THE CARBON STORY OF

CELLULOSE INSULATION

NOVEMBER 2023

BUILDERS FOR CLIMATE ACTION

CIMA
Naturally Better Insulation

Table of Contents

About the Cellulose Insulation Manufacturers Association (CIMA)

The Cellulose Insulation Manufacturers Association (CIMA) is an association of cellulose insulation producers and trade affiliated members in Canada and the United States. CIMA's mission is to "ensure the highest quality cellulose insulation products and standards." CIMA was formed in 1992 as a result of the restructuring of the Cellulose Industry Standards Enforcement Program. As a trade organization, CIMA provides information and educational resources to members, regulatory officials, industry professionals, and homeowners.

www.cellulose.org

About Builders for Climate Action (BfCA)

Builders for Climate Action (BfCA) is a non-profit organization working with builders, designers, developers, policy-makers, researchers and manufacturers to tackle the serious impact of buildings on our climate and work toward real zero carbon buildings.

We want to offer future generations our best efforts to reign in the worst effects of climate change through smart, coordinated and effective action to address emissions in the sector while building a world that is just and equitable.

www.buildersforclimateaction.org

Citation

Megan Nedzinski, Mélanie Trottier, and Chris Magwood, *The Carbon Story of Cellulose Insulation*, Builders for Climate Action, 2023.

Purpose

Understanding that carbon emission reductions within the built environment are a key strategy for mitigating climate change, CIMA sought to understand the challenges, benefits, and opportunities that exist within the insulation industry to accelerate carbon emission reductions.

In 2023, in service to its mission, CIMA hired BfCA to conduct research to investigate these questions and to produce a report describing the findings for trade partners, material producers, government agencies, and policymakers.

The Climate Context

The production of building materials is responsible for approximately six percent of total fossil fuel emissions in the US,[1] amounting to approximately 370 million metric tonnes (408 million US tons), and a comparable proportion in Canada. The US and Canadian federal governments have strongly signaled that curbing emissions that arise from the production of building materials – commonly called "embodied carbon" – will be a priority of government projects in the near term and will be addressed by regulations in the coming decade. The US General Services Administration, the largest constructor in the country, has committed to a 20 percent reduction in embodied carbon beginning in 2023[2] and published a roadmap for achieving zero embodied carbon by 2050.[3] A number of US states have introduced Buy Clean legislation, obliging state-funded construction projects to procure materials with lower embodied carbon.[4] The Canada Green Buildings Strategy commits the federal government to achieving 30 percent reductions in embodied carbon in government projects by 2025 and calls for the development of "model building codes for measuring, reporting and reducing the embodied carbon of building materials."[5]

In addition to strong action from governments, a broad cohort of architects, engineers, developers, homebuilders, and real estate companies have made commitments to dramatically reduce embodied carbon between now and 2050. Clearly, manufacturers of building materials need to understand how their products rate on embodied carbon to remain competitive in a low-carbon marketplace.

Beyond reductions in emissions, it is becoming evident that carbon dioxide (CO_2) removal strategies are required to meet the pathways outlined by the Intergovernmental Panel on Climate Change (IPCC), shifting atmospheric carbon back into storage to tip the scales back toward a more balanced whole.

This report examines the potential for cellulose insulation to meet today's requirements for low-carbon insulation products while also offering meaningful opportunities for carbon storage in line with CO_2 removal targets.

«In the building industry, **embodied carbon** refers to the greenhouse gas emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of building materials.»

-Carbon Leadership Forum

Operational and Embodied Carbon Emissions

Until recently, all efforts to reduce emissions from the building sector focused on operational emissions that arise from heating, cooling, and powering buildings. Building owners, design professionals, builders, and policymakers have been promoting energy efficiency as a means to reduce these operational carbon emissions. The Inflation Reduction Act[6] in the US and the Canada Greener Homes Initiative[7] provide substantial incentives to reduce operational emissions by improving energy efficiency in existing and new homes. Adding insulation to the roof, walls, and floors of buildings is a leading strategy in energy efficiency efforts, and cellulose insulation is widely used in this context.

It is becoming clear that embodied carbon from building material production must be considered alongside efforts to reduce operating emissions. Reducing embodied carbon through material selection can be "the most impactful intervention at the individual building level"[8] for the first 5-50 years in the lifespan of a new home in North America. Strategies that enable the construction and renovation of highly energy efficient buildings using very low-embodied carbon materials will be the win-win required to stay aligned with climate targets.

This win-win scenario is possible to achieve today. A comprehensive study[9] in 2021 reviewed three different residential archetypes in five Canadian cities and found that material-related emissions can be reduced dramatically without changing the building design or sacrificing improvements in operational performance. All of the best-case scenarios in this study use bio-based insulation materials that provide carbon storage in the building, with cellulose insulation a leading material selection for its combination of thermal performance and net carbon storage.

Embodied Carbon and Growth in the Construction Sector

There is approximately 97 billion square feet of existing commercial space,[10] and 244 billion square feet of residential space[11] in the US. Eighty percent of this space, or approximately 273 billion square feet, are expected to remain in service through the next 30 years and much of it will require additional insulation to meet climate targets.[12]

In addition to the need to improve the performance of existing buildings, approximately 6 billion square feet of new construction is built each year in the US and 600 million in Canada. This implies continued increases in the amount of building insulation being manufactured to keep up with this demand. The embodied carbon effects of creating all this new insulation material will be substantial, and minimizing these emissions is necessary to avoid increasing the embodied carbon footprint while attempting to reduce the operational footprint of our existing and new building stock.

The Time Value of Carbon

There is a growing understanding about the scale of embodied carbon in construction and its critical climate effect due to the "time value of carbon emissions."[13] The embodied carbon emissions that result from material production occur "upfront" or at the outset of a project while any operational reductions due to improved performance are realized gradually over the lifespan of the building. Immediate emissions reductions have better climate outcomes than equivalent emissions reductions that happen over a longer time period.[14]

The time value of carbon is further increased if building materials are able to provide "negative emissions." As determined by the IPCC, "limiting warming to 1.5 degrees Celsius will require removing carbon from the atmosphere in addition to reducing emissions."

