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# How the Construction Industry Can Better Use Recycled Building Materials

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## Don't Waste, Reuse: How Recycled and Reclaimed Materials will Impact the Future of the Construction Industry

In 2019, the global rate of consumption of materials (https://www.circularity-gap.world/2021#downloads) was 100 billion tons and is projected to reach 175 billion tons in 2050. The buildings and construction sector is responsible for 36% of final energy demand globally, representing 39% of energy and process related emissions. The largest volume of waste currently comes from the demolition of buildings, with only ⅓ of construction waste being reused. (https://iea.blob.core.windows.net/assets/3da9daf9-ef75-4a37-b3da-a09224e299dc/2019_Global_Status_Report_for_Buildings_and_Construction.pdf)

# The Future of Recycled Building Materials

**There are 3 key areas relevant to the future of recycled building materials, which I will cover in this blog:**

- Circular Economy (https://www.weforum.org/projects/circular-economy)
- Retrofitting
- New Builds

# Recycled Construction Materials: Designing for Less Waste

When considering that the largest volume of waste currently comes from building demolitions, it is no surprise that attention is turning towards solving this problem. The problem is that the conventional way of doing things has been to “take, make, then waste”, also known as a linear economy. It is called ‘linear’ because the flow of materials is one directional.

Recycling materials is seen by many as the solution to this issue; however, recycling is flawed (https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#NationalPicture), with inefficiencies resulting in 5-30% of viable outputs compared to the volume of waste input. In essence, we can’t recycle our way out of the waste problem as the demand on resources outweighs supply, even for seemingly endless resources such as sand (https://www.bbc.com/future/article/20191108-why-the-world-is-running-out-of-sand).

As an example, Dubai, which resides on the edge of a desert, imports sand from Australia (https://www.bbc.com/worklife/article/20160502-even-desert-city-dubai-imports-its-sand-this-is-why). While it seems surprising that Australia is selling sand to a prominent city next to a desert to meet construction needs, it is because the grade of useful aggregate comes from specific types of sand deposits, more typically associated with riverbeds. Demand is now so high, sand quarries are actually under armed guard in places like Colombia. This is why it's important to talk about the circular economy – of which recycling makes up just one part.

To best understand the future of recycling building materials though, it is important to expand on how a circular economy (https://www.unido.org/our-focus-cross-cutting-services/circular-economy) ties into the construction industry. **Generally, the goal of a circular economy is to change the linear model of "take, make and waste" to "take, make and make use of again".**

This requires the reuse, repair, refurbishment, and recycling of products, materials, equipment and infrastructure. By doing so, we reduce resource consumption and the creation of waste, pollution and carbon emissions.

When considering the construction industry as a whole, and everything that goes into turning raw materials into a functioning building, taking those materials and making use of them again is no easy feat. We will therefore look at some fundamentals and key principles to consider how to be most effective.

**Fundamentally, there are four types of resources from which we make the products and services that meet basic human needs:**

- Minerals – e.g. sand that goes into concrete apartment towers on 6 continents
- Ores – typically used to make the metals for rebar, ships, diggers and dozers
- Fossil fuels – used to make plastics and power our vehicles
- Biomass – e.g. wood products like timber, paper

# 4 Key Principles for Recycling Building Materials

1. Use Fewer Resources
2. Use Resources Longer
3. Use Resources Again
4. Use Clean Resources

## 1. Use Fewer Resources

When waste is diverted from landfill and used again, it can have enormous effects and contribute significantly to achieving carbon reduction targets. Recycling is far more inefficient compared to using less materials in the first place.

Typically, in household waste for example (https://www.europarl.europa.eu/EPRS/EPRS-Briefing-564398-Understanding-waste-streams-FINAL.pdf), mixed recycling yields 5-10% efficiency, whereas separated recycling yields 10-25% efficiency. This is due to material composites, poor sorting and contamination. The two issues to address here are sustainable product design and financial incentives for recycling.

