Urban housing as carbon store

Green building materials could be a two-fold answer to the climate crisis

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The crisis of climate change that the world faces calls for urgent solutions. Solar, wind or tidal energy, and improving efficiency of traditional processes are all well, but, as Greta Thunberg says, our house is on fire. We need measures that bite large chunks out of the carbon economy, not ways that inch towards uncertain targets.

Galina Churkina, Alan Organschi, Christopher PO Reyer, Andrew Ruff, Kira Vinke, Zhu Liu, Barbara K Reck, TE Graedel and Hans Joachim Schellnhuber, from Yale University, the Potsdam Institute, Gray Organschi Architecture (architects in New Haven) and Tsinghua University, Beijing, present, in the journal, *Nature Sustainability*, a strategy that could do just this. The solution they present is to replace cement and steel, which consume large energy to produce, with wood, in building construction. On the one hand, the move would eliminate one of the largest sources of atmospheric CO_2. On the other, regrowing trees, which would be felled to provide building material, would draw carbon out of the atmosphere — as good as storing carbon in the buildings where the forest has moved!

Apart from the heat required to produce cement and steel, the very processes of production are sources of CO_2 emission. The main component of cement is lime, which is produced by the reduction of limestone, or calcium carbonate, by heat, in kilns. The reaction is like this: $CaCO_3 \longrightarrow CaO + CO_2$. We can see that along with lime, CO_2 is produced. And in good quantity, 44 parts, by weight of CO_2 for 56 parts of lime.

The production of steel is by the reduction of oxides of steel, mainly like this: $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$. The process produces 132 parts, by weight, of CO_2 for 112 parts of iron. The carbon monoxide (CO) comes from coal and the production of steel is one of the largest sources of CO_2 in the atmosphere.

The automobile sector and use of coal for power and in industry, of course, are the main causes of rising CO_2. The use of concrete, which consists largely of cement and steel, has been the other major contributor. With plentiful energy and food supply (thanks to chemical fertilisers, whose manufacture emits huge CO_2), the last century has seen unprecedented population rise and building activity. And construction, during the last century, has been more and more with concrete.

The paper in *Nature Sustainability* points out that vegetation alone cannot work as a carbon sequester, as microorganisms break vegetable matter down and put carbon back in the atmosphere. The great storage of carbon, as coal and oil, in ages past, was perhaps because present-day microbes had not evolved, and thanks to conditions that buried and compressed organic matter. As microbes are active now, burying trees would not work today, but using wood as the material for building construction could still achieve the same end. Why find methods to capture and confine CO_2, with the attendant risks, when we have the job done in giant trees? We only need to keep these trees from decomposing — our buildings would become the carbon stores — and we would block the CO_2 that comes from cement and steel manufacture too, the paper suggests.

Wood, which was the dominant building material in the past, has limits to the crushing loads it can bear. This puts a cap on how high a wooden structure can get. Tall buildings were hence of masonry, and with the advent of cement, of concrete, which is cement with sand and rubble. As concrete, which has compressive strength, cannot take bending loads, the load-bearing beams in buildings were of wood or steel. But it was found that concrete could be strengthened with steel bars. And, with the additional advantage of uniformity and specific shapes being possible, very strong structures are now built using a framework of reinforced concrete.

"The buildings and construction sector currently accounts for about half of all global steel demand," the paper says. There could be marginal improvements in efficiency, and reuse of scrap steel is only a partial solution. Yet another cost of using concrete is extracting sand from beaches, rivers and the sea, and the environmental effect of mining. The result is reduction in the capacity of water bodies to absorb CO_2, as well as loss of forests, the paper says.

Mass timber that is now available, the papers says, consists of specifically designed structural components that are laminated using smaller board, as glue-laminated (gluelam) beams or cross-laminated timber (CLT) panels. Methods of fabrication and use, with adhesives and mechanical fasteners have made it possible to build on the strengths of wood as a building material, even fire-resistant (see box) buildings 18-storeys tall have been found practical, the paper says. "…engineered timber products and structural systems offer a potential substitute for much of the mineral-based materials in urban building construction," the authors write.

Analyses by the authors suggest that using timber for new urban housing has carbon storing potential between 0.01 to 0.68 billion tons a year, depending on how far timber replaces concrete, and the how dwellings are designed. For comparison, the carbon absorbed by the Earth's whole biosphere is 2.3 billion tons in a year. Over 30 years, if half the new constructions used wood, the paper says, between one billion to 11 billion tons of CO_2 would get stored.