So while increased building performance is a critical part of the strategy to reduce carbon emissions, operational reductions alone are not enough to reach the global emissions reductions targets set forth by the Paris Agreement and the GHG emissions reductions commitments of the US and Canada. In the next 5-7 years, insulation materials that reduce operational emissions, avoid embodied carbon emissions, and store carbon are paramount to making a significant impact on the carbon emissions of buildings. Fortunately, all three of these requirements are characteristics of cellulose insulation.

Embodied Carbon and Insulation in New Homes and Retrofits

Insulation is a major contributor to embodied carbon emissions. Three recent studies of materials used in the structure, enclosure, and partitions of new homes found that after concrete, insulation was the second largest emitting product category, representing between 15-26% of total emissions.[15]

Embodied Carbon Emissions from New Homes by Material Category

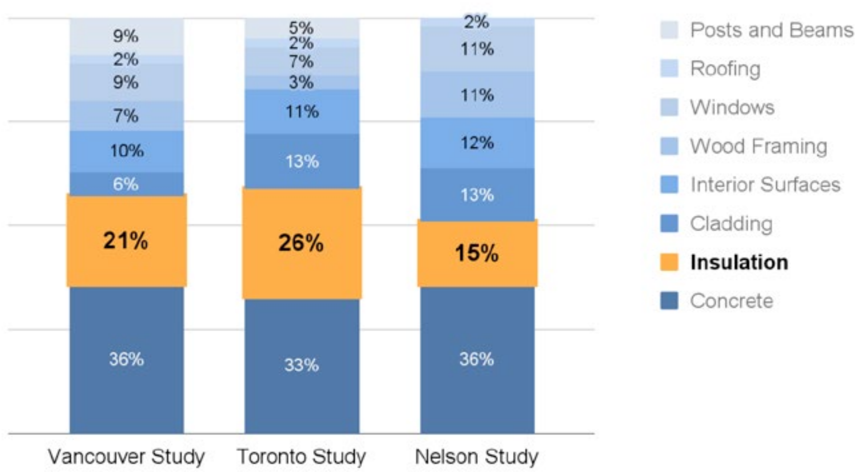


Figure 1 Emissions from home construction based on 550 as-built homes from studies by Builders for Climate Action in 2021-2022

For energy efficiency retrofits, insulation products represent an even more significant portion of the overall embodied carbon because new insulation is a high volume addition among the smaller number of new materials added to a retrofitted building.

These substantial contributions from insulation products emphasize the importance on reducing the embodied carbon of insulation moving forward. The materials for new home construction in the US contribute approximately 55 million metric tonnes (60 million US tons) of greenhouse gas emissions annually.[16] Assuming that 15-26% of this total may be attributed to insulation, the current mix of insulation products for new homes alone contribute 8-14 million metric tonnes (9-15 US tons) of emissions annually in the US, which is equivalent to the GHG emissions from 2-3.5 coal-fired power plants each year.[17] Adding emissions for all the insulation used in retrofits would increase embodied carbon substantially, though there is currently no reliable data indicating the extent of insulation use in retrofits.

Understanding Embodied Carbon from Insulation Products

Builders, homeowners, and designers have numerous insulation materials to choose from when considering new construction or renovation work. Many factors have traditionally been weighed when selecting insulation, including cost, availability of materials and installers, and crucial building science factors [See Sidebar: Co-benefits of Cellulose Insulation]. All must be considered and balanced to achieve the desired thermal performance.

To this list, considerations of embodied carbon must now be added. The range of embodied carbon is wider for insulation materials than any other category of building materials. Figure 2 below shows a comparison of 1 square foot of insulation products at an R-value of 20 and demonstrates that emissions factors vary by orders of magnitude.

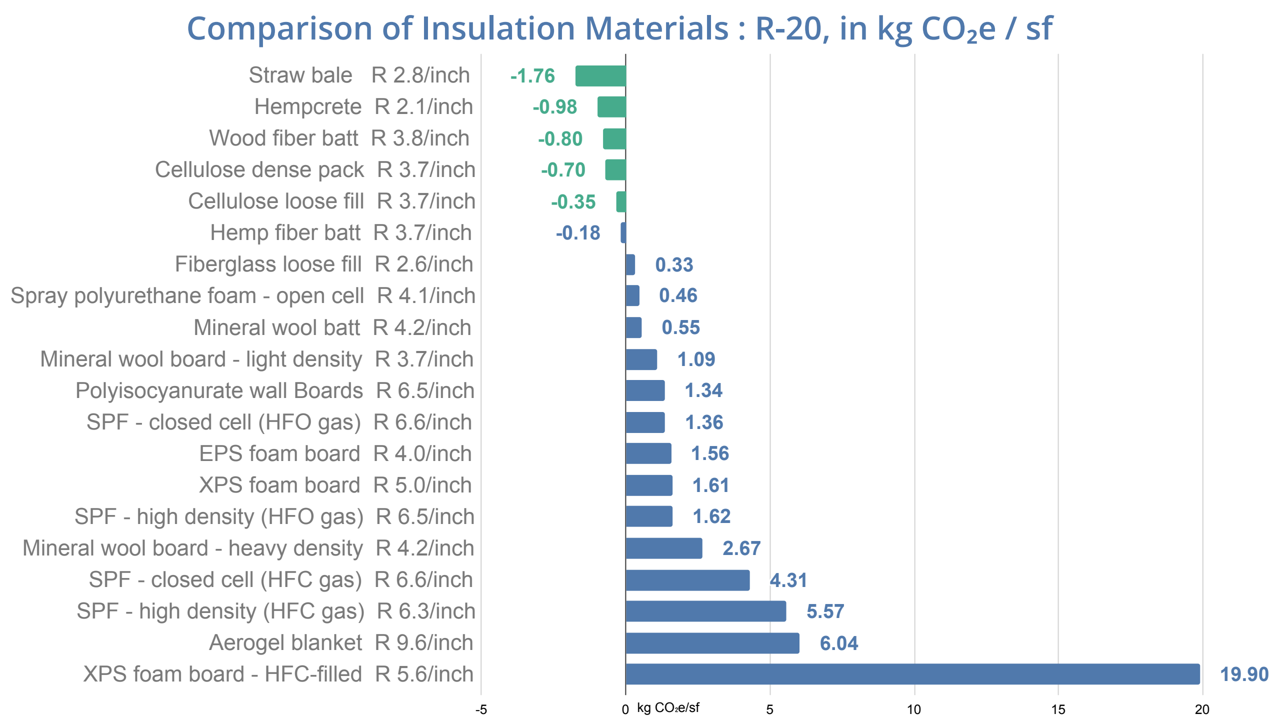


Figure 2 BEAM comparison of insulation materials at R-20, in kg CO_2e/sf

Embodied carbon comparisons of this sort are now possible due to the creation of Environmental Product Declarations (EPDs), which are transparency documents that report on environmental consequences using an ISO-standardized methodology.[18] The Global Warming Potential (GWP) of building products can be determined using EPDs. For insulation materials, most EPDs cover the complete life cycle (cradle to grave) and report environmental impacts for the same R-value achieved over the same surface area.

