V1.0

White Paper:

How to reduce embodied & lifecycle carbon in balconies.

25/05/21

UK/CA

MD250521NRH

SAPPHIRE®

Executive Summary

In a world where focus is more and more being put onto sustainability, and where at these early stages of the process, it is often lacking clarity and consistency, we explore what some of the common talked about challenges are and how generally the industry considers the priorities lie.

We explore:

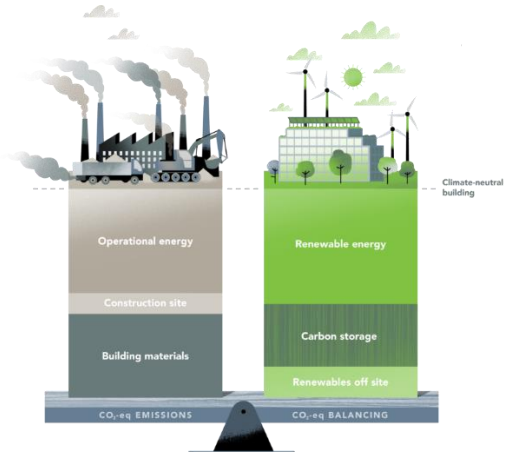
- What 'Carbon Neutral' is. We debunk the myth that there are certain products which can simply be bought as 'Carbon Neutral', we show the ethical approach of reduction then offsetting to achieve this.
- The Whole Life Carbon (WLC) of a building looking at what needs considering and why.
- The 3 main types of Carbon to consider: Embodied Carbon, Operational Carbon of Companies and Operational Carbon of the building during its life.
- The importance of factors like recycled material content and the 'Red List' and why Carbon is the more important factor.
- We study example balconies constructed of various materials and consider the theoretical Embodied Carbon of each.

Is it a myth that there is such a thing as Carbon Neutral construction products?

The short answer is no there is not really unless you do something about offsetting it or it natural reduces carbon like a living tree! In reality, to build buildings either traditionally or with Modern Methods involves many workers and materials travelling to the site and even if these are minimised each material requires some element of energy to produce, assemble etc. meaning that in reality all products have embodied carbon. That said the reduction of carbon emissions both in the build and the ongoing use of the building is a key role we all play, after which offsetting this comes into play to make a product "Carbon Neutral".

Although the balcony is only a small part of the overall construction project, it is clear that "Carbon Neutral" construction is not only a laudable and ethical goal, but an achievable one. The target of entirely carbon neutral new builds, particularly in the large residential/commercial project space, *is* achievable *when* specific steps are taken.

Whilst not specifically mandated in legislation across most countries building regulations, carbon neutral construction is widely seen as important for meeting the 2016 Paris Accord agreement. The 2016 Paris Accord aimed to make all new build projects carbon neutral by 2030. Climate awareness is also increasingly important for the public & hence affects all industries.



Source: White Arkitektur

Whole Life Carbon

Together, operational, and embodied emissions over the whole life of the building are known as whole life carbon emissions (WLC), and these factors are what are being considered by key stakeholders. Whilst Sapphire Balconies products make up only a small percentage of the “carbon costs” of the envelope of the building, and even less overall, we still recognise that facilitating our clients’ goals in this regard is essential. We at Sapphire Balconies believe that we are well placed to help our customers achieve the minimum carbon creation possible, and that our balconies can play a role in achieving buildings that are as energy efficient as possible, prior to any offset efforts.