As for the supply of wood, the paper finds that until 50 per cent of construction becomes wood-based, almost all the wood needed could be met from just part of the wood being drawn for short-term purposes, without affecting the net harvest from forests. The paper cites a Food and Agriculture Organization study that says out of 65 countries that were evaluated, 43 harvested less wood than the forests grew. And overharvesting, where there was any, has been declining. There is hence wood to meet the demand even with 90 per cent of new constructions being wood-based, at the current average floor area. And then, materials like bamboo and other plant fibres could supplement wood resources.

The paper emphasises that a precondition to harvest and transfer carbon to the city is that we maintain forest sustainability and continue reforestation. This would need legal and political commitment. Forest dwellers need to be empowered.

"The history of trans-cultural familiarity with wood and plant-based construction material and assemblies, especially in Asia, Oceania and Africa, suggests an alternative future for buildings. In a few decades, a material revolution, scaled in its application to global urbanisation and to the sustainable capacities of its forest sources, may balance material supply, material demand and environmental burdens and benefits, while answering the challenge of urgent climate action," the paper says.

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OVERLOOKED OPPORTUNITY

The world is striving to harness the sun's energy or to capture carbon as efficiently as nature does. The idea is to cut down on carbon-intensive methods of energy generation or to put away, without tears, the carbon that is loading the atmosphere.

Here is a way to use nature herself to attain both the ends. Using wood in place of cement and steel amounts to generating, at no cost, the energy that it would take to manufacture the cement and steel. And when the forests, where we source the wood, grow back, the sun's energy draws carbon out from the atmosphere.

WOOD RESISTS FIRE

International building codes recognise that charring of the outer surface helps large structural timbers survive major fires. Accidents with light-frame structures, however, have promoted the association of wood with fire catastrophe. In fact, it is steel that becomes plastic and buckles at high temperature, which brought the Twin Towers down in New York in 2011.

WOOD IS ALL GREEN

Using one cubic metre of lumber in buildings sequesters one ton of CO_2 for an average period of 20 years. It reduced net emissions by 0.3 tons of CO_2 if concrete is replaced and 1.2 tons of CO_2 if steel is substituted.

How proteins work

Several common structural motifs allow regulatory transcription factors to bind to DNA and activate the process

TAPAN KUMAR MAITRA

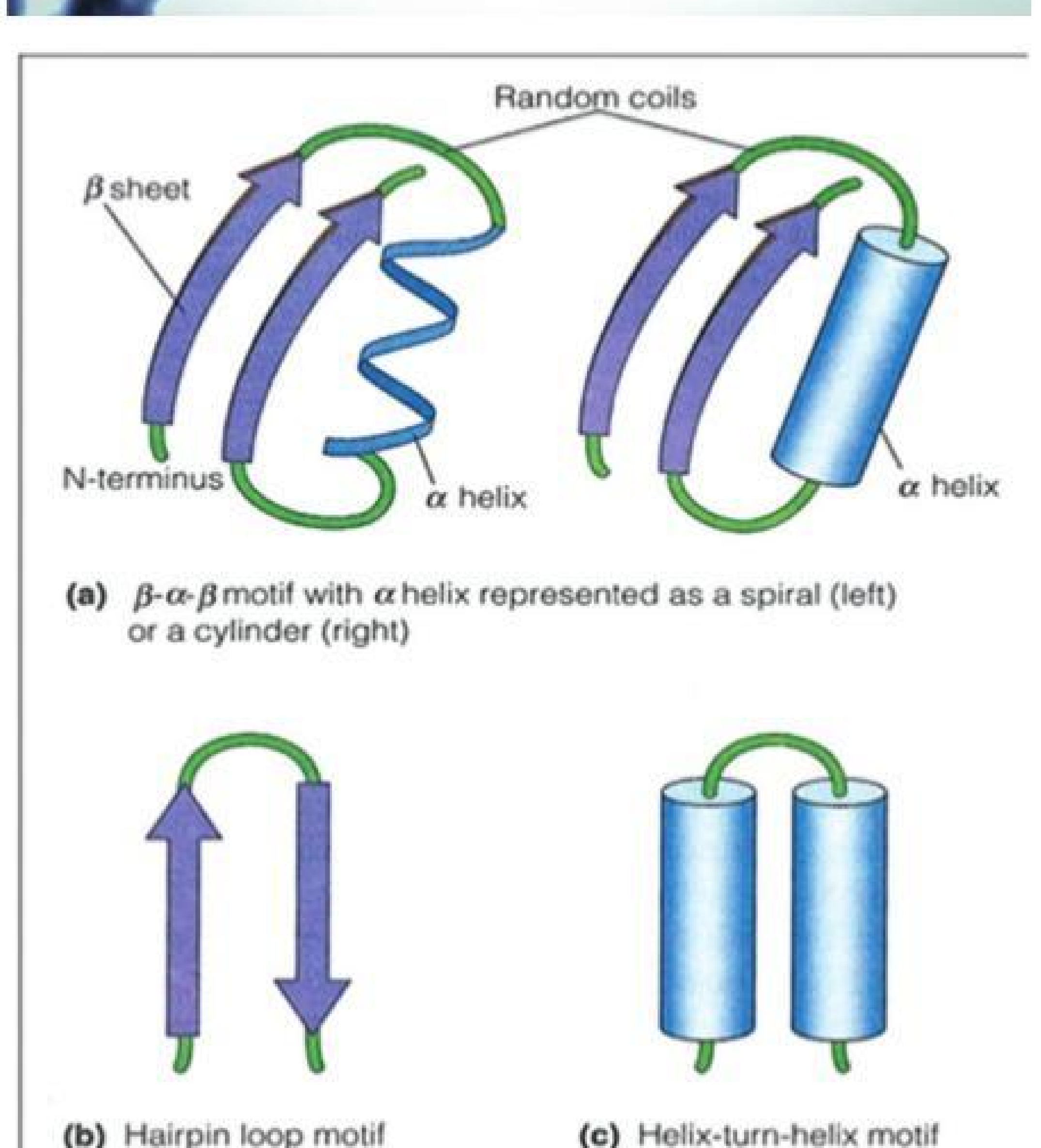
Although not all transcription factors bind directly to DNA, those that do play critical roles in controlling transcription. Proteins in this category include the general transcription factor TFIID and, more importantly, the wide variety of regulatory transcription factors (activators and repressors) that recognise and bind to specific DNA sequences found in proximal control elements, enhancers, and silencers. What features of these regulatory transcription factors enable them to carry out their functions?