Viewed this way using EPD data, insulation choices can clearly have a very large effect on embodied carbon emissions. Using insulation products with low embodied carbon will result in a short offsetting period before the operational emission improvements are realized, whereas products with high embodied carbon could negate the positive outcomes of insulation use for longer periods of time, up to seven years for deep energy retrofits.[19]

Cellulose Insulation and Net Carbon Storage

Figure 2 shows a unique result for cellulose insulation in which there is a negative number for embodied carbon. This indicates there is more carbon stored in the material than was emitted in manufacturing. From an embodied carbon perspective, this is considered a "negative emission" or "carbon storage" and means that there is a climate benefit to the material rather than an undesired consequence. This notion can seem counterintuitive. What is happening with cellulose insulation that creates net carbon storage?

Cellulose insulation is made from fibers that primarily include recycled paper and cardboard fibers shredded finely (containing up to 85% recycled content)[20] to provide a matrix to create tiny air pockets that greatly reduce heat flow. These fibers are plant-based and were created via photosynthesis when the source trees were growing. During photosynthesis, trees draw carbon dioxide out of the atmosphere and store it as carbon atoms, releasing the oxygen back to the atmosphere. Approximately 50 percent of the weight of softwood paper fiber is carbon that came from the atmosphere. As a waste stream material, the carbon stored in paper fibers would be released back to the atmosphere as CO_2 if the waste is burned or sent to landfill (landfill emissions also include methane, a more potent GHG), but using this material in buildings prevents the return of the stored carbon to the atmosphere for many decades, resulting in less CO_2 concentration. In the case of cellulose insulation, this carbon storage volume is greater than the emissions required to manufacture the product. If the carbon storage is larger than the production emissions, the product has net carbon storage.

The practice of using cellulose and cellulosic fibers for building insulation dates back many centuries in the US and Canada.[21] Industrially manufactured products were introduced in the 1950s and cellulose insulation has remained a widely available, affordable, and accessible material ever since.

There are three common methods for using cellulose in building insulation applications: loose fill, spray-applied, and dense-pack,[22] offering flexibility unmatched by most insulation counterparts.

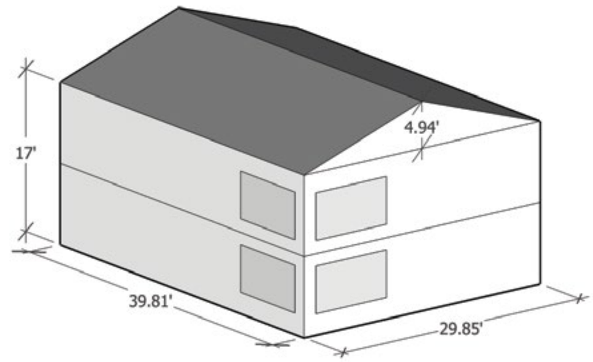


Cellulose Insulation Compared to Competitors in the DOE Model Home

Recognizing that insulation products have very different climate effects, from high emissions down to net carbon storage, it is valuable to understand what that means for emissions in a construction project. The US Department of Energy (DOE) Model Home is used to explore the emissions for a range of common insulation materials to make this comparison.

The DOE prototype home assumes a slab-on-grade foundation with 30-foot by 40-foot exterior dimensions on two levels, each 8'-6" tall and including one standard size window per floor per each building aspect. Insulation areas were derived from these dimensions for the comparison.

US DOE Model Slab-on-grade
Two stories above grade, 2x6 framed wall



Roof insulation area : **1188 ft²**

Exterior wall insulation area : **2021 ft²**
*Excludes window area

Total floor area : **2377 ft²**

Figure 3 US DOE model home inputs for BEAM software

To be sure the comparisons are functionally equivalent, the wall and roof insulation areas for the DOE Model Home are given the R-value requirements from building codes for three different US and Canadian climate zones (one warm and two cold zones), as shown in Figure 4. The requirements for cavity insulation are used for this comparison, but continuous insulation (ci) is not factored into the results, as cellulose insulation is not applicable for this use.

R-Value Reference for Models

	US R-Value according to IECC 2021, Table R402.2.3		**Canada** Typical nominal insulation to achieve effective requirements of Section 9.36. NBC 2020.
	Zone 3	Zone 5	Zone 7A
Wall	**20**	**20**+5ci	**20**+5ci
Roof	**49**	**60**	**60**

Figure 4 US and Canadian code required insulation levels for zones 3, 5, and 7A.

The Building Emissions Accounting for Materials (BEAM) Analysis Software

The authors used the Building Emissions Accounting for Materials (BEAM) software developed by BfCA to perform the embodied carbon analysis for wall and roof cavity insulation. The BEAM tool uses both industry-average and product-specific EPDs which "quantify environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function."[23] For this comparison, industry-average data was used or product-specific data was averaged to create a

"BEAM average" to best represent the emissions of different material categories. In addition to carbon emissions data, for products like cellulose with biogenic carbon content, BEAM also includes carbon storage values in its results.[24]

For the wall cavities, 2x6 wall framing was assumed. Calculated R-values for each of the materials assumed a completely filled cavity or 3-inch installation lifts of spray foam insulation until the requisite R-20 code value is reached or the cavity is filled. Each of these assumptions represent common practice to meet code minimum insulation values. This results in a slight difference in final wall R-value for some products (see Figure 5).