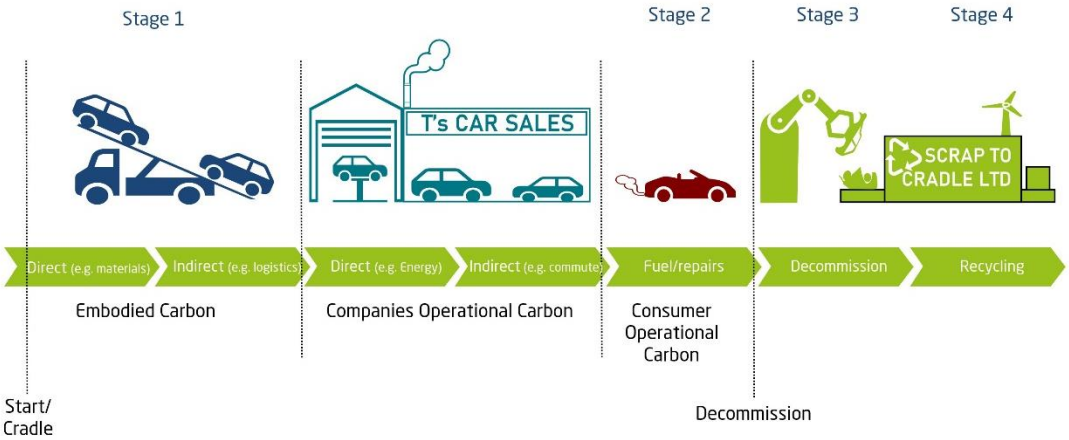
An assessment of WLC impact must contain several stages- including Upfront, Use-stage embodied, and End-of-life Carbon. The manufacturing and installation aspects of Sapphire Balconies can be seen within the context of upfront usage, with the lifetime carbon cost of the balcony the latter stages.

The following information will detail the current progress and situation for balconies generally as well as Sapphire Balconies when it comes to the carbon generation/present in the generation of raw materials through the construction and occupation phases.

Given that balconies are connected to the outside of the external envelope there is always the issue of cold bridging to think about. Thermal bridges (read more about these in our thermal bridging whitepaper) need to be a major consideration when considering carbon. The reason is simple; if you do not have a thermal break, a lot of thermal transfer or ’bridging’ will occur through the slab and obviously heat requires energy, and usually carbon emissions go hand in hand. Whilst in Europe, the are mandated in many countries, in North America, they are yet to be mandatory in most areas.

Practical steps for considering whole life carbon.

To understand the Whole Life Carbon, it is easiest to start with a familiar analogy, the lifecycle of a vehicle. There are four stages to both:



1. **Creation of the product and delivery to its new owner**. This is where we look at embodied carbon. Both direct such as carbon from the aluminium, steel, rubber etc. and the indirect which may be the shipping of the goods to the factory or the delivery of the finished car. In construction terms, everything up to handover.
2. **The use of the product.** With cars we will be familiar of putting in fuel and seeing exhaust fumes. This is where the operational performance makes a big difference to the carbon footprint, in the case of a car this is likely to be the biggest part of carbon emissions. We are familiar with considering different fuel types and the efficiency of a car in performing its function. In a building it is not much different. The type of fuel used

and how much heat is used/lost. In essence the performance of the façade and other components make a big difference for the years of the building's life.

3. **Decommission.** Most cars probably end up being mainly recycled, however things like batteries may be difficult to recycle or reuse. In a building, many components may be able to be recycled however concrete frames and other materials like this may be really difficult to effectively recycle. Often these products will be referred to as cradle-to-grave.
4. **Recycle/reuse.** The purpose of recycling is to bring the same materials back to the start to avoid as much of the embodied carbon as possible. In the purpose of a car, think of it as perhaps taking an engine and wheels etc from a written-off car and using them in another car. Like a car, a lot of the metal products can be recycled and in the case of aluminium, this can save up to 90% of the energy compared to the process of creating virgin material. This is often referred to as cradle-to-cradle. There is an interesting interview about the reuse of materials in new buildings between White Arkitektur and Resibuild.

Along these 4 stages there is also the operational carbon of those who are operating businesses which support or involved in the lifecycle. This is the **company's operational footprint,** and this happens alongside the 4 stages and is not directly related to one of these steps. With both buildings and cars there are various businesses which assist at different parts of its life (maintenance, cleaning, repair's, upgrades, etc.) all these companies have a footprint. In the case of Sapphire this has been reduced and offset to make it carbon neutral as explained later.

Aspiring for "Net Zero"

Traditionally, when applied to construction, net zero carbon has usually been understood to apply only to a building's operational energy usage & efficiency. However, for a new-build structure, completed to modern standards, emissions from operational energy could account for as low as 4-5% of total lifetime emissions, particularly in residential construction (Allowing for grid carbonisation). Hence, a fuller definition of net zero must include *embodied* emissions from materials sourcing & manufacture, as well as construction, maintenance, repair, replacement and so on.