Think of recycling like mining. If presented with a bulk of waste and you are mining for valuable metals, the amount of effort you can spend getting the metal out needs to balance with the value of the metal or the effort isn't economical (https://www.youtube.com/watch?v=iBGZtNJAt-M). When materials are mixed and very difficult to separate, it either becomes impractical or uneconomical.

Scrap metal is recycled comparatively well because of its value. For less valuable materials, taxes and incentives are needed to either avoid fees from e.g. landfill tax, or gain benefits from government schemes. Due to these difficulties, most waste will end up in incinerators for energy recovery or sent to a landfill.

While it might seem glib to say to "use less materials", there are techniques currently available that can replace the need for steel rebar in concrete constructions. For example – graphene has long been absent since its discovery in 2004, but now, 3D-printed, graphene-enhanced concrete is being used in the UK's high speed rail construction – HS2. This reinforced concrete can be used without steel rebar for reinforcement, reducing the demand for steel and the need to transport and recycle it.

Materials can also be saved at the design phase through the use of prefabrication and modular construction (https://www.e-builder.net/blog/benefits-of-prefabrication-modular-construction-for-healthcare/), and building information modeling or BIM (https://resources.e-builder.net/home/bim-are-we-getting-what-wepaid-for).

## 2. Using Resources for Longer

This means designing with longevity in mind, as well as reparability. One example is the FairPhone (https://www.slashgear.com/fairphone-4-will-have-a-modern-feature-you-wont-like-27692766/). This is designed to be modular so that as parts break, they are easily replaceable with a standard screwdriver and the individual parts are available online. It is designed to be repaired, meaning the lifecycle of the product can be extended far beyond that which is expected today.

Buildings should be similarly designed so that elements can be more easily reused, repaired, recycled or recovered. This can be achieved by building with components created via 3D printing, prefabrication, BIM and modularity of buildings.

## 3. Using Resources Again

Recycling building materials can pose challenges depending on the material. Fortunately, steel, glass and gypsum board are all highly recyclable. Almost all (98%) structural steel (https://www.steelconstruction.info/The_recycling_and_reuse_survey) will avoid landfill, whereas around 70% of rebar used to reinforce concrete will be recycled. Careful separation can increase this efficiency.

Gypsum board (drywall) can be infinitely recycled without significant loss of performance if kept whole, meaning forward planning is needed to allow its removal intact. Synthetic gypsum made in coal-fired power plants should be avoided due to toxicity. By recycling drywall efficiently, it reduces the need to mine more of the soft gypsum sulfate mineral which is the main constituent of many forms of plaster.

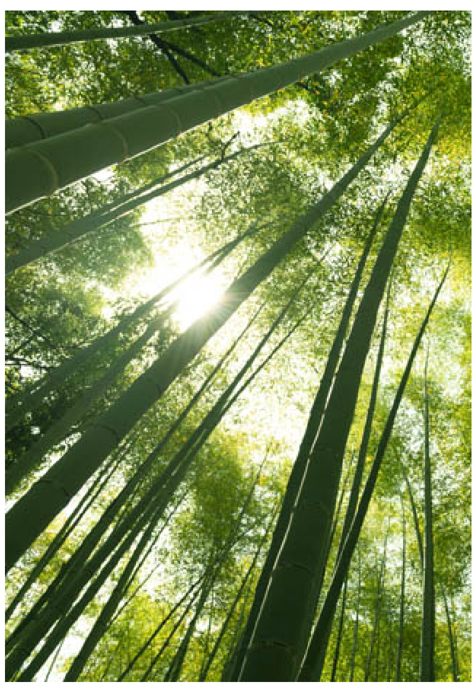
The old adage of "one man's waste is another man's treasure" applies here, where old building components can be used again at a fraction of the cost.

Glass can similarly be infinitely ground down to its virgin quality. It is a highly energy intensive process to make glass, making it an ideal candidate for recycling and should be carefully separated to avoid impurities.

