

An illustrated transcript from the film series

The Complete Guide to Saving the Earth

For People in a Hurry

MANUFACTURING

Green Concrete



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<https://youtu.be/SFDXwc5ngM4>



Stone circles, pyramids, great walls, even sandcastles, humans have always loved to build things. And though they have many building materials to choose from, none is more popular than **concrete**.

Thanks to its unique strengths, it's the most widely used solid material in the world^[1,2,3]. In fact, concrete - together with the other man-made materials - now weighs more than all the plants and animals on earth combined^[4,5,6].



Please note that this resource follows American English spelling conventions



Unfortunately, concrete production releases harmful greenhouse gases, and accounts for 8% of global carbon emissions^[7,8]. If concrete was a country, it would be the third biggest polluter on the planet^[9,10].

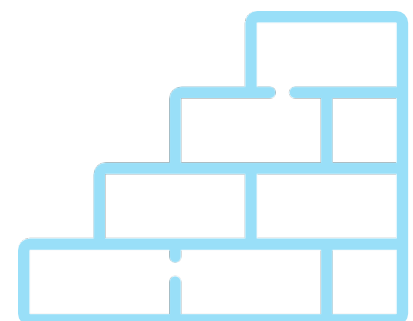
So, if humans want to build a cleaner world, they're going to need solutions; and **green concrete** is the key.

If concrete was a country it would be the third largest polluter on the planet

Primitive forms of concrete were used to make floors over 10,000 years ago in the Middle East^[11,12,13], but the first to truly master it were the Ancient Romans who used it to build the Pantheon, which remains the world's largest unreinforced concrete dome to this day^[14,15,16].



Unfortunately, the secrets of concrete were lost to the sands of time^[11-16].





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It took until 1824, before British bricklayer Joseph Aspdin re-discovered how to make cement, the key ingredient in concrete, while mucking about in his kitchen ^[12,17,18] and he paved the way for a concrete that could rival that of Ancient Rome.



JOSEPH ASPDIN



Today, humans produce 30 billion tonnes of the stuff a year^[19]. That's enough to pave over Austria with six inches of concrete, every year! ^[20,21,22]

And with demand growing, so are emissions. But how exactly does concrete generate CO₂ anyway?



30 BILLION TONNES



Well, concrete is essentially an artificial rock. Like a sandcastle, it's made from **sand**, plus **gravel** and **water**. But add **cement**, the magic ingredient that binds it all together ^[23-27] and the mixture becomes solid as a rock.



Unfortunately, cement also creates nearly all the emissions ^[26-29]. To understand why, we need to look at how it's made.





The recipe is remarkably simple, but the process is quite complicated:

First, take a generous portion of **limestone**, which is usually made of the shells and fossils of sea creatures that lived millions of years ago. It contains the calcium needed for cement as well as a store of trapped carbon ^[30-33].

To access the calcium, you crush it up and then add a dash of **clay**, and a sprinkle of **sand**. This mixture is then preheated and fed into a rotary kiln to mix them together at a sizzling 1450°C until the limestone burns. This forms a calcium rich material called **clinker** ^[23-27, 34-37].