For the roof insulation, an unobstructed cavity was assumed, as would be the case in a flat attic condition. The appropriate volume of each type of insulation required to meet the thermal performance was used to make the embodied carbon comparisons equal regardless of material thickness. R-value per inch comes from manufacturer declarations and is indicated in Figure 5.

Insulation Comparison for DOE Model Home

			US - Zone 3		US - Zone 5		CANADA - Zone 7	
	MATERIAL	R / inch	NET EMISSIONS (kg CO_2e)	R-Value Input	NET EMISSIONS (kg CO_2e)	R-Value Input	NET EMISSIONS (kg CO_2e)	R-Value Input
WALL CAVITY INSULATION	Cellulose dense pack - CIMA	3.7	-1,405	20	Same as US-Zone 3		Same as US-Zone 3	
	Emisions / Storage		644 / -2,049					
	Fiberglass batt [BEAM Avg]	3.6	444	20				
	Spray polyurethane foam - Open Cell	4.1	1,080	23*				
	Mineral wool batt [BEAM Avg]	4.2	1,289	23*				
	Spray polyurethane foam - Closed Cell (HFO gas)	6.6	2,751	20				
	Spray polyurethane foam - Closed Cell (HFC gas)	6.6	8,703	20				
ROOF CAVITY INSULATION	Cellulose loose fill - CIMA	3.7	-1,012	49	-1,239	60	-1,239	60
	Emisions / Storage		464 / -1,476		568 / -1,807		568 / -1,807	
	Fiberglass loose fill [BEAM Avg]	2.6	953	49	1,167	60	1,167	60
	Spray polyurethane foam - Open Cell	4.1	1,352	49	1,656	60	1,656	60
	Mineral wool loose fill - NAIMA	3	1,486	49	1,819	60	1,819	60
	Spray polyurethane foam - Closed Cell (HFO gas)	6.6	3,962	49	4,852	60	4,852	60
	Spray polyurethane foam - Closed Cell (HFC gas)	6.6	12,534	49	15,348	60	15,348	60

*For a 2x6 framed wall cavity

Figure 5 Results of BEAM comparison for three climate zones in the US and Canada.

Cellulose insulation stands out as having significantly lower – in fact, negative – embodied carbon emissions at installation compared to all other insulation types. In the case of wall cavity insulation cellulose offers approximately 130% less emissions than the next lowest option (fiberglass batt) and nearly 720% lower than the highest emitting option (SPF closed cell foam with HFC blowing agent).

Figure 6 presents a closer look at embodied carbon emissions when comparing cellulose with other insulation materials. When totalling the emissions from both wall and roof insulation for climate zone 5, cellulose offers net storage of 2,644 kilograms of carbon dioxide equivalent (kg CO_2e) while its closest competitor emits 1,611 kg CO_2e and its worst competitor results in 24,052 kg CO_2e.

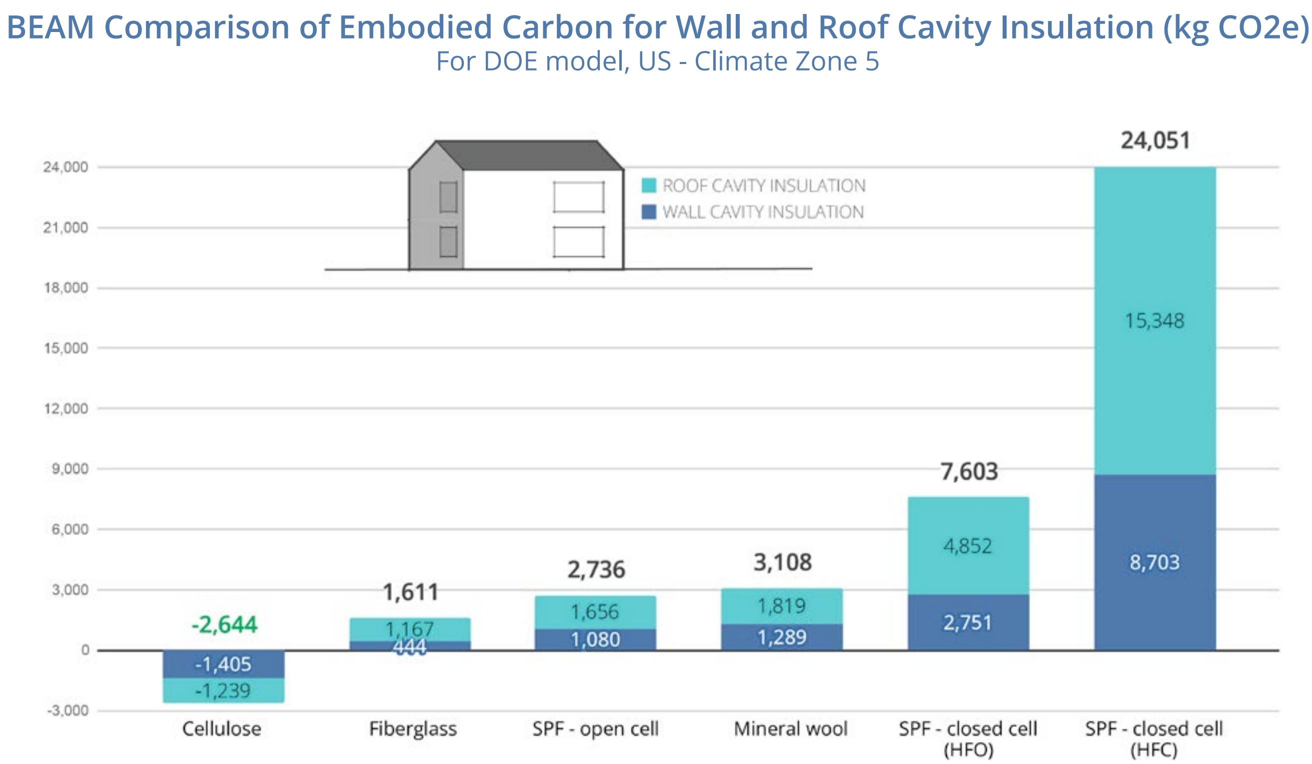


Figure 6 Embodied carbon emissions relative to dense pack cellulose cavity insulation

At the level of a single home, these differences in embodied carbon are substantial. Extrapolated to typical new home construction across the US and Canada, it becomes increasingly clear that the use of carbon-storing cellulose insulation could alter the emission profile of new homes.