The relationship between balcony cost and carbon

We are now all very familiar with being offered a variety of options which are better for the environment or more sustainable. (FSC, Fairtrade, Rainforest Alliance, etc., etc.) and with most we are used of seeing a premium price tag. Well, the good news is different with a lot of the reduction process of carbon in balconies.

Embodied carbon: reducing anchors, reduce the weight of a balcony, reducing transport trips to site, reducing complexity to create better material utilisation and less waste. All of these reduce the embodied carbon but also reduce the material and the design complexity to deliver them. We are used to seeing this as a cost saving but the two work well to the same end of saving carbon and cost.

Operational carbon: again, the reduction of the number of penetrations and the simplification of the façade (e.g., removing intricate door reveals etc. both cut cost considerably but also help to maintain the best thermal performance of a façade. Again, cost and carbon work together. In addition to the construction cost savings, a better performing façade means less heat loss which ultimately means less carbon and reduced running costs during the life of the building.

How to reduce embodied and lifecycle carbon in balconies

Embodied Carbon (Stage 1)

Manufacturing

Sapphire Balconies is following the worldwide standard of the Greenhouse Gas Protocol Initiative, which offers a widely accepted overarching framework that distinguishes between a company's direct GHG emissions (Scope 1), electricity indirect GHG emissions (Scope 2), and other indirect GHG emissions (Scope 3).

Our balconies use a unique design composed predominantly of aluminium, sourced mainly from modern mills in Europe. Whilst there is a necessary carbon cost from this manufacturing process, our use of recycled aluminium and up-to-date facilities can keep this to a minimum. Sapphire balconies weigh around 30% of a steel balcony, and around 18% of a concrete balcony- using dramatically less material by weight. Sapphire Balconies have undergone a detailed process to work out the *true* carbon impact of our Glide-On balconies, as compared to those of competitors. This long-term process has considered as many factors as possible to ensure the most accurate result, including gases created from manufacturing, transport & installation.

Case Study Comparison

To get an understanding of what three similar looking balconies would typically have as embodied carbon we have taken a case study of a project. The assumptions are that balconies are an approximately 4mx1.5m balcony with vertical bars and approximately 90 miles from the factory where assembly/fabrication happens. It is assumed that there are materials being shipped from the other side of the world (approx 5000miles) and that final delivery of both metal balcony types can enable an average load of 5.5 balconies per delivery throughout the project.

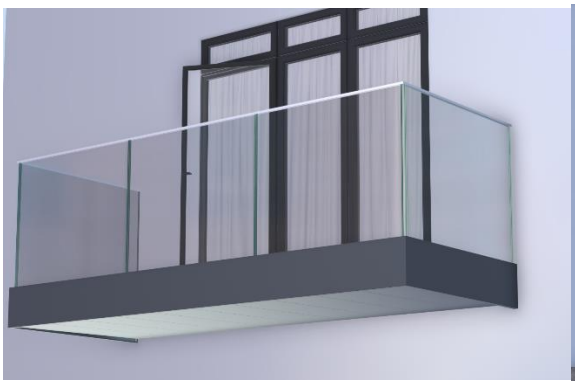
Option 1 is a vertical bar balcony example.

Images captured using COACH balcony software coach.balconies.global

	ALUMINIUM		STEEL		CONCRETE	
Raw Material / tonnes	2.32	95.3%	3.66	96.7%	4.09	96.7%
Material Shipping / tonnes	0.06	2.3%	0.21	5.6%	0.34	8.0%
Travel of workers / tonnes	0.01	0.6%	0.05	1.4%	0.08	2.0%
Production / tonnes	0.02	0.8%	0.03	0.7%	0.03	0.8%
Site Delivery / tonnes	0.02	1.0%	0.04	1.2%	0.02	0.5%
Embodied Carbon per balcony	2.44	tonnes per balcony	3.79	tonnes per balcony	4.23	tonnes per balcony
Embodied Carbon per m^2	0.41	tonnes/M²	0.63	tonnes/M²	0.71	tonnes/M²

How to reduce embodied and lifecycle carbon in balconies

Option 2 is a structural glass balcony example.