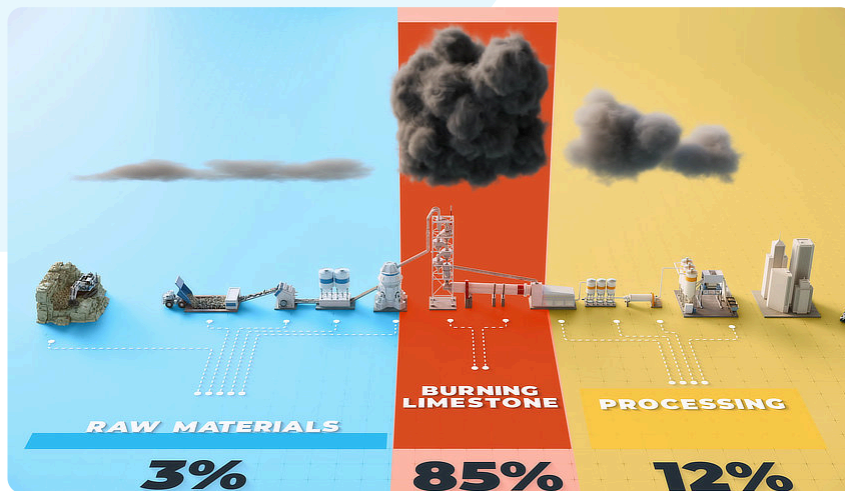
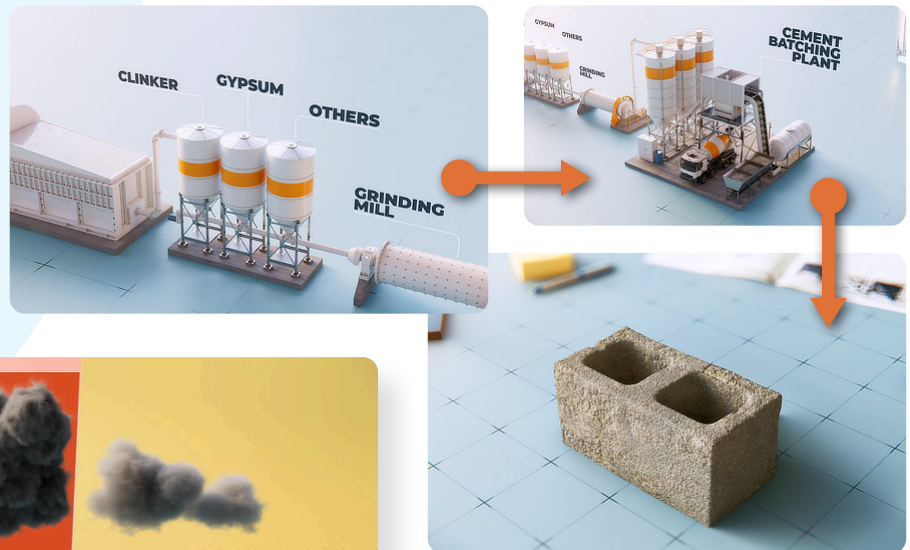
But burning fossilized sea creatures releases a lot of CO_2 , and because fossil fuels are burned to generate the heat, even more CO_2 is produced ^[38-42].





Next, mix the clinker with gypsum and other additives, then grind them together in a grinding mill to produce cement powder ^[34,35].

All that's left to do is mix the cement with water, sand, gravel, and other aggregates ^[23-27] and Voila! You've made concrete!



Along with a whole bunch of pollution. And as you can see, most of the emissions come from producing cement, with the biggest chunk produced by burning all that limestone! ^[38-43]



Every 1000 kilograms of cement in the mix produces 900 kilograms of CO₂ ^[43,44,45]

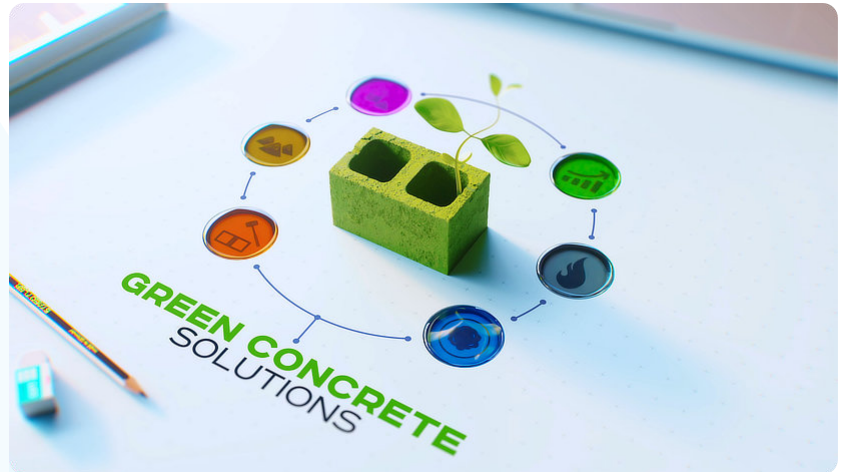




So how can humans reduce the emissions of their favorite fake rock?

