are required to meet certain fire-resistance standards. Typically, walls must meet a one- to three-hour rating. When a fire occurs, a wall must not lose structural integrity or combust for a minimum of one to three hours, depending on the overall design and program of the building, allowing inhabitants to safely exit a building. According to European testing facilities, hemp wall assemblies at 300 millimeters or 12 inches thick, can withstand flames without combusting for one hour and 40 minutes.[185] As this test was performed, it was noted that the mortar between hemp blocks failed before the blocks themselves.[186]

Hemp mixes satisfy the performance requirements currently handled by a multitude of layers in a typical wall assembly. With this the relative amount of embodied carbon in a singular structure is reduced. Architecture 2030, a nonprofit and nonpartisan independent organization that formed in 2002 to develop strategies and solutions to combat climate change, points to embodied carbon as an often overlooked and invisible quality of the built environment. "Unlike operational carbon emissions, which can be reduced over time with building energy efficiency renovations and the use of renewable energy, embodied carbon emissions are locked in place as soon as a building is built. It is critical that we get a handle on embodied carbon now if we hope to phase out fossil fuel emissions by the year 2050.[187] On average, a typical brick exterior wall can have an embodied carbon content of 34.7 kgCO2/kg, while a hemp wall assembly is roughly 10.4 kgCO2/kg. As hemp and lime absorb carbon dioxide over the course of its lifespan, it will be a useful tool in reaching the goals set out by Architecture 2030.

Fig 7.4 Floor fabrication

Typical Brick Veneer and Wood Frame Wall Assembly

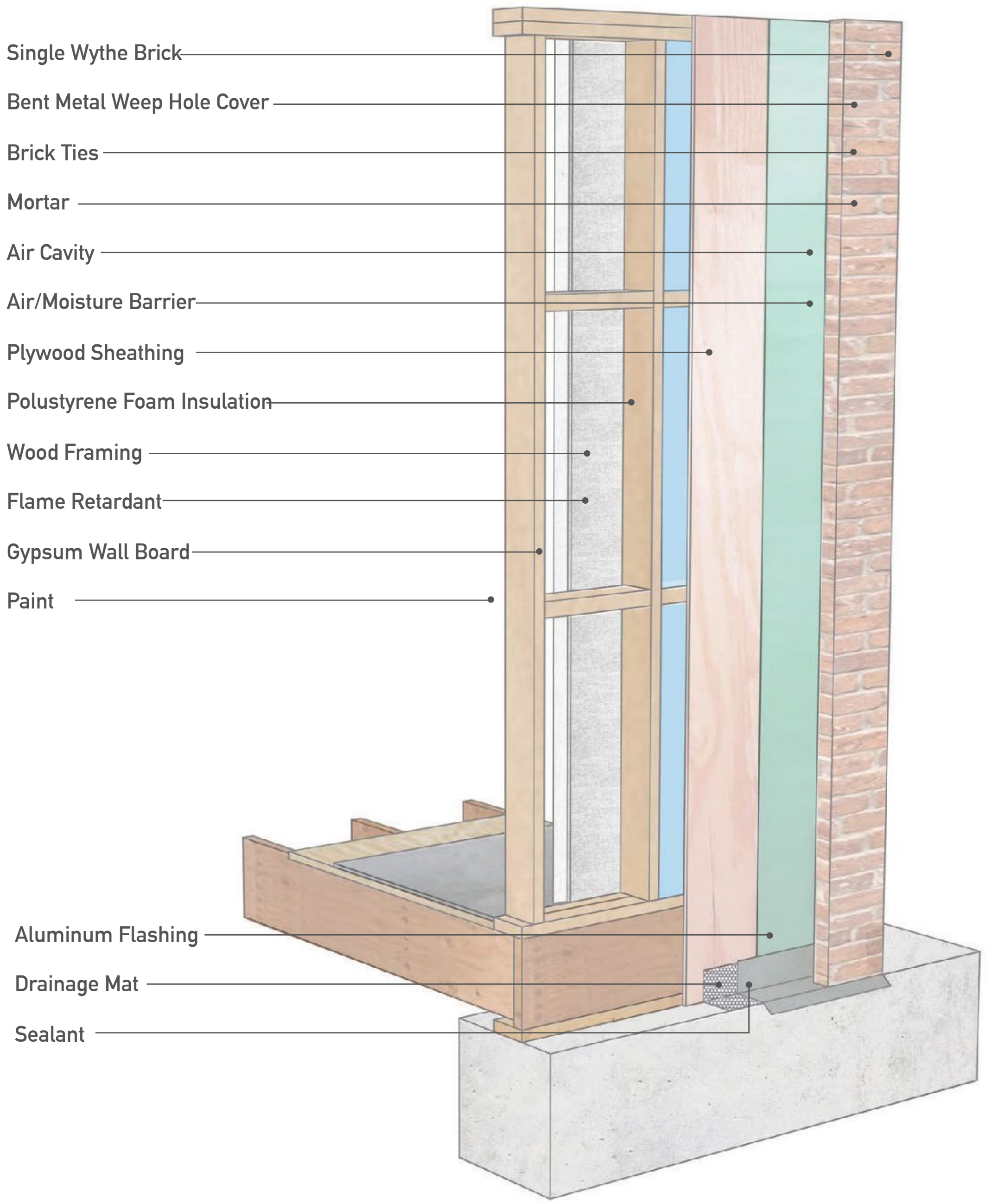


Diagram 7.2 Brick Venee Wall Section

BRICK RAINSCREEN	
MATERIALS	EMBODIED CARBON (kgCO2/kg)
Wood Framing	0.59
Flame Retardant	(See Note 1)
Interior Paint (Single Coat)	0.44
Gypsum Wall Board	0.13 (See Note 2)
Polystyrene Foam Insulation	3.43
Plywood Sheathing	0.681
Air/Moisture (Polyethylene)	2.54
Single Wythe Brick	0.45
Mortar	0.2
Brick Ties (Electrogalvanized Steel)	3.03
Drainage Mat (Nylon Plastic Filament)	9.14
Sealant (Epoxide Resin)	5.7
Aluminum Flashing	5.65
Weep Hole Cover (Steel, Hot-Dip Galvanized Steel)	2.76
TOTAL = 34.7 kgCO2/kg	