Images captured using COACH balcony software coach.balconies.global

As can be seen above, when going by the average UK balcony size (4m x 1.5m), embodied carbon in balconies produced in aluminium by Sapphire result in much lesser quantities of carbon produced as compared to the popular alternatives of steel and Aluminium.

	ALUMINIUM		STEEL		CONCRETE	
Raw Material / tonnes	2.52	93.6%	4.01	97.0%	4.71	97.2%
Material Shipping / tonnes	0.10	3.8%	0.21	5.1%	0.34	6.9%
Travel of workers / tonnes	0.03	1.0%	0.05	1.3%	0.08	1.7%
Production / tonnes	0.02	0.7%	0.03	0.7%	0.03	0.7%
Site Delivery / tonnes	0.02	0.9%	0.04	1.1%	0.02	0.4%
Embodied Carbon Per Balcony	2.70	tonnes per balcony	4.13	tonnes per balcony	4.85	tonnes per balcony
Embodied Carbon per m^2	0.45	tonnes/M²	0.69	tonnes/M²	0.81	tonnes/M²

Key Embodied carbon Takeaways

- Sapphire's Aluminium balconies generate only 62% of the CO2 per Square Metre that a comparable steel balcony does, and just 54% of the CO2 per Square Metre generated in for Concrete Balconies. This covers all the way from Raw Materials to Delivery & Installation on site.
- Sapphire's CO2 generation during delivery is comparable to those of others, with additional efficiencies possible. However, raw material transport is greatly reduced.
- The CO2 generated at the typical key Sapphire subcontractor during manufacture from raw material is 67% less than Steel & Concrete balconies.

Even though aluminium has a far higher level of CO2 per tonne when produced, the lower density of an aluminium balcony equates to a lower overall level of embedded carbon- our superior design and process ensure that the manufacturing process of our balconies creates less emissions than concrete and steel. Our balconies are manufactured at our trusted subcontractors in the UK, which use modern processes and typically enables low distances travelled for delivery after manufacture. Our balconies are also typically carried in greater quantities per vehicle, due to their lightweight design, reducing overall emissions from transport.

How to reduce embodied and lifecycle carbon in balconies

Sapphire Balconies are keen to assist customers with carrying out a whole life carbon (WLC) assessment regarding our balconies, and we believe the analysis tools, (such as our carbon by postcode calculator with over 1M postcodes in 4 countries), as well as efficient balconies make us well placed in this regard. Sapphire continues to explore improvements that can reduce the emissions generated during the manufacturing process, including greater use of sustainable materials, material reduction. Working closely with contractors is also important in this regard.

Installation

The installation of the balcony generates quantities of greenhouse gases due to the reality of the need for personnel travel, heavy plant, machinery etc. However, due to Sapphire Balconies' pre-existing philosophy of efficient install, this process is significantly simplified compared to similar products.

How Sapphire's Engineering Drives Carbon Efficiency – An Example

Sapphire brackets are particularly simple to fit as the beam stub is pre-assembled onto the anchor in the factory and cast into the slab as one assembly. All that is required to do once casting has happened is to fit an arm to each stub using four bolts. Whilst there is tilt adjustment to the stub if necessary, this rarely needs to be used in practice as the balcony cassette design is such that full adjustment can be made within it. Once the arm is fitted and the façade finished, the installation phase is very fast- as many as 44no balconies have been fitted in 7 hours on a single day using our Glide-on system. This saves both time and cost, but also reducing energy usage and emissions from travel, heavy plant, and other systems. Sapphire continually pushes towards improving our systems, both reducing material utilisation and also the efficiency of assembly, transportation and installation.

Technologies and processes that are under development at Sapphire, or have already seen use, include the creation of a balcony where the finished deck is the structure- reducing waste, emissions, and aluminium usage & reduced size anchors. Other innovations include the use of RLDs (Remote Locking devices) to lift balcony arms within the balcony- again saving resources on site, in particular that of crane time and personnel.