Well, there are several solutions available ^[43-50].

The easiest solution in the short term is simply using concrete more efficiently ^[43-48,50]. At the moment, most structures are built with a lot more concrete than they actually need, so many architects are now optimizing designs to use less concrete, lowering demand and reducing emissions.



Efficiency is also improved by crushing up old concrete and reusing it in new concrete mixtures ^[51,52,53], and exciting new technologies like **electric recycling** are also being tested ^[54].

This uses renewable electricity in an electric arc furnace to recycle both concrete and steel together, reducing the emissions of steel making and creating cement in the process.

Better yet, this cement is theoretically **zero carbon** ^[54].

While this is a huge improvement, the human appetite for concrete is so large that recycled concrete is just never going to meet demand.





The next strategy is to replace the fossil fuels needed for production. Grinding mills can be powered by clean renewable electricity from wind and solar ^[55,56].

But it's difficult to use electricity alone to reach the toasty temperatures of a kiln, so alternative fuels like green hydrogen ^[57-61] or sustainable biomass ^[61-64] can be used.

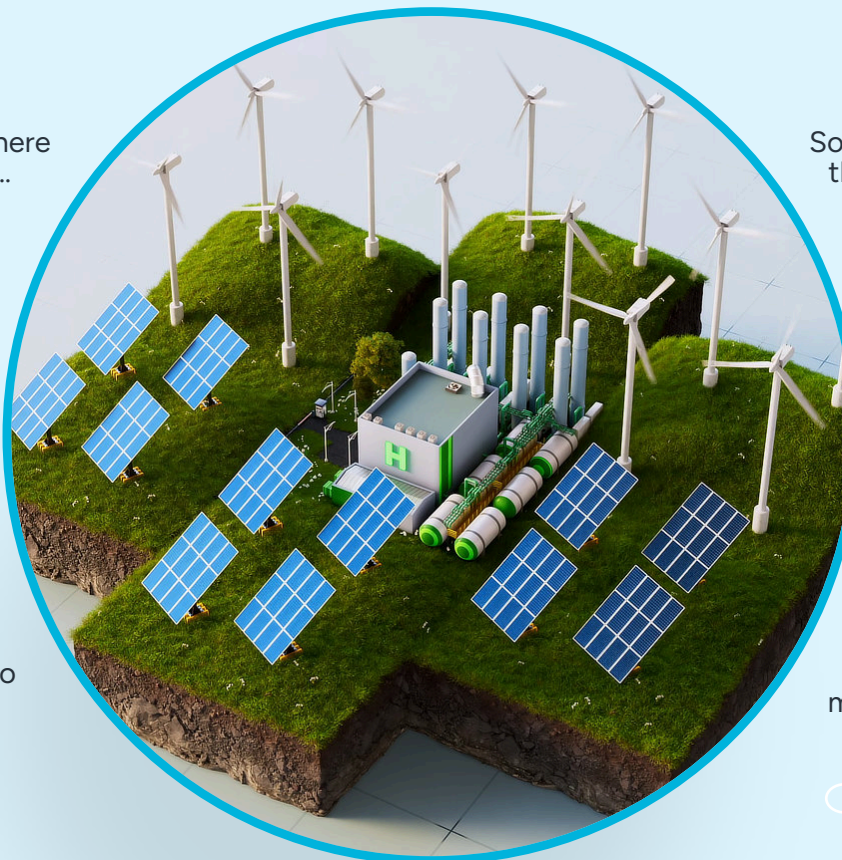


By eliminating the need for fossil fuels like coal, these alternative fuels can make a big dent in CO2 emissions ^[50].

But unfortunately there are a few problems...

Biomass is mainly derived from wood and obtained by cutting down trees, making it hard to produce sustainably ^[65,66,67,41].