Table 7.1 Embodied Carbon Brick Rainscreen Wall System

Typical Wood Clapboard and Wood Frame Assembly

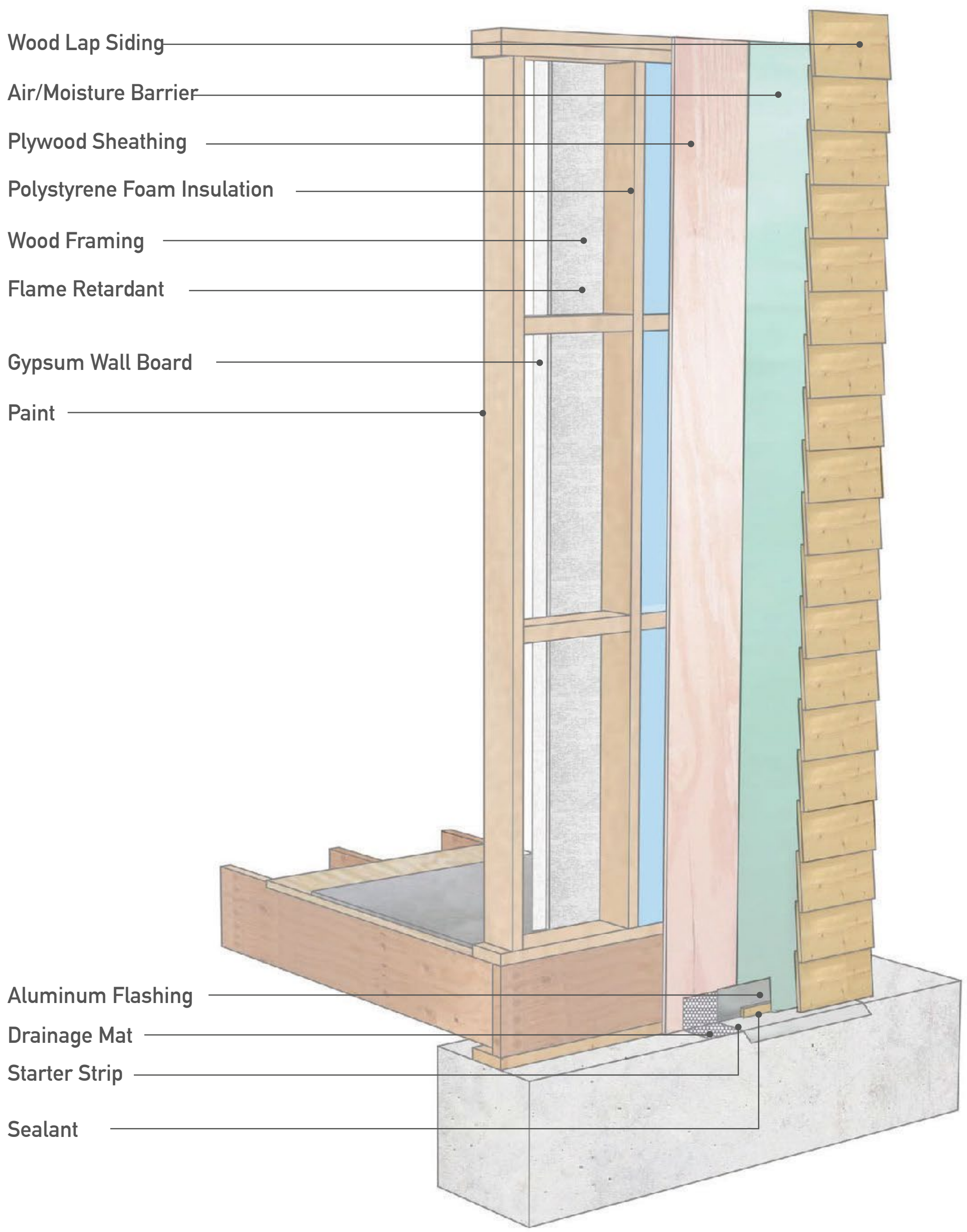


Diagram 7.2 Wood Clapboard Wall Section

WOOD CLAPBOARD (LAP SIDING)	
MATERIALS	EMBODIED CARBON (kgCO2/kg)
Wood Framing	0.59
Flame Retardant	(See Note 1)
Interior Paint (Single Coat)	0.44
Gypsum Wall Board	0.13 (See Note 2)
Polystyrene Foam Insulation	3.43
Plywood Sheathing	0.681
Air/Moisture (Polyethylen)	2.54
Lap Siding (Softwood)	0.263
Starter Strip (Plywood)	0.45
Drainage Mat (Nylon Plastic Filament)	9.14
Sealant (Epoxide Resin)	5.7
Alunminum Flashing	5.65
TOTAL = 34.7 kgCO2/kg	