Figure 7 explores a scenario in which all new homes in the US and Canada have walls and roofs insulated (to Zone 5 requirements) with cellulose or another type of insulation. While it is not practical to assume that every new home would use a single type of insulation, it is clear that moving toward the use of carbon-storing insulation materials like cellulose would change the carbon footprint of new home construction in a positive way. These figures are based on new home construction reports from the US[25] and Canada[26] that indicate combined annual construction of approximately 1.1 million new homes of comparable size to the DOE Model Home.

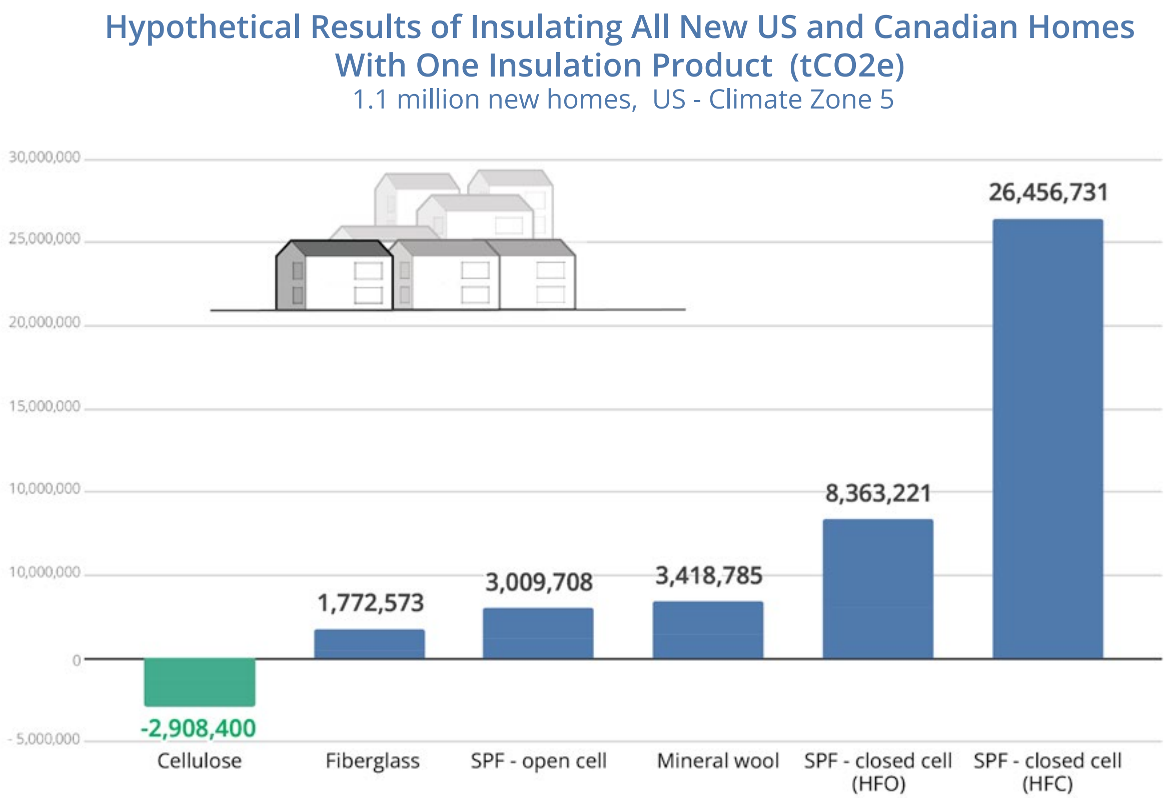


Figure 7 Comparison of insulating new homes with various insulation types

When viewed in this hypothetical manner, it is clear that the differences in emissions between insulation products are equivalent in scale to major climate initiatives, such as decommissioning coal-fired power plants (average 3.7 million metric tonnes CO_2e/year) or removing millions of cars from the roads (100,000 cars equal approximately 460,000 metric tonnes CO_2e/year).[27]

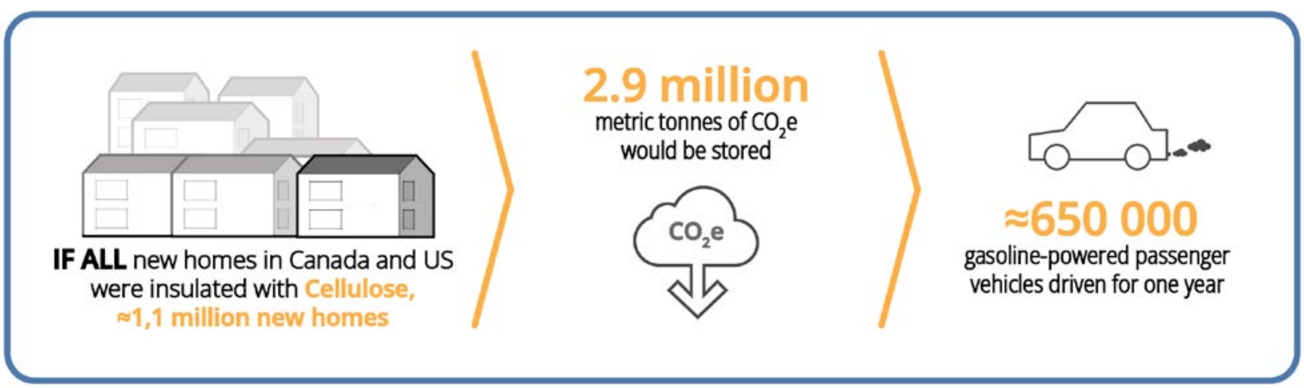


Figure 8 Scale of carbon storage achievable in new homes using cellulose insulation

These results further illustrate the outsized opportunity that cellulose presents to not only reduce operational carbon emissions through increased insulation, but also to leverage the storage potential for additional positive climate change mitigation effect. A home insulated with cellulose will realize its operational emission reductions immediately, while other insulation products will require additional time before there are net benefits to operational emissions.