And while green hydrogen has promise, producing enough requires a massive expansion of the renewable electricity needed to make it ^[68,69,70].



So, for the time being, these solutions are a long way from making a serious impact.

And, even with these fuels powering the kiln, you still have to burn limestone which is responsible for over half the emissions of cement production ^[38-43].

Clearly humanity still needs other methods.

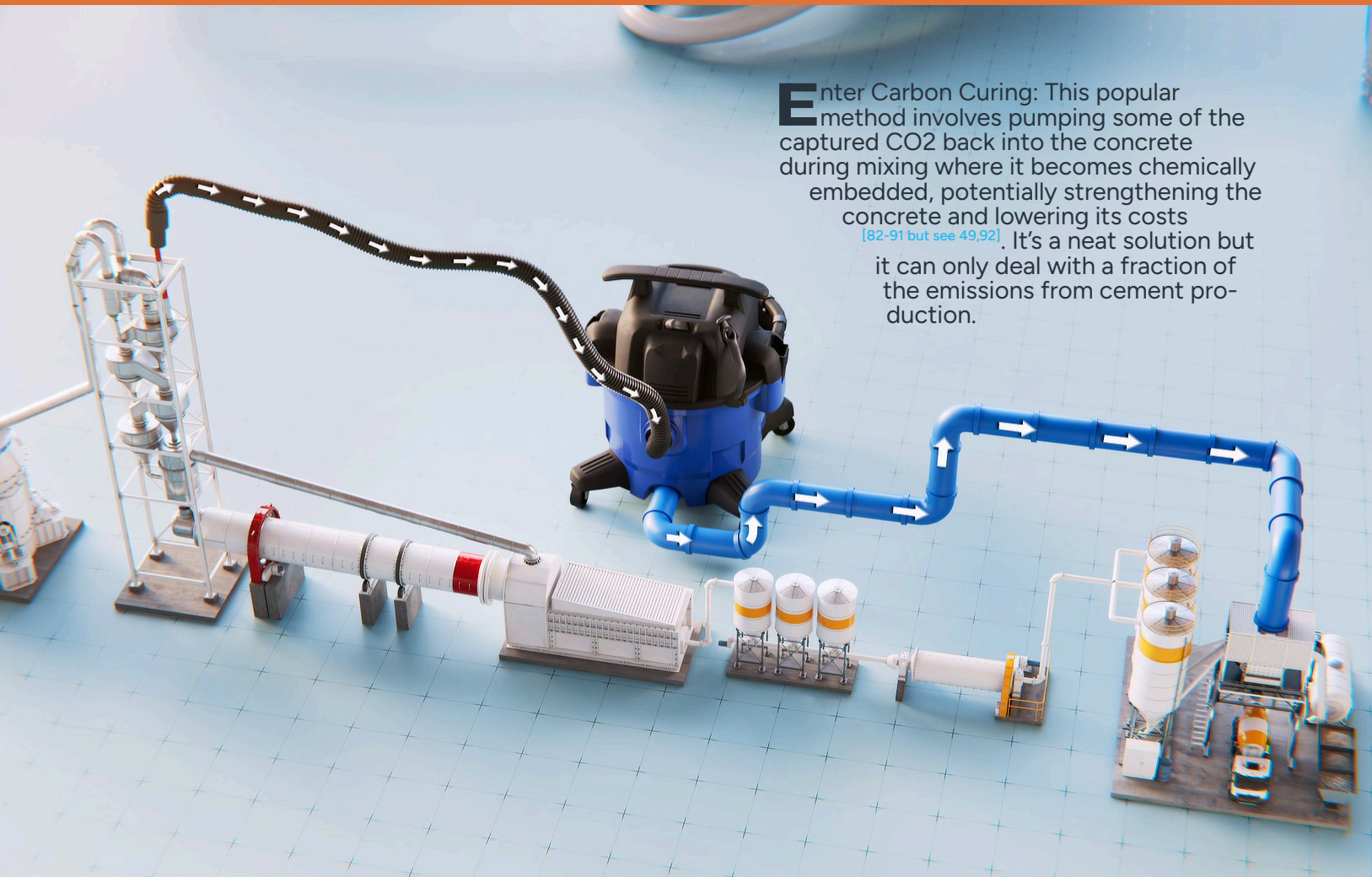


Carbon capture is often hailed as the answer ^[71-78]. Used to catch the CO₂ as it is released and store it underground, it can reduce emissions, but it can't catch them all ^[50,79,80].