Table 7.2 Embodied Carbon Wood Clapboard Wall System

Hempcrete Block and Wood Frame Assembly

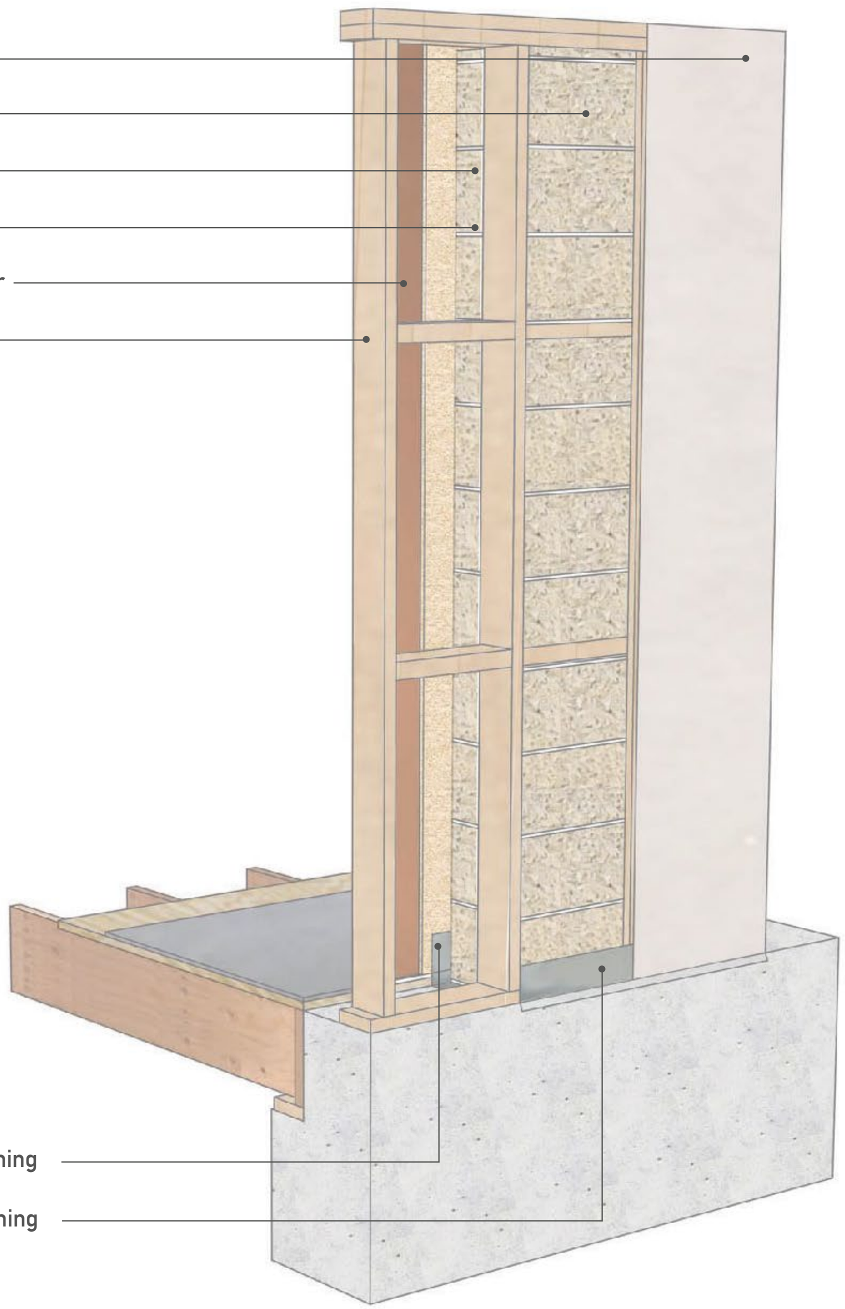


Diagram 7.5 Hemp+Lime Wall Section

HEMP + LIME	
MATERIALS	EMBODIED CARBON (kgCO2/kg)
Wood Framing	0.59
Flame Retardant	(See Note 1)
Lime Paint	0.86 (See Note 3)
Lime Plaster	0.174
Hempcrete	-2.73
Mortar	0.133
Sealant (Epoxide Resin)	5.7
Aluminum Flashing	5.65
TOTAL = 10.4 kgCO2/kg	