Regulatory transcription factors possess two distinct activities, the ability to bind to a specific DNA sequence and the ability to regulate transcription. The two activities reside in separate protein domains. The domain that recognises and binds to a specific DNA sequence is called the transcription factor's DNA-binding domain, whereas the protein region required for regulating transcription is known as the transcription regulation domain (or activation domain because most transcription factors activate, rather than inhibit, transcription). The existence of separate DNA-binding and activation domains has been demonstrated by "domain-swap" experiments in which the DNA-binding region of one transcription factor is combined with various regions of a second transcription factor. The resulting hybrid molecule can activate gene transcription only if it contains an activation domain provided by the second transcription factor.

Studies of this type have revealed that activation domains often have a high proportion of acidic amino acids, producing a strong negative charge that is generally clustered on one side of an a helix. Mutations that increase the number of negative charges tend to increase a protein's ability to activate transcription, whereas mutations that decrease the net negative charge or disrupt the clustering on one side of the a helix diminish the ability to activate transcription. In addition to acidic domains, several other kinds of activating domains have been identified in transcription factors. Some are enriched in the amino acid glutamine, and others contain large amounts of proline. Hence several different types of protein structure appear to be capable of creating an activation domain that can stimulate gene transcription.

Several kinds of structures are also found in the DNA-binding domains of transcription factors. In fact, most regulatory transcription factors can be placed into one of a small number of categories based on the secondary structure pattern, or motif, which makes up the DNA-binding domain.

One of the most common DNA-binding motifs, detected in both eukaryotic and prokaryotic regulatory transcription factors, is the helix-turn-helix. This motif consists of two helices separated by a bend in the polypeptide chain. Although the amino acid sequence of the motif differs among various DNA-binding proteins, the overall pattern is always the same — one a helix, called the recognition helix, contains amino acid side chains that recognise and bind to specific DNA sequences by forming hydrogen bonds with bases located in the major groove of the DNA double helix, while the second a helix stabilises the overall configuration through hydrophobic interactions with the recognition helix. The lac and trp repressors, the CRP protein, and many phage repressor proteins are examples of prokaryotic proteins exhibiting the helix-turn-helix motif, and transcription factors that regulate embryonic development are eukaryotic examples.



Common Structural Motifs.

On the other hand, initially identified in a transcription factor for the 5S rRNA genes (TFIIIA), the zinc finger DNA-binding motif consists of an a helix and a two-segment sheet, held in place by the interaction of precisely positioned cysteine or histidine residues with a zinc atom. The number of zinc fingers present per protein molecule varies among the transcription factors that possess them, ranging from two fingers to several dozen or more. Zinc fingers protrude from the protein surface and serve as the points of contact with specific base sequences in the major groove of the DNA.