Worse, it's difficult and extremely pricey to capture, transport, and store all that carbon and it's not always that effective! ^[43,77,78,81]



But what if some of that CO₂ could be used in concrete production itself?



Enter Carbon Curing: This popular method involves pumping some of the captured CO₂ back into the concrete during mixing where it becomes chemically embedded, potentially strengthening the concrete and lowering its costs [\[82-91 but see 49,92\]](#). It's a neat solution but it can only deal with a fraction of the emissions from cement production.

So, to truly achieve green concrete, humans are changing the recipe, and one of the best ways they are doing this is by adding ingredients called **SCMs** to replace some of the polluting cement [\[45-49,93-97\]](#).

These are made with fine powdery materials like fly ash from coal plants or slag from the steel industry. Since these are both waste products, this helps clean up the environment too, and because SCMs reduce

the amount of cement that's needed, they can lower emissions by between 15 and 40% [\[48,97\]](#). Better yet, they also improve concrete's strength and durability [\[98,99,100\]](#).



Unfortunately, on their own they can never replace cement entirely, but there is a solution:



ALKALINE SOLUTION

Alkaline Solution! If you take substances like the industrial waste products used for SCMs and mix them with alkaline solutions, it's possible to create a binding agent that can replace cement entirely ^[101-104].

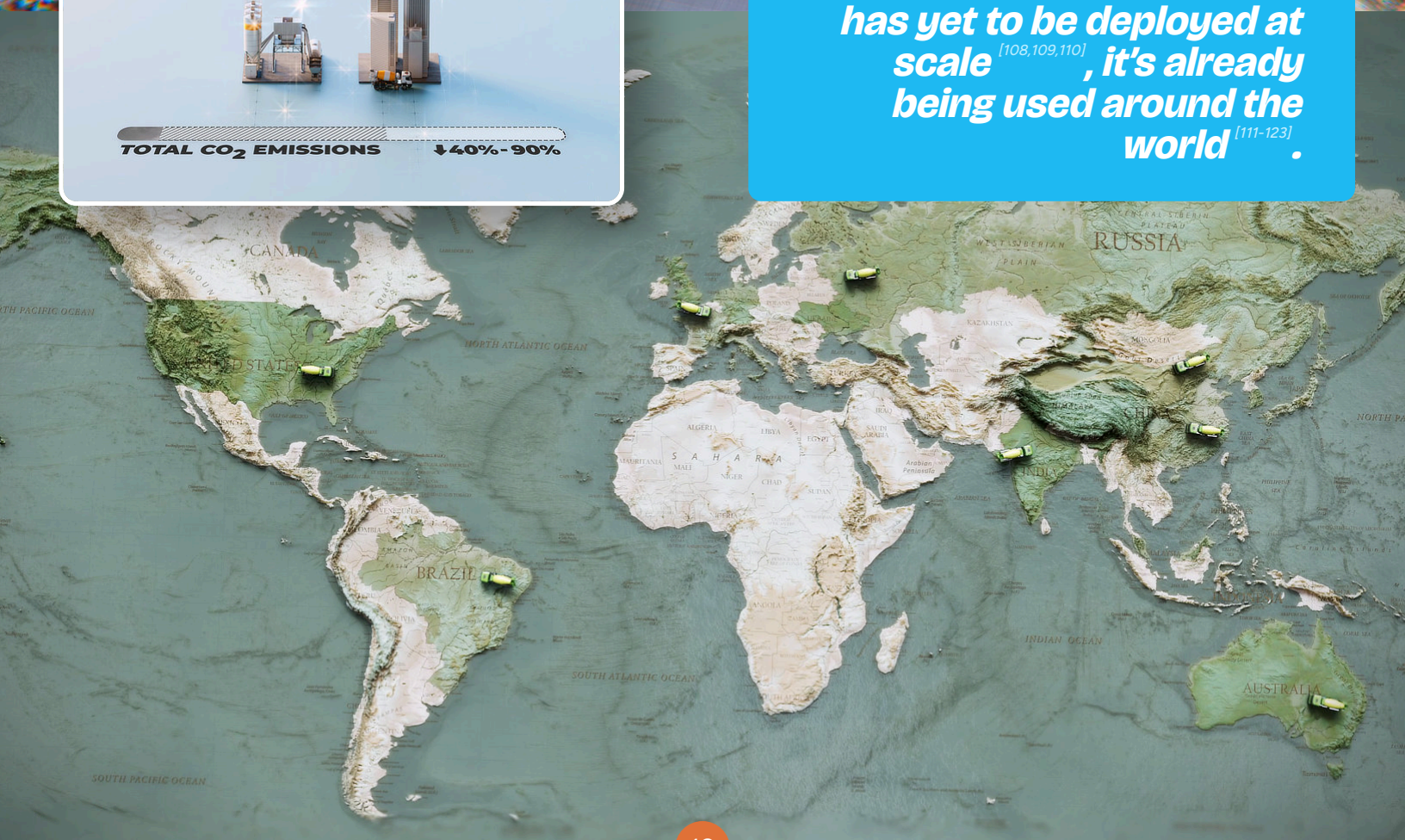
And because you don't need to dig, crush, grind or burn the ingredients for conventional cement, the resulting concrete **can reduce emissions by up to 90%** ^[49,104-107].