Converting C to CO_2

It can be counterintuitive to see net storage figures for a material like cellulose insulation that are larger than the mass of the material itself, but the explanation is quite simple. Misunderstanding can arise because we tend to use the term "carbon emissions" as shorthand for "carbon dioxide emissions," but carbon (C) and carbon dioxide (CO_2) are not the same thing.

When plants grow, CO_2 is absorbed by the plant during photosynthesis. The plant holds onto the C and releases the O_2 (a byproduct that enables us to breathe!). Typically, between 35-55% of the weight of dry plant matter is C that came out of the atmosphere. When the plant is burned, eaten, or decomposed, the C content will go back to the atmosphere, often as CO_2. When this happens, the atoms of C are recombined with two oxygen atoms. So the CO_2 that came out of the atmosphere and the CO_2 that goes back to the atmosphere are heavier than the C atoms that are in the plant itself.

The formula looks like this:

Atomic mass of Carbon: 12
Atomic mass of Oxygen: 16
Atomic mass of O_2: 32 (16 + 16)
Atomic mass of CO_2: 44 (12 + 16 + 16)
Ratio of CO_2 to C: 44/12 = 3.67
1 kilogram of C = 3.67 kilograms CO_2
1 kilogram of wood/paper = 0.5 kilograms of Carbon

For example, to figure out the CO_2 value of 10 tonnes of waste paper (just over 1,000 25-pound bags of cellulose insulation), the calculation is:

10 metric tonnes of paper x 0.5 carbon content of paper x 3.67 CO_2 to C conversion factor = 18.35 metric tonnes of CO_2

While this number is the total CO_2 that was pulled from the atmosphere and stored in the paper, the emissions caused by manufacturing the paper into cellulose insulation needs to be subtracted from this total storage. This is the methodology prescribed in a life cycle assessment.

In a life cycle assessment, all GHG emissions are combined into one number, called CO_2 equivalent (or CO_2e). CO_2e is the "common denominator" that allows all emissions to be easily compared, and since emissions are counted this way, so is storage.

Context for Claims of Cellulose Insulation Emissions Benefits

For carbon storage in cellulose insulation to provide a meaningful climate benefit, the use of the cellulose feedstock must prevent the release of carbon emissions to the atmosphere. Cellulose insulation in the US and Canada is typically made from recycled fibers including paper, paperboard, and cardboard, and the existing waste stream pathways for this material provide insight into claims of emissions avoidance.

According to the EPA,[28] in 2018, paper and paperboard constituted 23% of total municipal solid waste, or about 67 million tons (60.8 million metric tonnes) in the US. It also represented the greatest percentage of all recycled materials at 66.54%, or approximately 46 million tons (41.7 million metric tonnes). One metric tonne of decomposing paper in a landfill generates 1,890 kg CO_2e[29] when the emitted GHGs are not captured, meaning the 513,516 tons (465,854 metric tonnes) of waste paper diverted to cellulose production in 2022 could represent 960,000 tons (approximately 870,000 metric tonnes) of averted emissions.

The opportunity exists to divert more of the 21 million tons (approximately 19 million metric tonnes) of un-recycled paper waste to cellulose manufacturing. Even small additional diversions from combustion and landfilling could dramatically increase available feedstock for future cellulose production and proportionally reduce the associated emissions.

Co-Benefits of Cellulose Insulation

This study points out the climate benefits of cellulose insulation, but the material offers numerous co-benefits.

Indoor Environment Quality

Healthy Buildings Network provides "Insulation Product Guidance" for potential health effects of different construction materials.[30] In the insulation category, cellulose is among their best rated materials. The lack of formaldehyde, carcinogenic de-dusting oils, halogenated flame retardants, and isocyanates found in many types of insulation makes cellulose a healthier option for installers and occupants.

Air and Moisture

Building professionals know that air movement through building assemblies is a major concern for both thermal comfort as well as building durability. When air moves through a building assembly, it transports not only air, but vapor that can condense on a cold surface within the assembly and result in mold, mildew, and even building rot. Cellulose insulation is hygroscopic, which means it manages to "buffer" moisture levels by wicking moisture from areas of greater concentration to areas of lesser concentration and is able to safely store a considerable amount of moisture without permanent damage.

Furthermore, dense-packed cellulose hinders the movement of air through assemblies and is easily able to conform to the irregularities of the cavities and spaces that it fills, avoiding gaps that can reduce thermal performance and create moisture issues.

Smoke and Fire

Cellulose is a combustible material but offers benefits related to fire and smoke spread. Since 1978 all cellulose insulation contains organic fire retardants, making it one of very few combustible materials that is always fire treated.[31] Depending on installation characteristics, cellulose allows wall assemblies to achieve a one-, two-, or three-hour fire-rating.

A growing concern with building professionals is what happens to building materials when they burn and the effect that this burning has on both building occupants as they escape the building and responding emergency personnel. When appropriately installed, cellulose insulation can not only achieve requisite fire ratings but it can also reduce the spread of flames and avoid the toxic fumes produced by other insulation materials.

Historic Preservation and Adaptability

Cellulose is one of the strongest insulation options for historically sensitive applications because it is 100% reversible (i.e. non-permanent) which allows it to be easily removed in the future as necessary, easing the ability to inspect if leaks or problems arise and to re-expose a historic artifact. This is of particular interest to builders, architects, and historic preservationists faced with improving the performance of a historically significant building while also protecting and preserving the historic fabric of the architectural work. Additionally, cellulose lends itself well to the prospect of future deconstruction efforts which allow for the reuse of building materials in new applications and to avoid future embodied carbon emissions.

Monetizing Carbon Benefit

Strategies for monetizing carbon dioxide removal (CDR) as a means to promote and accelerate climate mitigation continue to advance in the US and Canada. Voluntary carbon removal markets and certificates are being developed, with standards for building products beginning to be introduced. As the understanding of the time value of biogenic carbon storage in buildings continues to emerge and develop, we expect that valuation not only of avoided emissions will occur but also that some valuation of carbon storing materials may also be considered.[32]

Cellulose insulation already is widely available and affordable, and as a biogenic material it would also benefit from this monetization of emission reduction and carbon storage, therefore making it an even more attractive insulation choice.