Table 7.3 Embodied Carbon Hemp+Lime Wall System

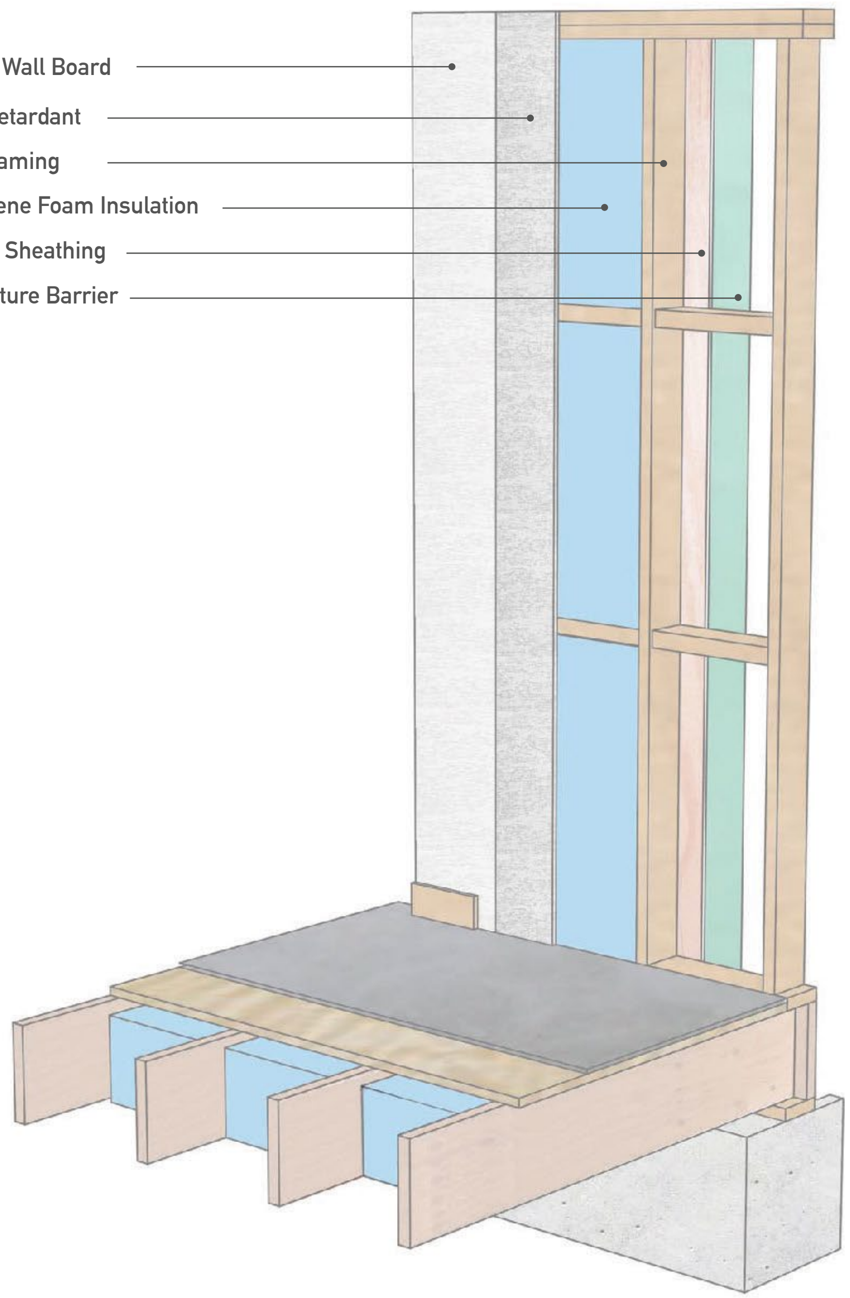


Diagram 7.3 Interior of Brick Veneer/Wood Clapboard Wall Section

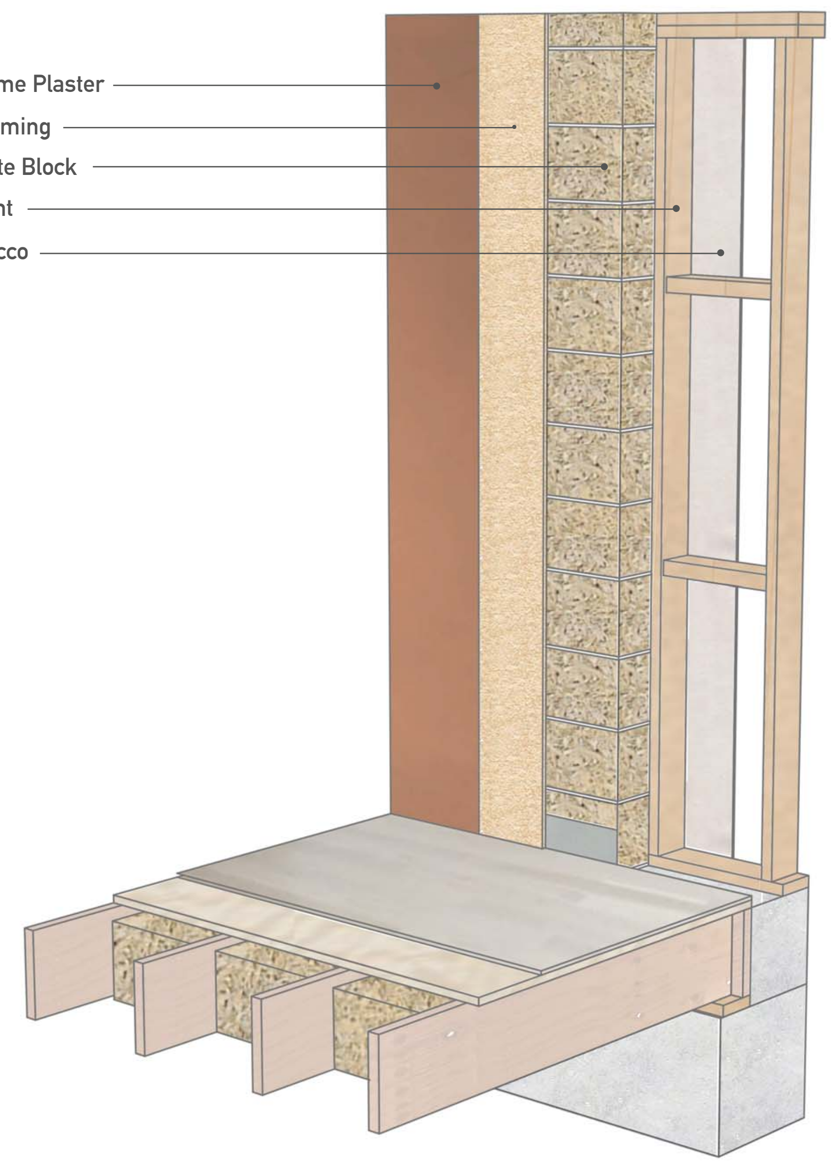


Diagram 7.4 Interior of Hemp+Lime Wall Section

Comparison Table of Embodied Carbon of Building Wall Systems

EMBODIED CARBON (KGCO2 PER KG)	BRICK RAINSCREEN	WOOD CLAPBOARD (LAP SIDING)	HEMP + LIME
Wood Framing[1]			
Flame Retardent			
Interior Paint (Single Coat)			
Gypsum Wall Board			
Hemp			
Polystyrene Foam Insulation* (General Purpose Polystyrene)			
Plywood Sheathing			
Air/Moisture Barrier (General Polyethylene)			
Brick (single)			
Mortar (1:3 cement: sand mix)			
Mortar (1:2:9 Cement: Lime: Sand Mix)			
Wood Lap Siding			
Starter Strip (Plywood)			
Brick Ties (Electrogalvanized Steel)			
Drainage Mat (Nylon Plastic) Filament			
Lime			
Sealant (Epoxide Resin)			
Aluminum Flashing (North American)			
Weep Hole Cover (Steel, hot-dip galvanizd steel)			
Water			
Total Embodied Carbon =	34.7 kg CO2 per kg	28.9 kg CO2 per kg	10.4 kg CO2 per kg

Table 7.4 Embodied Carbon of Building Wall Systems

Affordable Housing in Rural Communities

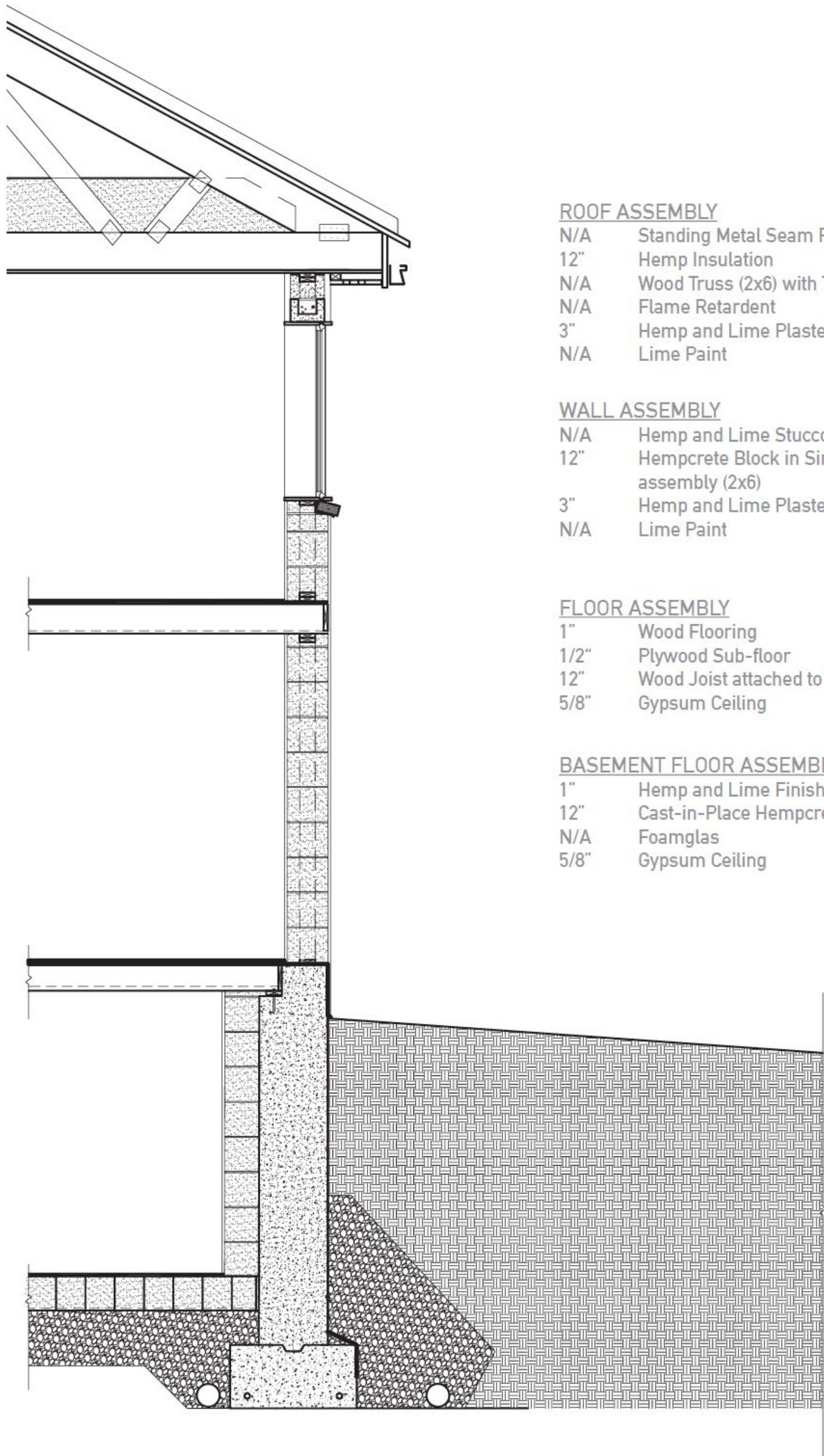
While urban communities receive the majority of focus when discussing affordable housing, access to affordable and healthy living conditions is a significant concern in rural communities across the country where there are high levels of homelessness. As homelessness continues to increase due to rising rent costs and the minimal construction of new affordable housing, there becomes a pressing requirement to transform the way we address basic housing needs.[188]