TOTAL CO₂ EMISSIONS

↓40%-90%

It's called alkali-activated concrete, and although it has yet to be deployed at scale ^[108,109,110], it's already being used around the world ^[111-123].





Humans love building things more than ever, building an area the size of Manhattan every 3 days, but can they do this without heating the planet? ^[124]

Well, yes!

By investing in research and development, deploying the full range of available solutions, and by expanding renewable electricity generation to support them, humanity can finally perfect the recipe for green concrete and build a **zero-carbon future!**





More Ways to Save the Earth

Earth 2050 has identified 42 solutions to get the planet to net zero carbon by the year 2050

Hydropower - The Sleeping Giant of Clean Energy



youtu.be/hck5urV5DWM

Can water power entire cities?

Hydropower has been around for millenia, and today comes in three forms: reservoir dams, run-of-river, and pumped-storage.

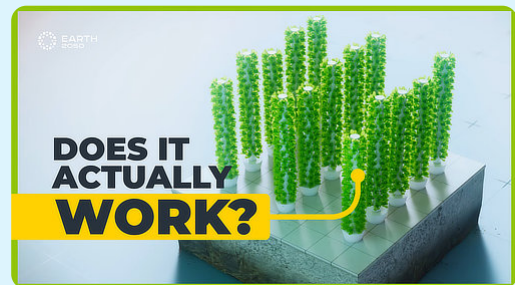


We show how each works, and how pumped-storage pairs with wind and solar to act like a giant water battery, and how better planning and design reduce impacts on people and ecosystems.

Is Vertical Farming the Future of Food?

Growing food upward, not outward, saving space and water, and keeping food local.

We show how crops grow without soil using hydroponics and aeroponics. They're lit by LEDs and guided by automation. We look at where urban sites could shine. Then we outline today's limits; energy, crop choice, skills and high costs, and the pathways that could help, like using renewables and waste heat. Big harvest, small footprint, great choice for space exploration!



youtu.be/kITR8FhkPIY

Why Solar Power Is the Future of Our Planet



youtu.be/8lCC9k-cKFQ

Could humans power the entire planet from a desert?

We explore this idea and other options, from rooftops to agri-voltaics to floating arrays. We show how solar power actually works, and explore new materials like perovskite that turn windows into solar panels.