It's important to note the distinction between recycling and reclaiming. Reclaiming can be thought of as a 2nd hand item being used again. It won't have been through an intensive process to convert it back to its constituent elements. In the waste hierarchy, this is referred to as upcycling. Two examples of a growing market for upcycling buildings and their contents are Globechain (https://globechain.com/) and Rockwool (https://www.rockwool.com/group/about-us/our-thinking/sustainability-and-circularity/upcycling/).

The old adage of "one man's waste is another man's treasure" applies here, where old building components can be used again at a fraction of the cost. e.g. old bricks, wood cutoffs and glass panels. When considering the inefficiencies and energy requirements of recycling, it is clear why this is a much higher priority that should be factored in at the planning stage where possible.

Designing to make separation easier at the end of a products lifespan and separating the materials as best as possible before sending to a sorting facility increases efficiency. Plastic resin numbers is one such way that the plastic manufacturer can indicate to the recycling facility the type of plastic used. Not all plastic resin numbers (https://www.2ea.co.uk/Plastics--Resin-Codes-What-do-they-mean.html) can be recycled, or require specific facilities to do so.



## 4. Using Clean Resources

Offsite, modular-construction allows for easier selection of recyclable or sustainable (https://www.e-builder.net/blog/what-is-sustainable-construction-building-more-with-less/) building materials such as timber. Timber, also known as lumber, is mainly used for structural purposes in buildings and can last around a hundred years. As carbon is locked into the timber during this time, this helps to lower the embodied carbon (https://www.e-builder.net/blog/5-ways-to-reduce-embodied-carbon-on-your-next-building-project/) of the overall project.

While it is not currently possible to build skyscrapers on the scale of which we associate with the Empire State Building without concrete and steel, the height of buildings that can be made from timber is increasing (https://constructionreviewonline.com/biggest-projects/top-5-tallest-timber-buildings-in-the-world/) to over 80m with modern methods of construction (https://youtu.be/p_8LlcuV0gc). The new Forest Green Rovers football club stadium (https://www.fgr.co.uk/eco-park) in Gloucestershire has recently won planning permission to be the world's first wooden football stadium.

Bamboo is another "wonder" material which grows very quickly (3ft a day) and absorbs carbon from the air while doing so. It has a higher tensile strength than steel but is prone to natural degradation. The Swiss Institute of Technology (https://ethz.ch/en.html) is looking into bamboo fibre composites as an alternative to steel. It has the potential to be as strong as carbon fibre, at 1% of the cost. As carbon budgets are applied to projects, attention will increasingly turn to the embodied energy of building material selection.

# Sustainable Construction Materials Retrofitting and Renovation

## 80% of the buildings that will exist in 2050, exist today. The next boom in Construction will be in retrofitting (https://www.insidehousing.co.uk/home/home/london-councils-reveal-98bn-plan-to-retrofit-38-million-homes-72906). It is important therefore, that efforts aren't only applied to new builds, where new, advanced building techniques can be deployed to solve carbon and waste issues, but rather to fixing up our existing stock.

The UK, Denmark, France, Hungary, New Zealand and Sweden (https://www.visualcapitalist.com/race-to-net-zero-carbon-neutral-goals-by-country/), all have net zero emissions (https://www.wri.org/research/designing-and-communicating-net-zero-targets) by 2050 targets enshrined in law. Other countries either have policy documents making emission reduction commitments, are proposing legislation, discussing making commitments or have made none at all.

The trend is that countries will gradually move to legally enshrined net zero targets over time which will bring with it the impetus to favor low emission / highly efficient buildings over low quality, cheaper stock. This can already be seen in motion by the UK's new budget for retrofitting buildings in London (https://www.insidehousing.co.uk/home/home/london-councils-reveal-98bn-plan-to-retrofit-38-million-homes-72906), the attention to housing in Glasgow (https://glasgowcityregion.co.uk/what-we-do/strategyand-programmes/economic-recovery/housing-energy-retrofit/) ahead of COP26 (https://ukcop26.org/), as well as the new infrastructure bank (https://www.ukib.org.uk/) that has been established as the first of its kind in the UK.