A household that pays 30% or more of their income on housing costs is considered to be burdened.[189] Outside of the New York Metropolitan area, the percent of households paying over 30 percent of their income on housing or rent does not drop below 46% and is as high as 52.7% in certain counties.[190] Major cities outside of New York Metro have populations severely burdened by their inability to pay for housing. This creates vulnerable populations even when homelessness is avoided.

With approximately 3 million renters across the state of New York and 59% of all households in upstate New York being rented, tenants are at risk of not only rent hikes, but of predatory landlords.[191192] Through preferential rent loopholes, landlords have been able to significantly increase the cost of rent for those looking to potentially renew current leases.[193] In addition to unethical tactics used to coerce people out of their homes, like refusing basic maintenance, landlords have preyed upon low-income communities to the financial and physical detriment of the tenants.

Neglected and poor living conditions and high rent burdens (rents above 60% of tenant income exist in locations such as Rochester, New York) can create a severe financial strain on families and the community.[194] When one considers that poor housing conditions equates to poor health, communities with limited access to health care facilities cannot afford to live in such conditions. The New York State Nurses Association claims 68% of all hospitals outside the New York City metropolitan area are affiliated with at least one other hospital,"[195] for their own ensured survival. Additionally, hospitals such as Adirondack Medical Center are transitioning to part-time emergency department residents, and visitors are forced to travel seventeen miles for emergency overnight service.[196] What this means in terms of location is that those living in rural areas experience a higher health risk when considering distance to the nearest health care facility.

It is now time to consider consider the lives of all residents in designing the sustainable housing of the future. Construction that utilizes industrial hemp hurd and lime has the potential to transform both the construction industry in the United States and shape new equitable communities in which building materials reflect the best interests of all the inhabitants and the environment. Introducing a new crop to rural communities will require adaptation and support within the existing agro-economy/industry. But it also provides communities with new jobs and the potential for new trades. Adaptation and industry and trade support will ensure that a clear path for commerce exists for industrial hemp. A new market for industrial hemp products and new hemp crop production for local farmers where they can individually and collectively compete within the economy provides new opportunities to revitalize rural communities regeneratively and sustainably.



ROOF ASSEMBLY

N/A	Standing Metal Seam Roof
12"	Hemp Insulation
N/A	Wood Truss (2x6) with Truss Ties
N/A	Flame Retardent
3"	Hemp and Lime Plaster
N/A	Lime Paint

WALL ASSEMBLY

N/A	Hemp and Lime Stucco
12"	Hempcrete Block in Single-Stud assembly (2x6)
3"	Hemp and Lime Plaster
N/A	Lime Paint

FLOOR ASSEMBLY

1"	Wood Flooring
1/2"	Plywood Sub-floor
12"	Wood Joist attached to Wood Frame
5/8"	Gypsum Ceiling

BASEMENT FLOOR ASSEMBLY

1"	Hemp and Lime Finish Flooring
12"	Cast-in-Place Hempcrete
N/A	Foamglas
5/8"	Gypsum Ceiling

DOOR DETAIL

N/A	Hemp and Lime Stucco
8"	Hempcrete in Single-Stud Wood assembly (2x6)
1"	Hemp and Lime Plaster
N/A	Lime Paint