Solar is now the cheapest source of energy in human history, but there are still some problems to overcome...

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We would like to thank the expert advisors.

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FURTHER VIDEOS (NON-AFFILIATED)

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[The material that could change the world... for a third time | TedEd](#)

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[Are Geopolymers BETTER than Portland Cement? | Belinda Carr](#)[The story of geopolymers in just two minutes | Geopolymer International](#)

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[Reclaiming concrete: How Swiss cities are going green | Focus on Europe | DW News](#)

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(alternative press releases: [The Past](#); [Open Access Government](#))
[How seawater strengthens ancient Roman concrete | UNews](#)

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[Why cement emissions matter for climate change | Carbon Brief](#)
[Cement Industry & Emissions | Cement](#)
[The Cement Manufacturing Process | Thermo Fisher](#)

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[Top 10 Ways To Reduce Concrete's Carbon Footprint | NRMCA](#)
[An Introduction to Low Carbon Concrete | CarbonCure](#)
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[4,5,6] Global man-made exceeds all living biomass

The comparison reported in Nature ^[4] is based on dry mass, not wet weight. Biomass estimates exclude water content, which is significant in living organisms.

Man-made materials refers to the cumulative dry mass of inanimate anthropogenic materials (e.g., concrete, aggregates, metals, plastics etc). The finding indicates that total dry human-made mass surpassed total dry global biomass around 2020.

[20,21,22] The annual production of concrete and the calculations for its comparison to the area of Austria:

One cubic meter of concrete weighs an average of 2.4 tonnes ^[20]. Therefore 30 billion tonnes = 12.5 billion cubic meters. This value is supported by [21].

Converting to cubic kilometers, 12.5 billion cubic meters is equivalent to 12.5 km³.

The area of Austria is 83,879 km² ^[22].

To find thickness of concrete, divide volume by surface area: $12.5 \text{ km}^3 / 83,879 \text{ km}^2 = 0.0001490242 \text{ km}$.

$0.0001490242 \text{ km} = 14.90242 \text{ cm} = 5.8671 \text{ in}$

[82-91] Carbon Curing, Carbonation, Mineralisation and Carbon Embedding – Clarification

‘Carbon curing’ refers specifically to a method in which captured CO₂ is injected into fresh concrete during mixing or curing, where it reacts with calcium compounds in the cement to form stable carbonates. This can modestly improve strength while permanently storing small quantities of CO₂ within the material matrix. However, carbon curing is only one form of carbon utilisation in concrete.

Alternatively, ‘carbonation’ refers to the reaction of CO₂ with hardened, hydrated cement-based compounds, such as concrete, over time. Natural carbonation occurs slowly during a concrete structure’s life, allowing it to gradually absorb CO₂ from its surroundings. Accelerated carbonation processes (sometimes called mineralisation curing) expose concrete or recycled aggregates to concentrated CO₂ streams to deliberately increase CO₂ uptake. These processes are chemically related but operationally distinct from in-mix carbon curing technologies.

Beyond curing-based approaches, carbon embedding can also be achieved through materially different strategies. One route involves incorporating bio-based carbon-containing materials (such as biochar) into concrete mixtures ^{A,B}. Biochar-concrete composites can physically store natural, biogenic carbon while potentially improving durability and moisture regulation properties. These approaches differ from carbonation because they embed carbon in solid form rather than infusing or mineralising gaseous CO₂.

A further extension involves developing bio-based cement composites or partially replacing mineral aggregates with renewable fibres or plant-derived materials ^{C-1}. At the far end of this spectrum, some construction systems substitute conventional concrete entirely with bio-based or hybrid composites



designed for structural or semi-structural applications ^{E-I}. These approaches are distinct from carbon curing, as they reduce or replace mineral cement inputs rather than treating emitted CO₂.

In sum, carbon curing is one specific carbon utilisation pathway within a wider landscape of strategies. Carbonation/mineralisation technologies, biochar incorporation, biobased composites, and alternative bio-based construction systems represent technically distinct approaches that either store carbon, reduce cement demand, or substitute mineral binders altogether.