Operational carbon of the building (Stage 2)

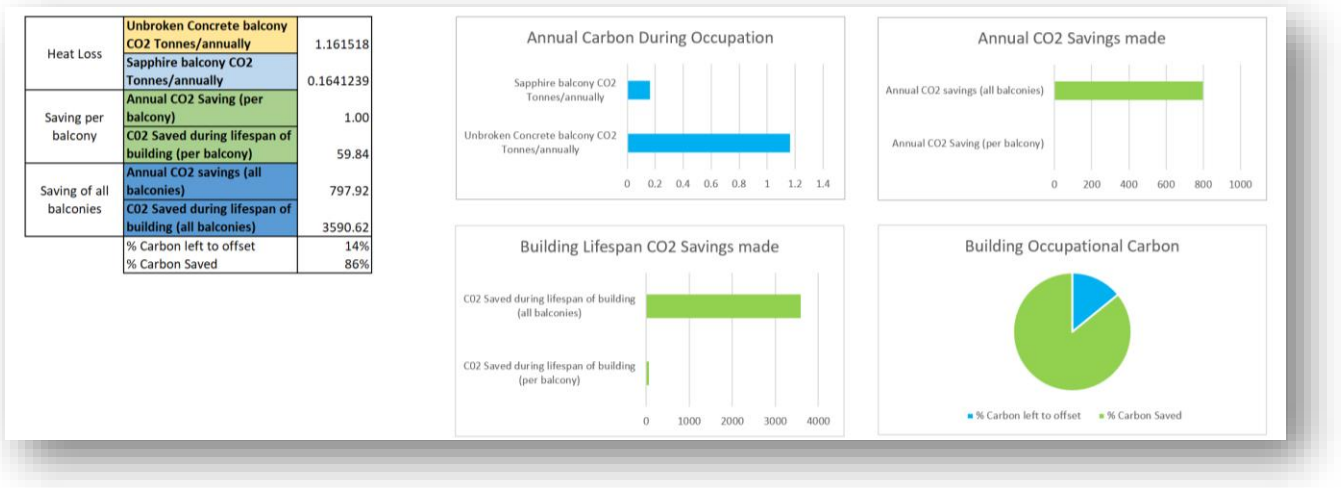
By far the most significant aspect of whole life carbon emissions as regards our balconies is the escape of building heat via the balcony anchor, generally more so than initial manufacture and installation. Whilst in the UK building regulation Part L already mandates a thermal break, not all countries do, even many harsh climates still are yet to mandate this in their building codes. That said we undertake significant efforts to reduce this as much as possible and have done prior to Carbon Neutral policies becoming significant in recent years. Our mild steel stuns arms and end plate attaches to the concrete slab, which would be the only source of heat transfer- via the floor slab and wall area very close to the anchor. Therefore, Sapphire Balconies utilise a dedicated thermal break between the bottom of the end plate and the floor slab edge to limit the thermal transfer as much as possible. We regularly review the number of anchors to see if the loads can be achieved with a good safety margin but with less anchors. Depending on the wall construction it may also can work to reduce the penetrations by fixing to external walls rather than back into the slab. In turn these lead to lower heating costs and of course reduced carbon usage, which becomes significant as part of a whole life carbon assessment. Trade-offs between absolute thermal efficiency and balcony rigidity must be made, however our Research and Development department is continuing to develop the most effective solution possible.

Sapphire Balconies are currently in final stages of developing an offering to improve the thermal efficiency further by potentially having a greater gap between the concrete slab edge and the back of the arm end plate and reducing the amount of metal used within the cavity to transfer loads back into the slab. A thermal FEA has been produced and performance analysis is being conducted with experts in both the UK (Oxford Brookes University) and North America (RDH).

Working out a specific project locations heat loss

If you can work out the degree days and the thermal heat loss of a balcony anchor at a specific site, you can then work out how much carbon could potentially be saved.

Sapphire has created a tool which does just that, the COACH location specific carbon calculator. The tool contains location specific data which covers over one million postcodes across Canada, Ireland, NZ, and UK. Entering the balcony dimensions, lifespan and postcode enables the tool to draw relevant information form the database and provide location specific graphs comparing concrete and aluminium balconies.