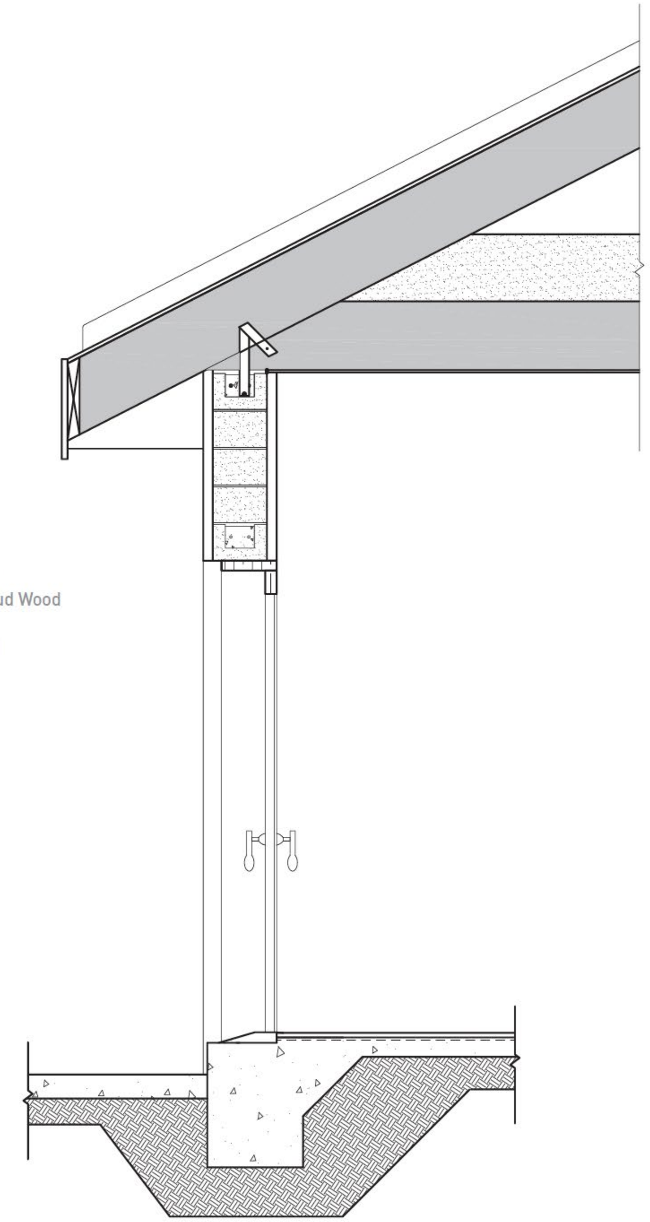
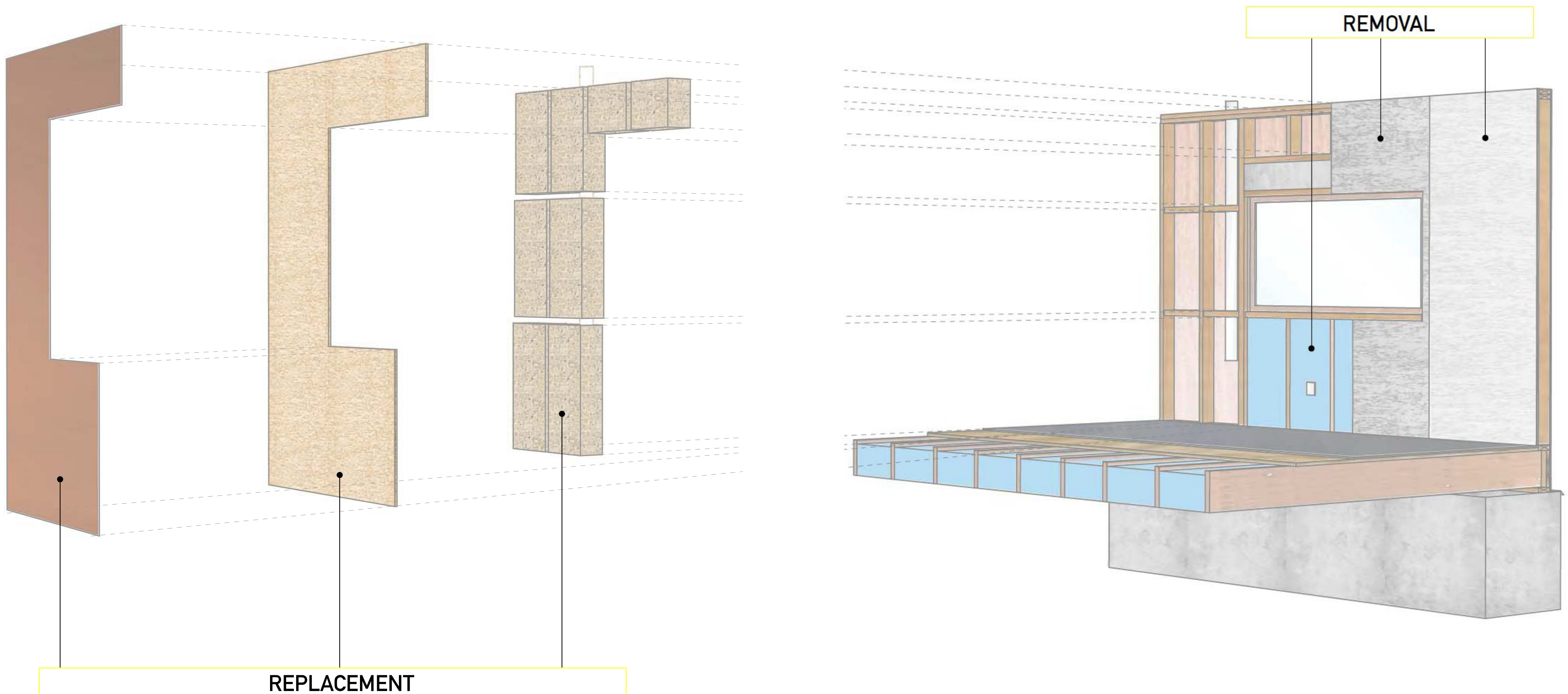


Diagram 7.6 Typical Wall Section: Hemp+Lime Construction

Hemp Renovation Axon



CASE STUDIES

Casa di Luce
Marks & Spencer: Cheshire Oaks Retail Store
Ein Hod
Push House
The Hemp House
Guilleminlaan
Clay Flelds
Douvaine Renovation
Nakamura Family Residence
The Rediscovery Center
Suffolk Park Studio