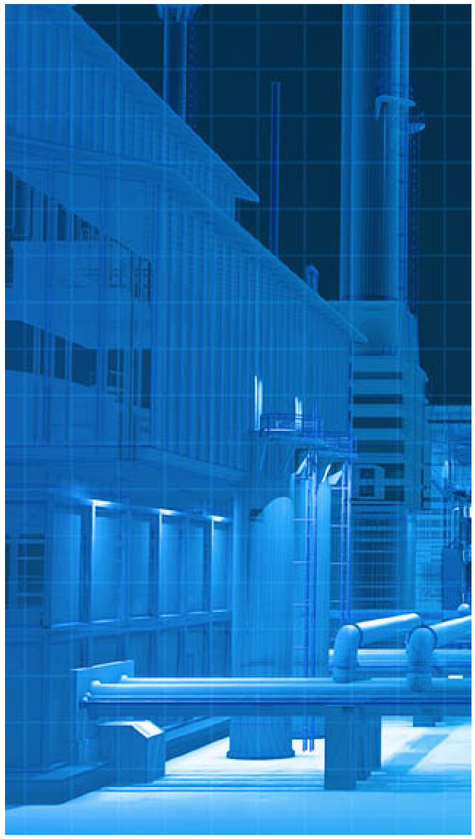
In the UK for example – on a thermal efficiency rating scale of A-G –74% of the housing stock (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/724339/Energy_efficiency_2 is rated between D-G. This means only 26% of housing has an A-C rating for thermal efficiency (as of 2016 – up from 10% in 2001). It is understandable if looking back in time where fuel prices were cheaper and there was a demand for quick builds; but modern requirements are for efficiency and longevity.

## So how do we cost-efficiently refurbish outdated buildings to meet modern requirements?

It is possible to retrospectively create an internal and external model of a building using laser scanning solutions (https://geospatial.trimble.com/3DScanning?gclid=CjwKCAjwkvWKBhB4EiwA-GHjFlBQZqW3ZKiJtAd66ikSYGi3qW9mr-fG4BcbjmjXfMwCDGOiwHHF3RoCbz0QAvD_BwE). This can produce an accurate digital twin of the building.

Original schematics could provide component material types and age to allow for smart predictive maintenance. The business case is there for commercial real estate managers concerned with the operational costs of an asset over time.

Cheap, nature-based solutions are also an aspirational target. Living walls/panels can be a relatively cost effective way to improve insulation by fixing them to external walls, as well as providing some greenery for insects, absorbing some emissions from the air, and giving people a sense of wellbeing. By increasing the performance of a building cheaply, it can help reduce the need to replace and therefore recycle old components of building stock.



There is also the risk factor of climate change to consider for investors, as operational costs rise and the attention to sustainable developments increases. Climate risk modelling plays an increasing role in financial systems, as risk is a key evaluator for stocks and shares and insurance companies.

Downplaying climate or environmental risk can cause serious issues for unaware customers or investors. The impacts of unsustainable development can be seen in the effects of Hurricane Katrina in New Orleans, where reckless development was undertaken below sea level whilst also eroding the wetlands (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1332684/) of the Mississippi Delta and removing this buffer against storm surges. The same is true for substandard infrastructure in affordable housing, which will be more susceptible to storm shocks and may be excluded from insurance coverage when in high risk areas of weather events.

## New Construction Builds: Sustainability Across the Entire Building Material Life Cycle

Looking to technological innovations to solve issues associated with climate change and waste is known as a technocratic or a "golden bullet" solution, and the danger is that the industry holds out for such innovation. However, with 20% of buildings in the next 30 years forecast to be new builds and new building regulations becoming more stringent, there is still great scope to apply such methods, while slowly transitioning the old stock to align with modern standards.