Workforce and "Green Jobs"

The 2023 CIMA survey of member producers notes that one-third of respondents described their utilized capacity as "full," and 11 manufacturers noted "availability of labor" as the greatest challenges facing the industry. Both of these findings point to opportunities for expansion and job creation within an industry with continued potential to reduce carbon emissions in the built environment.

Summary

Cellulose Insulation Emissions Reduction Benefits and Opportunities

As the US and Canadian building stock continues to increase and the number of energy retrofits is encouraged to grow, the initiative to reduce greenhouse emissions from buildings is becoming increasingly important. In order to meet the goals of the Paris Agreement, meaningful mitigation strategies for both operational and embodied carbon emissions are necessary in the next 5-7 years. The use of cellulose insulation is currently a leading option for emissions reduction due to its positive impact on operational and embodied carbon. Because of its carbon storing properties as a bio-based material that would otherwise return to the atmosphere as emissions, cellulose insulation avoids the elevated levels of embodied carbon emissions that are characteristic of many of the most commonly used insulation materials today and also offers important carbon storage opportunities. The use of buildings as safe, durable places to store carbon are essential as the world works to tip the carbon scales back toward a more balanced climate in the decades to come.

CIMA reported that 582,318 metric tonnes (641,896 US tons) of cellulose insulation was produced in 2022 (21% in Canada and 79% in the US). This volume of material could insulate 802 million square feet of wall at a value of R-20, and represents 558,000 metric tonnes (615,000 US tons) of net CO_2 storage. By comparison, Figure 9 shows the emissions that would result from replacing this functional amount of cellulose with other insulation products.

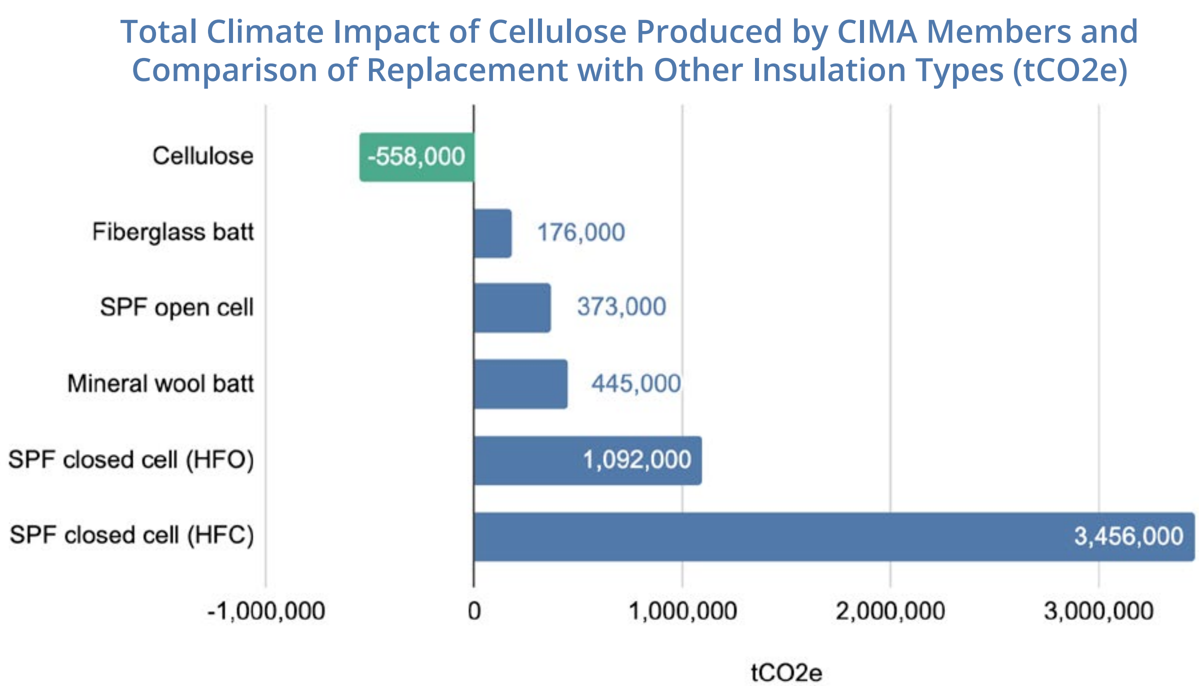


Figure 9 BEAM results for 802 million ft² at R-20 thermal performance

As the insulation market evolves to increasingly decarbonize, there is additional opportunity for the cellulose industry in the form of carbon offsets. Should demand for cellulose insulation increase, it will be important to consider additional feedstock material for production, ideally from non-virgin fiber sources.

As the largest incumbent producer of biogenic, carbon storing insulation, the cellulose industry is well-positioned to lead a movement toward a built environment that begins to store more carbon than it emits. Governments at all levels are currently incentivizing and mandating energy efficiency improvements in buildings, which requires the use of more insulation as a leading strategy. Those same governments are gearing up to invest in embodied carbon reductions in their own building projects and indicating that broader regulations are in the works. With private sector actors also taking action to improve energy efficiency and reduce embodied carbon, cellulose insulation is poised to play a critical role in meeting climate goals while reducing landfill waste and creating more green jobs.

Endnotes

1 Larry Strain, Time Value of Carbon, 2017, https://www.siegelstrain.com/wp-content/uploads/2017/09/Time-Value-of-Carbon-170530.pdf

2 GSA and Embodied Carbon, Green Building Advisory Committee, 2022. https://www.gsa.gov/system/files/Horn_GBAC_Embodied%20Carbon.pdf

3 Anish Tilak, Connor Usry, and Victor Olgyay, Roadmap to Reaching Zero Embodied Carbon in US Federal Building Projects, RMI, 2022. https://rmi.org/insight/zero-embodied-carbon-in-federal-buildingprojects/

4 What is a Buy Clean Policy?, Carbon Leadership Forum, 2022. https://carbonleadershipforum.org/what-is-a-buy-clean-policy/

5 Canada Green Buildings Strategy, Natural Resources Canada, 2022. https://natural-resources.canada.ca/sites/nrcan/files/public-consultation/cgbs-discussion-paper-2023-08-03-eng.pdf

6 Inflation Reduction Act, PUBLIC LAW 117–169—AUG. 16, 2022. https://www.congress.gov/117/plaws/publ169/PLAW-117publ169.pdf