Heat Loss	Unbroken Concrete balcony CO2 Tonnes/annually	1.161518
	Sapphire balcony CO2 Tonnes/annually	0.1641239
Saving per balcony	Annual CO2 Saving (per balcony)	1.00
	C02 Saved during lifespan of building (per balcony)	59.84
Saving of all balconies	Annual CO2 savings (all balconies)	797.92
	C02 Saved during lifespan of building (all balconies)	3590.62
	% Carbon left to offset	14%
	% Carbon Saved	86%

Source: *COACH location specific carbon calculator found here*

End of life – decommissioning and recycling (Stage 3/4)

When it comes to the end-of-life of Sapphire balconies, Glide-On aluminium balconies (like steel) can be easily recycled, unlike concrete which needs to be crushed or pulverised. The decommissioning of a Cassette balcony is made much simpler because of the nature of the component based, weld free assembly meaning that parts can be taken apart and easily sorted into similar material types.

The Role of recycling

There are two roles of recycling in the reduction of balcony related Carbon; these two areas are:

1) As we have already discussed, a lot of the embodied carbon within a balcony product is directly related to the materials used. Recycled content does mean that a significant change to the percentage of recycled content within the aluminium for example could save between 0.5 and 1 Tonne of Carbon. Unfortunately, it is not quite that easy. A lot of aluminium used in sheet and extruded aluminium products is already using recycled content. For example, it is estimated that 75% of UK aluminium used for extrusions for construction are recycled content. But some sheet or extrusion products may not be readily available in recycled content for the specialist grades needed for processes like anodising. Especially with factors like the global shortages of aluminium seen in 2021. In reality you may be able to save embodied carbon with a lot of research however it is dwarfed by the savings during the operational phase of a building's life. (0.5-1 tonne of carbon max embodied saving vs 0.85 tonne saved each year by reducing heat loss in the building by getting the connection right).
2) End of life recycling is a key benefit to aluminium and in the context of a balcony is when a building is decommissioned. The Council of Aluminium in Buildings suggest that 95-98% of aluminium can be recycled again and that 75% of all aluminium produced is still in use thanks to the durability of the metal and its excellent recycling characteristics. When aluminium is recycled, the process of recycling is significantly less energy consuming than the original conversion process. Some figures suggest by as much as 10 times the energy is used with virgin material vs recycled material. Some examples where aluminium structures have been dismantled demonstrate that a 97% recycling and reuse rate can be achieved, even with offshore located structures. Again, if recycled into balcony products this will result in a reduction of the embodied carbon of a new balcony product.

Sapphire's Operational Carbon

The final part of the carbon reduction and offsetting in balconies is the reduction in the operational carbon of those in the supply chain. In the case of Sapphire, we have reduced and offset these as follows:

Sapphire Sustainability Policy & Active Offset

Sapphire has worked with external carbon specialists in formulating a forward-looking company policy to set a clear pathway for the reduction of carbon generated from company activities, from the manufacture and supply of Balconies to our daily operational usage of electricity, fuel and so on. Hence, agile working practices, changeover to renewable energy supply, electric/hybrid vehicles etc have either already been implemented or are under consideration/analysis to form long term improvements year-on-year as we head into the future. In having reduced our 2021 carbon activities we have now offset the remaining balance with certified investment credits. Whilst making our operations carbon neutral, since this point, we have further analysed and reduced our carbon meaning that our carbon offset has covered more carbon than the remaining. Leaving a carbon positive effect.

Sapphire Corporate Goals

We are focusing on two key ongoing goals, both of which have already been hit during 2021:

1) To decrease the carbon 5% per balcony year on year. (this is in addition to pushing for the offsetting of all remaining emissions.
2) To decrease our operational carbon per employee by 5% year on year.

Becoming carbon neutral through biodiversity investment.

Sapphire has worked with a leading climate solutions developer, to achieve certification as a company with carbon neutral operations. Sapphire has worked closely with supply chain specialists to identify, analyse, and reduce our emissions and carbon footprint. In doing so we have implemented steps like switching to 100% renewable energy supply etc and have now offset the un-avoidable/remaining carbon through investing into certified investment programs funding forest protection initiative in Zimbabwe and in Columbia.

We have specifically chosen these schemes and chosen to invest in forests because carbon and biodiversity specialists suggest that evidence points to forests being the most effective climate solution because you are saving mature trees with full capacity of carbon storage. New planting is a positive step however saplings take years to reach to their maximum storage meaning that the offsetting capacity is much more limited for their early stages.