Additional references:

- ^A [Biochar-concrete: A comprehensive review of properties, production and sustainability | Case studies in Construction Materials](#)
- ^B [Novel biochar-concrete composites: Manufacturing, characterization and evaluation of the mechanical properties | Science of The Total Environment](#)
- ^C [Structural and mechanical properties of bamboo fiber bundle and fiber/bundle reinforced composites: a review | Journal of Materials Research and Technology](#)
- ^D [Hemp as a potential raw material toward a sustainable world: A review | Heliyon](#)
- ^E [Biobased building materials for sustainable future: An overview | Material Today: Proceedings](#)
- ^F [Building with renewable materials | De Gruyter Brill](#)
- ^G [Improving the utility, performance, and durability of wood- and bio-based composites | Annals of Forest Science](#)
- ^H [Biobased Structural Composite Materials for Housing and Infrastructure Applications: Opportunities and Challenges | Proceedings of the NSF housing research agenda workshop](#)
- ^I [Reducing the Environmental Impact of Construction by Using Renewable Materials | Journal of Renewable Materials](#)

[111-123] Global alkali-activated concrete usage:

A few examples (but not limited to) of where alkali-activated concrete (AAC) has been used around the world:

- [111] Australia
- [112] USA
- [113] India
- [114] UK
- [115] China
- [116] The Netherlands
- [117] Germany
- [118] Malaysia
- [119] Brazil
- [120] Italy
- [121] South Korea
- [122] Singapore
- [123] Japan, Ukraine, Finland, Russia, Ireland are a few examples from this source

The references refer to both alkali-activated concrete as well as geopolymer concrete. In materials science literature, alkali-activated materials (AAMs) are generally treated as the broader category, while geopolymers are defined as a specific subset within that family. Under this prevailing framework, AAMs



refer to binders produced by activating 'aluminosilicate' precursors (e.g., fly ash, slag, and other SCMs) with alkaline solutions. This umbrella includes a range of systems with varying chemistries and reaction products.

Within that broad classification, geopolymers are typically described as low-calcium, aluminosilicate binders that form a three-dimensional structure. In this view, all geopolymers may be considered alkali-activated materials, but not all alkali-activated materials are geopolymers. This interpretation is widely adopted in peer-reviewed journals and by leading researchers, whereby AAM serves as the inclusive technical term, while 'geopolymer' denotes a particular compositional and structural subgroup.

However, an alternative school of thought argues that geopolymers constitute a distinct class of materials defined by specific polymerisation chemistry. In this interpretation, not all alkali-activated systems qualify as geopolymers, particularly calcium-rich systems whose reaction products differ structurally. This perspective resists using AAM as the primary umbrella term and instead treats 'geopolymer' as the more chemically precise category.

As a result, terminology can vary depending on author affiliation, research tradition, or institutional context. In most contemporary academic and engineering literature, the AAM-as-umbrella classification is dominant, especially in comparative studies assessing environmental performance against ordinary Portland cement. Nonetheless, emerging publications maintain a clearer separation between the terms.

[124] Area of Manhattan being built every 3 days:

[124] indicates that global urban extent expanded by 9,687 km² per year between 1985 and 2015. This is equivalent to $(9687/365 =) 26.539$ km² per day.

The area of Manhattan is 59.1km²^J.

$59.1/26.539 = \mathbf{2.2 \text{ days}}$.

However, the current rate of growth may be even faster. The World Bank^K estimates (as of April 2023) that 1.2 million km² of new urban built-up area is expected to be added to the world by 2030. From this we can assume a conservative, annual estimate for the rate of urban expansion across the entire decade of the 2020s of roughly 120,000 km² per year, 328.77 km² per day or 13.698 km² per hour. This is the equivalent of the area of Manhattan being built every 4 hours.

Additional references:

^J [Overview of New York City | NYMTC](#)

^K [Urban Development Overview -|World Bank Group](#)

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