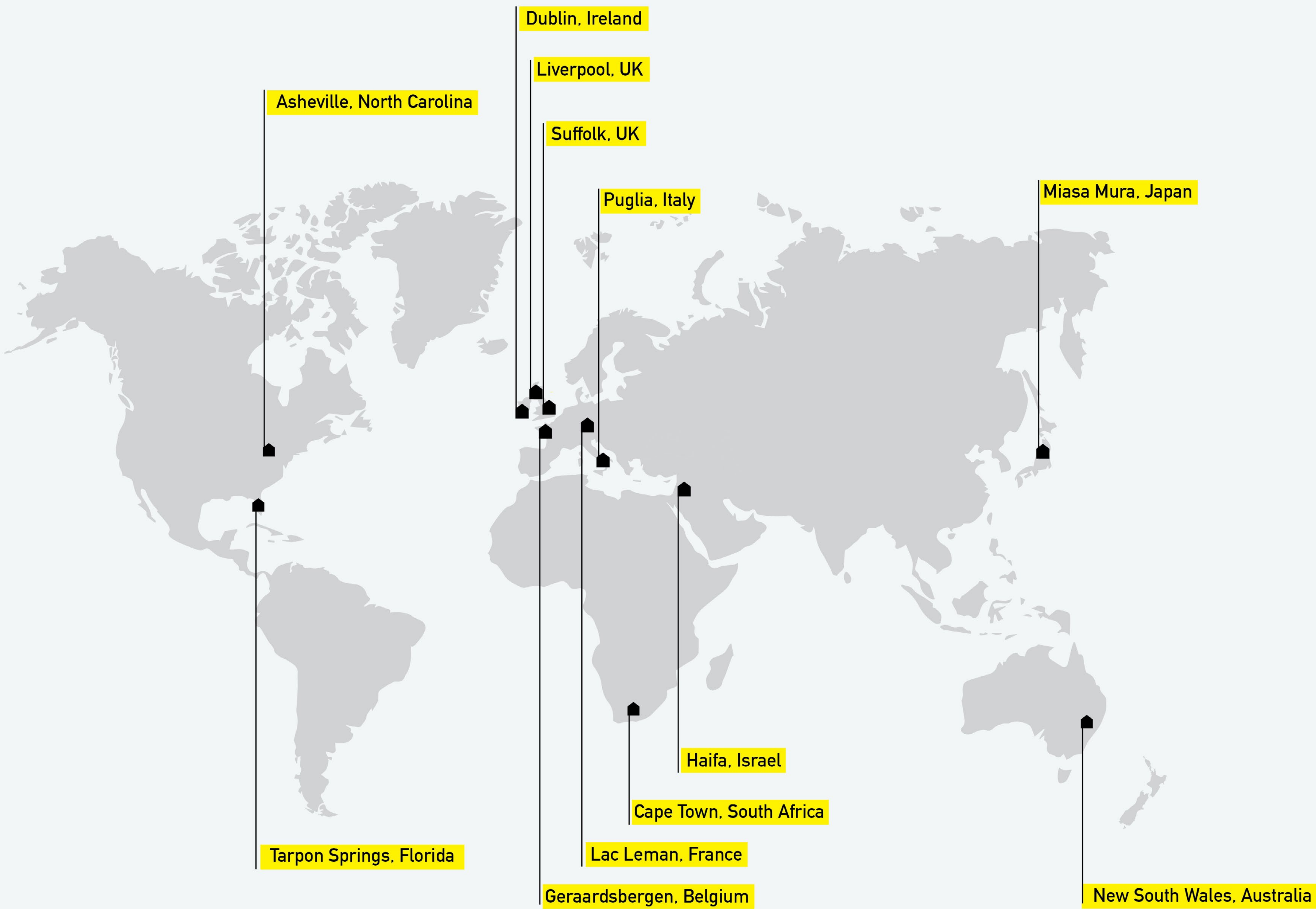


Diagram 8.1 World Map of Case Studies

Casa di Luce

Fig 8.1 Casa di Luce by Pedone Working, Italy

Fig 8.2 Casa di Luce by Pedone Working, Italy

Design by: Pedone Working
Location: Puglia, Italy
Completed: 2016
Size: 42 homes; 5 floors; sqm not available
Main Points:
Uses Natural Beton® hemp and lime mix 60 kg of CO_2 from atmosphere for every 1 m3 of material heating by heat pump and casing, highly performing from a thermal, acoustic and hygrometric point of view as completely natural in hemp and lime, natural raw materials with low consumption production and environmental impact close to zero.

Construction method sped up construction time and effectively reduced energy requirements

Marks and Spencer

Cheshire Oaks Retail Store

Fig 8.3 Marks and Spencer retail store by Aukett Fitzroy Robinson, Liverpool, UK

Design by: Aukett Fitzroy Robinson
Location: Liverpool, UK
Completed: 2017
Size: 210,000ft2

Main Points:
Uses Hemclad® external wall panels
U-value of 0.12W/m2.K and saving around 360T of CO2 emissions.
Wall panels partially sunken into ground and surrounded by earth mounding
"These features assist in keeping a stable temperature by improving the building's insulation resulting in the store losing less than 1°C of heat overnight compared to 9°C in other store environments."
"...predicted to be 42% more energy efficient and 40% more carbon efficient than a peer store."
Construction waste was 0%

Lime used in foundations reduced the amount of required concrete by 25%

Ein Hod

Design by: Tav Group
Location: Haifa, Israel
Completed: 2017
Size: 250 sq. meters

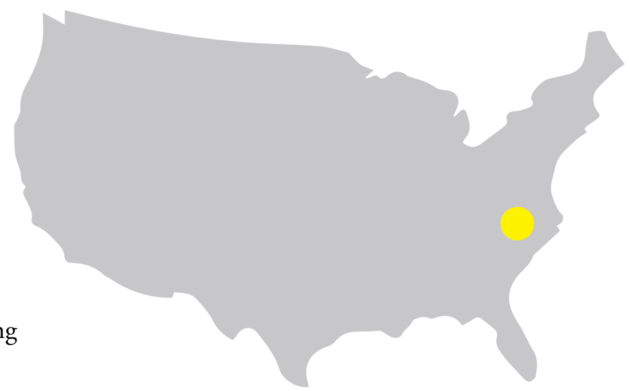
Main Points:
"An eco-minded home for artists"
Locally excavated stone used in construction of lower level walls
Hempcrete used with wood framing (upper levels)
Interior walls (where insulation requirements are less stringent) are comprised of rammed earth
Lime plasters used externally and earth based plasters used internally
Concrete used as minimally as possible

Fig 8.4 Ein Wood house by Tav Group, Haifa, Israel

Push House

Fig 8.5 Push House by Push Design, North Carolina, US

Design by: Push Design
Location: Asheville, North Carolina
Completed: 2010
Size: 3,400 sq. meters



Main Points:
Hempcrete mixed on-site and poured into a system of exterior supporting studs in lifts
Interior walls constructed using a product called Purepanel which consists of a corrugated paper core

A heat pump is used to handle additional heating and cooling demands

Cost $133 per sqft to build

The Hemp House

Design by: Tony Budden and Duncan Parker (Hemporium) + Erwin van der Weerd (Perfect Places)
Location: Cape Town, South Africa
Completed: 2012
Size: 187 sq. meters

Main Points:
Modular system for exterior walls: 4-layer hemp panels used, 4 layers of panel include: magnesium oxide (mgo) panels, foil membrane, and (2) layers of hemp insulation

Panels take approximately 2.5 weeks to make Magnesium oxide is exported from South Africa to China, where the panels are made, and shipped back making this process inefficient in this respect

'Our electricity bill was only R450 per month in winter, as only one wall-mounted heater was necessary to heat the whole house' - Tony Budden

Interior walls are built using hemp screed: a mix combined with water on site
Tiles were used in areas hemp screed is not suitable (kitchen and bathroom)
Wall thickness around 20cm and are said to "keep cool in summer and warm in winter"
Durable, water-resistant and non-toxic paint used; Paint to be re-touched every 4-5 years
The house cost about R7, 500/m2 to build; R10, 500/m2 with finishes,which compares favourably with building costs in Tony's neighbourhood of about R12, 000 to R15, 000/m2.