The biodiversity projects Sapphire have invested in so far are:

Kariba Forest, Zimbabwe

At more than 785,000 hectares, Kariba REDD+ is the largest community forest conservation and protection initiative in Zimbabwe. In recent years, more than a third of Zimbabwe's forests have been lost to agriculture, forest fires, and wild poaching. By teaching and supporting conservation farming, the project provides a more sustainable livelihood to local families, most of whom are small scale farmers.

Project activities include conservation agriculture, community gardens, beekeeping training, fire management, and ecotourism create jobs and facilitate sustainable incomes, benefiting the entire region. The Kariba conservation project is a community-based scheme, administered by the four local Rural District Councils (RDCs) of Binga, Nyaminyami, Hurungwe and Mbire.

The site of the forest is situated on the southern shores of Lake Kariba, near to the Zimbabwe-Zambia border. It is one of the largest REDD Projects by area and it connects four national parks, eight safari reserves and forms a giant biodiversity corridor for numerous vulnerable and endangered species including African Elephants, Lion's, and Hornbill's.

Vegachi Forest, Columbia

The Vegachi Forest in the Colombian department of Antioquia is one of the least developed and remote areas. Extensive timber extraction from forests and cattle ranching have led to deforestation and degraded lands in the area. By providing education for sustainable forest and land management the project helps farmers to create new livelihoods in this area of nearly 215ha of forest.

The project solution will provide the needed recovery of the native vegetation through the reforestation of 171ha of grazing land which has become degraded. An additional 44ha of forest conservation is part of the scheme which will protect Colombian endemic species like the Colombian Chachalaca and the endangered white-footed tamarin. Together the work connects forest patches and isolated areas of natural habitat and improves the biodiversity of the forest.

There continues to be a positive local community's impact of job creation through reforestation activities like fertilisation, thinning and establishment.

Other balcony sustainability factors.

The effects to carbon of adding balconies to a building.

Carbon effects of balconies go beyond just the embodied carbon. Whist the effects of balconies are varied according to the height and geographic location of a building, this has been studied in detail between Dr Rana of the University of British Columbia and Dr Mughal of The University of Lisbon.

How to reduce embodied and lifecycle carbon in balconies

This research titled “THE EFFECT OF BALCONIES ON ENERGY EFFICIENCY OF MURBs” (Multi Unit Residential Buildings) concludes that whilst methods may differ, adding balconies to a building generally helps decrease operational energy, in addition to providing a connection to the outdoor environment for the residents. This research suggests that if properly designed, MURBs balconies in cold climates can help in enhancing solar gains while in warm climates, they can be useful in providing a sub-space capable of cooling internal spaces.

Whether heating or cooling a building, it generally involves energy use and with-it carbon emissions. There are a few specifics noted in this research, and explored in our interview with the authors, which relate to energy usage:

- In Lebanon (and similar hot climates) adding glazing to a balcony guarding on the west side of a building should be avoided due to creating a heat trap.
- Increasing the projection of the balcony in hot climates can create more shading and contribute to a 10-30% energy consumption saving.
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- Simply adding a thermal break to a concrete balcony can also save approximately 67% of energy consumption.
- In Canada adding a thermal break to a concrete balcony was determined in 2016 to have saved 13% on heating during colder periods and a 1% reduction to cooling loads.