The potential application of new building techniques as well as the building requirements for new builds are broad and ever developing. A digital twin (https://www.e-builder.net/blog/the-future-of-as-built-drawings/) and building passports (https://www.greenfinanceinstitute.co.uk/wp-content/uploads/2021/03/GREEN-

FINANCE-BUILDING-RENOVATION-final.pdf) will likely play a role as we enter an era increasingly influenced by data. This is easier to implement in new builds, where a record of a building's 3D model can already exist, along with component material selection.

Modelling software can now provide sustainability insights, such as the Life Cycle Assessment (LCA) tool Sefeira (https://www.sketchup.com/products/sefaira), available as a plug-in for Sketchup, or the collaboration between One Click LCA and Trimble (https://www.prnewswire.com/news-releases/trimble-and-one-click-lca-collaborate-to-provide-embodied-carbon-calculations-for-different-phases-of-construction-projects-301395988.html), allowing users of Trimble's Tekla BIM software to calculate carbon emissions at different phases of a project.

Environmental Impact Assessment (EIA) tools link the environmental context (e.g. surrounding ecosystems) of a building to design considerations. The two most commonly used approaches to analyse the environmental performance of a building as a whole are Life Cycle Assessment (LCA) and Green Building Rating Systems (GBRS) (https://eprints.qut.edu.au/209067/). Whilst GBRS are mostly based on qualitative criteria, LCAs are more quantitative, facilitating the comparison between design choices.

Some GBRS, such as LEED, BREEAM and Green Star, have been incorporating LCA (https://www.sciencedirect.com/science/article/abs/pii/S235271022100036X#!) as part of their assessment system – with LCA tools becoming acceptable to the accreditation program. The application of a circular economy approach can therefore help buildings achieve certifications (https://www.breeam.com/BREEAMUK2014SchemeDocument/content/10_waste/waste.htm) such as BREEAM when applied in the planning stage.

# Transitioning to Recycled Building Materials

If all the concepts involved in a circular economy are applied, we will need to recycle and reuse less, but nevertheless the need will be there. But why would a construction company opt to use recycled materials, when a change to business as usual can introduce disruption to supply chains or design considerations?

The incentives are increasing—with countries and municipalities setting carbon budgets (https://www.theade.co.uk/assets/docs/nws/Buildings_and_the_5th_Carbon_Budget.pdf), funding is often available (e.g. European Regional Development Fund and potentially the Infrastructure Bill (https://www.e-builder.net/infrastructure/) in the US) for innovative techniques used in industry that help to meet these goals.

The same can be said for planning permission – when a project can be shown to aim for a positive impact on society, it is more likely to be granted permission. In the UK for example, 230 councils have declared a climate emergency and give preferential treatment in ITTs and PQQs when environmental considerations are taken into account in a development project. It's also a great PR opportunity for a company's reputation.

The challenges lie in bringing projects from concepts to reality. Connected construction (https://construction.trimble.com/en/trimble-connected-construction?gclid=CjwKCAjwtfqKBhBoEiwAZuesiHRyBCTdMM0FmxbqB2jJk3r1PecQ9jdtKHrRpjoSfjNFKeLuB-SiZBoC1doQAvD_BwE) has great potential in this regard. With data guiding component material selection from the concept phase to realisation, building passports can become more mainstream, where there is visibility into the material selected, its history and an associated life cycle assessment for the project as a whole.

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**Duncan Wiliams**

Sustainability Manager – Leeds – United Kingdom

Duncan is an environmental specialist, with over five years' industry experience in environmental management, ecology, geodesy and surveying. Prior to his industry experience, Duncan gained an MSc. in Sustainable Development, and a BSc. in Conservation Biology. He hopes to help Trimble become a leader in sustainability and adopt practices that help us become market leaders, as well as protecting the planet. His interests are climate change, ocean governance and growing fresh fruits and vegetables.

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