Fig 8.6 The Hemp House by Tony Budden and Duncan Parker, Cape Town, South Africa

Guilleminlaan

Design by: Martens Van Caimere Architecten
Location: Geraardsbergen , Belgium
Completed: 2015
Size: Information not available

Main Points:
Wooden boards used for formwork and hempcrete poured in layer by layer
Steel wiring adds additional strength to load-bearing walls "In the 1950s, 60s and 70s, Belgians were building houses that were badly or not insulated. So renovating these houses in a sustainable way tends to be expensive. Hempcrete combines the insulation and finishing in one layer, reducing building costs."
Hemp-based render improves structure's resistance to weathering
A hempcrete garden wall encloses the property
A wood-burning stove is used to offset heating demands in the winter, as well as, providing hot water

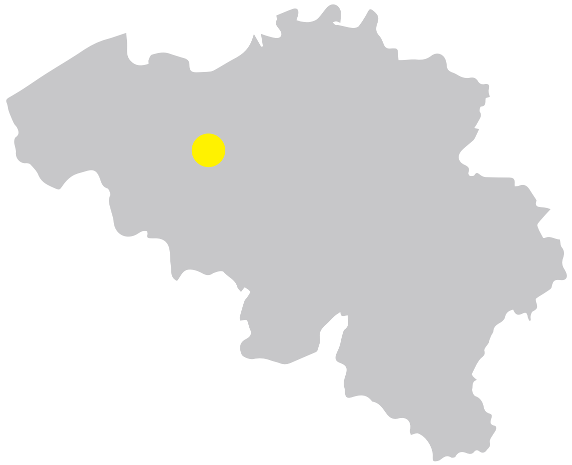


Fig 8.7 Guilleminlan by Martens Van Caimere Architecten, Geraardsbergen, Belgium

Clay Flelds

Fig 8.8 Clay Flelds by Riches Hawley Mikhail, Suffolk, UK

Design by: Riches Hawley Mikhail
Location: Suffolk, UK
Completed: 2008
Size: 26 homes; sqm not available

Main Points:
Uses a spray-on method to apply hempcrete

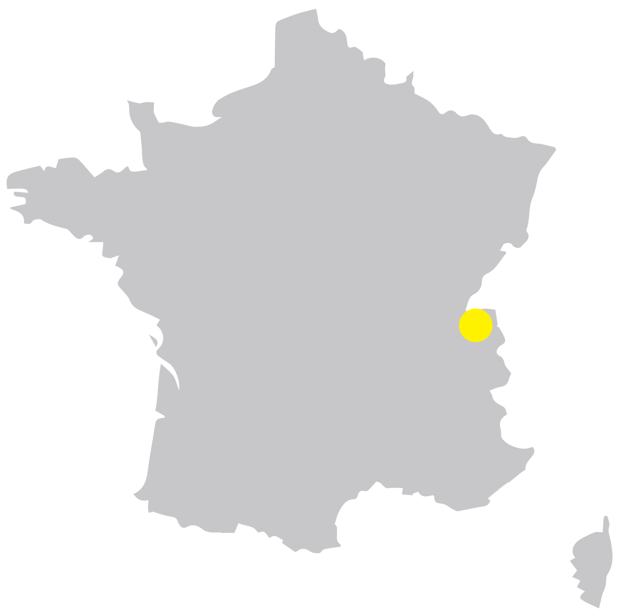
Optimizes use of locally-sourced materials
Boiler used in conjunction with biomass system provides heat for all dwellings
Exterior clad with wooden weatherboards
"...high quality, low carbon homes without any 'greenwash' or highly visible environmental interventions."

Douvaine Renovation

Fig 8.9 Douvaine Renovation by FRAR, Lac Léman, France

Design by: FRAR
Location: Lac Léman, France
Completed: 2015
Size: Information not available

Main Points:
Stone and hemp-based plaster, left exposed, achieves desired insulation ratings "We never intended to plaster the whole thing inside like some newly built apartments, although the temptation was there because the stone walls were so poorly built,"



Nakamura Family Residence

Design by:
Location: Miasa Mura, Japan
Completed: 1698
Size:

Main Points:
The Nakamura Family Residence, made predominantly out of hemp is one of the earliest examples of hemp based construction. Now considered a Japanese national heritage site, the 300 year old hemp house, uses the hemp plant in a multitude of ways not commonly used today.

Utilizing wooden beams as the structure, hemp ropes were used to bind the beams with the trusses of the roof and hold them in place. Hemp stalks were then used throughout the design in a number of ways. Stacked piles of hemp stalk would be layered on top of the roof beams and trimmed to length to form the exterior of the thatched roof. Hemp stalks, referred to as asagara were also used to form the interior wall surfaces. Bound together to create a mat of hemp stalks, the asagara created a wall surface with a vertical texture. Within the wall, hemp bundles doubled as insulation, similar to the way in which hemp insulation is used today. With several areas of the house used to process the hemp, many spaces also doubled as informal storage spaces for hem suchas up within the roof structure.

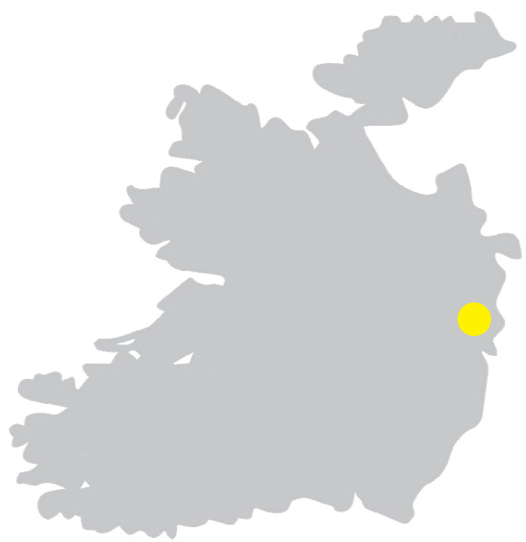
Fig 8.10 Nakamura Family Residence by Nakamura Family, Miasa Mura, Japan

The Rediscovery Center

Fig 8.11 The Rediscovery Center by The Rediscovery Center, Dublin, Ireland

,
Design by: The Rediscovery Center
Location: Dublin, Ireland
Completed: 2016
Size: Information not available

Main Points:
3.6 million euro in funding following a campaign by members of the centre and the Dublin City Council "It was inspiring to see hempcrete being used on such a massive scale in a project involving a local authority and local community." "The aim was to repurpose the building as a prototype '3d textbook' a novel concept in experiential learning which capitalizes upon the educational value within the built, natural and cultural environment." The building won the National Green Construction Award' in 2017 and the SEAI's Green Building award in 2018



Suffolk Park Studio

Design by: Nikki Mote
Location: New South Wales, Australia
Completed: 2014
Size: 58 mt² Studio

Main Points:

Joel and Danni Turner, with Danni's sister, Nikki Mote, an architect based in Freshwater, Australia, experimented with hempcrete for a compact studio. Nikki designed the studio and Joel, who is an environment scientist built it.

The compact 58-square-metre studio has a hempcrete base and a lightweight timber box on top.

The studio was built with a lot of recycled materials-including timber cladding and feature doors, as well as timber doors from the owner mum's house.

Fig 8.12 Suffolk Park Studio by Nikki Mote, New South Wales, Australia

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Diagrams

Diagram 1.1

Diagram 2.1

Diagram 2.2

Diagram 3.1

Diagram 4.3

Diagram 4.1

Diagram 4.2

Diagram 4.3
Diagram 4.4
Diagram 1.3
Diagram 6.1

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