7 Canada Greener Homes Initiative, 2022. https://natural-resources.canada.ca/energy-efficiency/homes/canada-greener-homes-initiative/24831

8 Low Rise Buildings as a Climate Change Solution (2019). Builders for Climate Action. https://www.buildersforclimateaction.org/whitepaper1.html

9 Magwood, C., Ahmed, J., Bowden, E., Racusin, J. (2021). ACHIEVING REAL NET-ZERO EMISSION HOMES: Embodied carbon scenario analysis of the upper tiers of performance in the 2020 Canadian National Building Code

10 2018 *Commercial Buildings Energy Consumption Survey* (CBECS), https://www.eia.gov/consumption/commercial/

11 Bruce King and Chris Magwood, Build Beyond Zero: New Ideas for Carbon-Smart Architecture, Island Press, 2022.

12 Jose Luis Blanco et al., "Call for Action: Seizing the Decarbonization Opportunity in Construction," McKinsey & Company, July 14, 2021, https://www.mckinsey.com/industries/engineering-construction-and-building-materials/our-insights/call-for-action-seizing-the-decarbonization-opportunity-in-construction.

13 Strain, L. 2020. "The Time Value of Carbon." Carbon Leadership Forum. https://carbonleadershipforum.org/the-time-value-of-carbon/

14 V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.). IPCC. "Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge University Press. In press.

15 Chris Magwood and Tracy Huynh, *The Hidden Climate Impact of Residential Construction,* RMI, 2023.

16 Carbon Leadership Forum, Embodied Carbon Benchmark Study: LCA for Low Carbon Construction, 2017. https://carbonleadershipforum.org/lca-benchmark-database/ Accessed October 20, 2022.

17 US EPA Greenhouse Gas Equivalencies Calculator : https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

18 ISO 14025:2006(en): Environmental labels and declarations — Type III environmental declarations — Principles and procedures. https://www.iso.org/obp/ui/#iso:std:iso:14025:ed-1:v1:en

19 Eva Rosenbloom, Chris Magwood, Heather Clark, and Victor Olgyay, Transforming Existing Buildings from Climate Liabilities to Climate Assets, RMI, 2023

20 https://cellulose.org/why-cellulose/

21 Circa 1770 a form of cellulose material was used as insulation in portions of historic Monticello in Charlottesville, VA.

22 See Appendix A for additional information about each of the three common methods of using cellulose as building insulation.

23 ISO 14025:2006(en): Environmental labels and declarations — Type III environmental declarations — Principles and procedures. https://www.iso.org/obp/ui/#iso:std:iso:14025:ed-1:v1:en

24 BEAM Methodology. https://www.buildersforclimateaction.org/beam-estimator.html

25 US Census Bureau, *American Housing Survey*, 2021.

26 Natural Resources Canada. (2020). Residential end-use model. In Residential Housing Stock and Floor Space. Natural Resources Canada.

27 https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

28 US Environmental Protection Agency (EPA) National Overview: Facts and Figures on Materials, Wastes and Recycling https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials

29 Neil MacEachern, The Environmental Impact of Paper Waste Recycling: A Comparative Study

30 https://healthybuilding.net/products/7-insulation

31 https://cellulose.org/why-cellulose/

32 Srubar III, W, S Barnes, M Grieshaber, A Orens. (2021). “A Methodology for Building-based Embodied Carbon Offsetting,” © Aureus Earth, Inc. http://www.aureusearth.com.

Appendices

Appendix A: Descriptions of three of the most common cellulose insulation applications.

Loose fill is most commonly used today in flat ceiling/attic conditions where it can be blown-in as a dry material to create a "blanket" over the underlying surface(s). Due to settlement concerns over time, best practice today avoids loose fill cellulose in walls.

Dense-pack cellulose employs dry loose cellulose material that is "packed" into a cavity with considerable density through pneumatic means. Dense-packed cavities have the advantage of eliminating potential for stack-effect or convective loops within them.

Spray-applied cellulose, referred to commonly as "wall spray," is often used in new vertical framed applications such as walls. A small amount of moisture is added to the cellulose material, along with other additives, and then sprayed through pneumatic means onto the vertical surface where it clings and creates a continuous insulative layer.

Appendix B: Environmental Product Declarations (EPDs) for materials included in the DOE analysis

Material		EPD #	Program Operator	Expiration date
Cellulose / dense pack / R 3.7/inch / CIMA [Industry Avg | US & CA]		CIM – 20191223 – 001	Sustainable Minds	2024-12-23
Cellulose / loose fill / R 3.7/inch / CIMA [Industry Avg | US & CA]		CIM – 20191223 – 001	Sustainable Minds	2024-12-23
Fiberglass batt / R 3.6/inch [BEAM Avg]		Average of the following EPD:		
	Certain Teed	4788647002.101.1	UL Environment	2024-01-01
	Knauf	KNA – 12032018 – 001	Sustainable Minds	2023-12-03
	Owens Corning	4788548937.101.1	UL Environment	2023-09-19
Fiberglass loose fill / ~R2.6/inch [BEAM Avg]		Average of the following EPD:		
	Certain Teed	4788647002.102.1	UL Environment	2024-01-01
	Knauf	KNA – 12032018 – 003	Sustainable Minds	2023-12-03
	Owens Corning	4788548937.101.1	UL Environment	2023-09-19
Mineral wool batt / R 4.2/inch / [BEAM Avg]		Average of the following EPD:		
	Owens Corning	4788956323.103.1	UL Environment	2024-10-01
	Rockwool	4789092768.101.1	UL Environment	2024-06-17
Mineral wool loose fill / NAIMA / R 3/inch [Industry Avg | N.America]		4788703029.102.1	UL Environment	2023-11-07
Spray polyurethane foam - Closed Cell (HFC gas) / R 6.6/inch / SPFA [Industry Avg | US & CA]		EPD-087	ASTM International	2023-10-29
Spray polyurethane foam - Closed Cell (HFO gas) / R 6.6/inch / SPFA [Industry Avg | US & CA]		EPD-085	ASTM International	2023-10-29
Spray polyurethane foam - Open Cell / R 4.1/inch / SPFA [Industry Avg | US & CA]		EPD-087	ASTM International	2023-10-29