The leucine zipper motif is formed by an interaction between two polypeptide chains, each containing an a helix with regularly spaced leucine residues. Because leucines are hydrophobic amino acids that attract one another, the stretch of leucines exposed on the outer surface of one a helix can interlock with a comparable stretch of leucines on the other a helix, causing the two helices to wrap around each other into a coil that "zippers" the two a helices together. In some transcription factors, leucine zippers are used to "zip" two identical polypeptides together; in other transcription factors, two kinds of polypeptides are joined together.

Last, the helix-loop-helix motif is composed of a short a helix connected by a loop to another, longer helix. Like leucine zippers, helix-loop-helix motifs contain hydrophobic regions that usually connect two polypeptides, which may be either similar or different. The formation of the four-helix bundle results in the juxtaposition of a recognition helix derived from one polypeptide with a recognition helix derived from the other polypeptide, creating a two-part DNA-binding domain.

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PLUS POINTS

Beyond opioids

Pain management in the immediate post-surgical period is an imperative aspect of surgical care. The use of morphine for surgical pain management has existed for some time. However, in the late 1990s, a lack of informed and evidence-based approaches by pharmaceutical companies reassured the medical community that patients would not become addicted to opioid pain relievers, which are complex chemical derivatives of morphine. This led to increased prescription by healthcare providers at greater rates with a genuine aim to provide pain-associated physical and emotional comfort.

Increased prescription of opioid medications led to widespread misuse of both prescription and non-prescription opioids before it became clear that these medications could indeed be highly addictive. The situation escalated to a national epidemic in the US and elsewhere across the globe. In 2017, the Health and Human Services of the US declared it as a national emergency.

Immediate adaptation to these policy changes were led by an ear, nose and throat surgeon Dr SambaSiva Reddy Bathula, who is currently affiliated with the Detroit Medical Center. In his otorhinolaryngology practice, routine pain management is a daily issue. After performance of surgeries like tonsillectomy, thyroid and sinonasal surgeries, Dr Bathula, a postgraduate of ENT surgery from Guntur Medical College, has emphasised and implemented the use of non-narcotic medications like acetaminophen (paracetamol) for pain management.

Though the mechanism of pain control by acetaminophen is not well-known, Dr Bathula has demonstrated that it is an efficient agent after most ENT surgeries, which are otherwise very painful. In an objective study, he has revealed that increased use of acetaminophen and other medications like ibuprofen has decreased the prescription of morphine milligram equivalents, both in comparison to other prescribers within the specialty as well as similar prescribers.

India is one of the largest legal producers of opium. Not surprisingly, India has an established pattern of use of opioid group of drugs. Indeed, a sizable number of people in India use opioid drugs, suffer from opioid dependence and seek treatment for the same. The prevalence of opioid use was found to be 0.7 per cent of the general population among whom, around 22.3 per cent were found to be dependent on opioids. India has twice the global average prevalence of illicit opiate consumption. It is estimated that currently India has about four million people who use opioids and around one million people who are opioid dependent.

ENT surgeries involve both children and adult populations. He has mentioned that only in the case of head-neck malignancies, there may be the requirement of prudent and guarded use of opioid medications. These nuanced nudging strategies of Dr Bathula is in the right direction for inspiring surgeons to have non-aggressive approaches for pain management and in the process, weaning society off unnecessary use of opioids.

According to Global Burden of Disease Study 2013, opioid use disorders accounted for 5.8 million additional years lived with disability, an observation that underpins attempts to treat pain with drugs other than opioids. Dr Bathula's emphasis on use of non-opioid medications is a step ahead. It should be of tremendous benefit if Indian healthcare establishments incorporate pain management units to counsel patients for less aggressive pharmacologic agents for recovery from pain.

In India, dispensing of pain medications like tramadol is often minimally regulated. Women, who walk long miles to obtain drinking water, are being increasingly reported to rely on pain medicines to obtain relief from low back pain, which unfortunately may be available over the counter.

"The use of non-opioid medication on post-surgical cases is getting familiar among medical surgeons slowly but steadily. Researchers in western countries are working on how to reduce pain of post-surgical patients with paracetamol drugs and this will be brilliant innovative work to avoid dependence on opioid or tramadol group medicines. We don't depend on opioid drugs for the pain management of a patient after surgery," said professor (Dr) Arunava Sengupta, head of ENT department at Institute of Post Graduate Medical Education & Research in Kolkata.

Subhendu Maiti