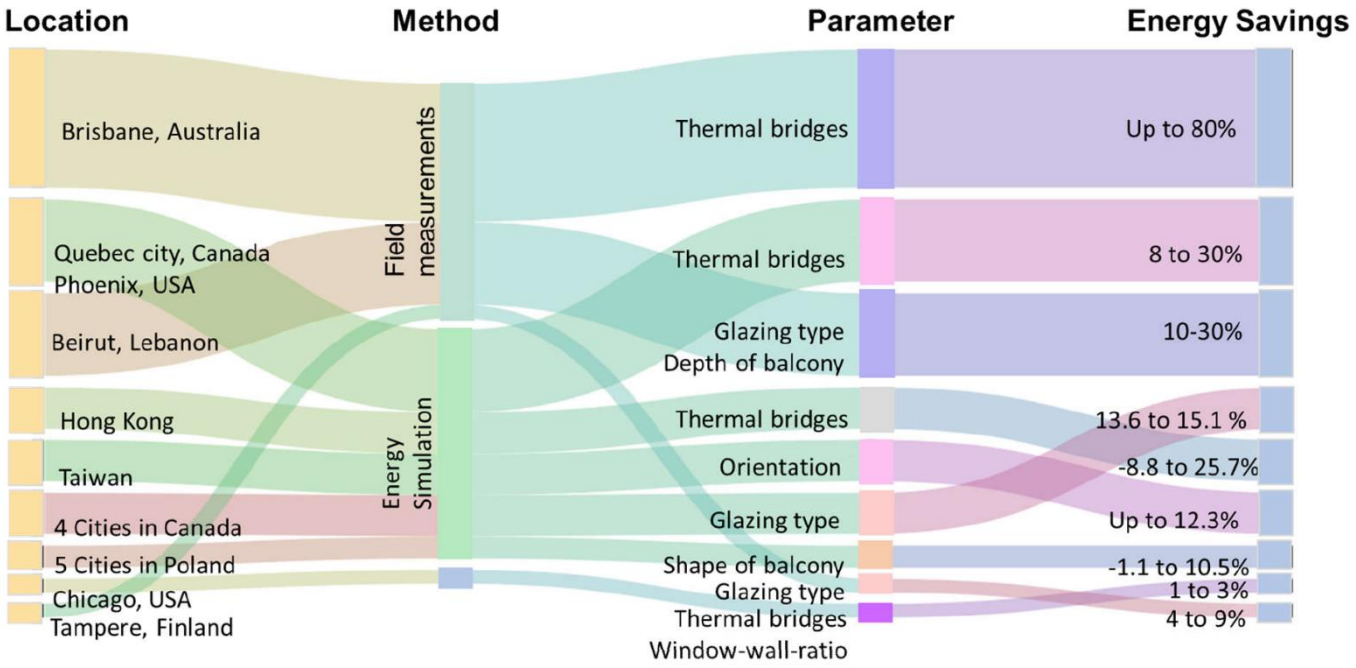

Fig: The effect of balconies on energy efficiency of multi-unit residential buildings (adapted from Rana and Mughal, 2019)

The Environmental Red List

The Living Building Challenge (LBC) has one of the most comprehensive red lists and strictest material certifications in the industry. As of July 2019, the LBC Red List contains 815 unique chemicals across 18 major chemical categories. Their watch list has another 3,400+ chemical compounds that are being reviewed for potential negative health

impacts. Whether looking to improve an architecture firm's material library or pursuing a material rating system for a specific project, the LBC standard is one of the most comprehensive in the industry.

The commonly used chemicals on the Red List are:

- Polluting the environment
- Bio-accumulating up the food chain until they reach toxic concentrations.
- Harming construction and factory workers

Whilst most balcony products do not include items on the red list (except for concrete balconies which are likely to include Chromium VI, a product commonly found in cement), It is not quite that simple. A biproduct of using zinc to galvanise steel can unintentionally create traces of lead and coating processes used by some powder coaters and galvanisers may uses toxic materials in the process, examples of these may be chemical pre-treatments which contain Chromium Trioxide or the use of Lead during galvanising.

Whilst some of these may be processes rather than a material included in the assembly, it is difficult to create a balance of corrosion proof balconies which are sustainable. Using less concrete and less galvanising may well be a design choice you can make however using bare aluminium is probably unlikely, that said it may be possible to choose a chrome-free pre-treatment process depending on materials, size, and coater suitability. Interestingly solar panels, which are widely considered good for the environment, often include materials on the environmental red list.

Across the world, Carbon is generally considered the priority focus for tackling climate change in construction. Our recommendation is that you prioritise your focus on carbon first, then the Red List.

Final Notes and Credits

This research has been led and written by Nick Haughton on behalf of Sapphire Balconies Ltd. We would like to acknowledge the input of others including Wates, White Arkitektur and David Davenport.

We also have several useful carbon tools and information on our website. This includes:

- The location specific carbon calculator
- A sustainability hub

If you have a specific query Carbon do not hesitate to contact our technical team for advice or guidance for your project application.

For more information on reducing carbon, you can book a project specific consultation or a carbon presentation by calling 0344 880 0553, emailing events@sapphire.eu.com or by visiting our CPD Lunch and Learn Presentations page