Net Zero Theatres

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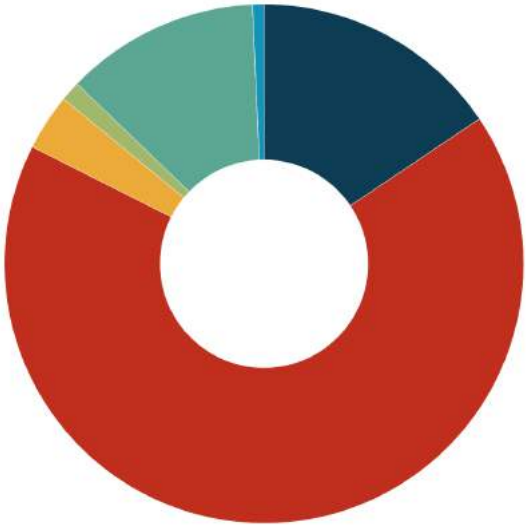
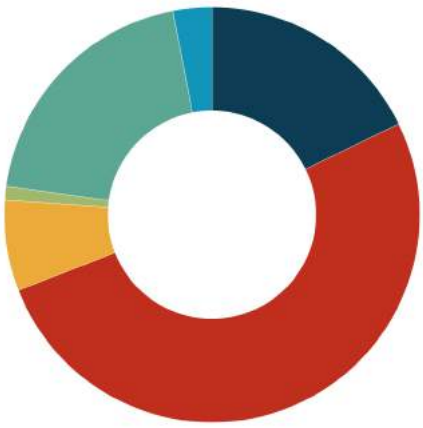
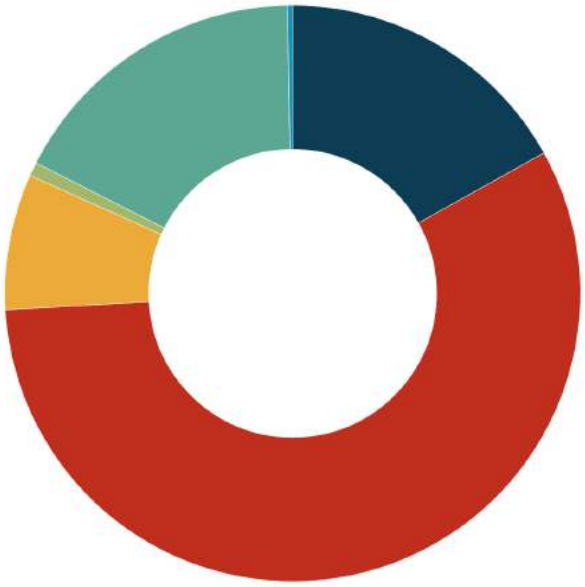
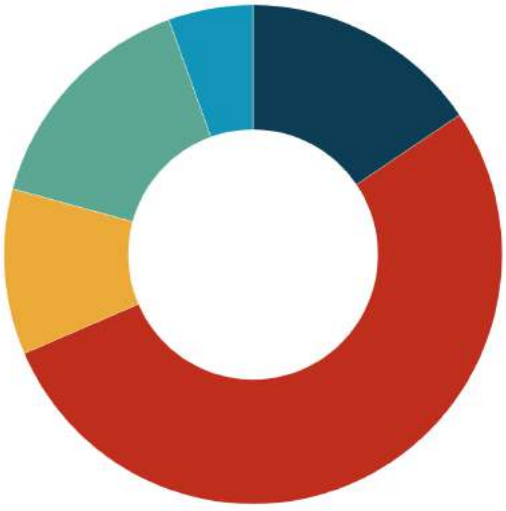








Executive Summary

Bennetts Associates is an architectural practice that is a leader in both low-carbon design and theatre design. Historically these two worlds have not overlapped significantly, but as we seek to half all emissions within the decade, climate action is becoming a theme in all of our projects, and a demand of clients, funders and end users who want projects to align with their values and climate ambition.

The following study is our attempt to start building the framework for integrating ambitious climate change targets into capital theatre projects. It analyses embodied carbon of four theatres with a varying degree of refurbishment and newbuild works: King's Theatre, Citizen's Theatre, Hertford Theatre and Storyhouse. The aim is to gain a better understanding of the most carbon intensive elements and their relationship with technical and commercial requitements of a theatre project. We propose embodied carbon benchmarks and a rating system similar to that used on other typologies.

The study shows clearly that retrofit projects are key to meeting climate change targets, and shows the impact of the upfront carbon (emissions before and during construction) versus the operational emissions. It also shows that there is significant variation within capital projects based on the type of interventions being undertaken and makes it clear that highly technical performance spaces are inherently higher carbon.

Based on our analysis, the elements that have the biggest impact on the figures are structure, substructure and services. Larger structural interventions within the performance spaces, such as constructing a new flytower within an existing stagehouse or creating a large span balcony within an existing auditorium, tend to be areas with the highest carbon intensity. New-build extensions (usually containing front of house and smaller performances spaces) can also be large contributors to the overall embodied carbon; however, using alternative structural materials such as timber can significantly help reduce the embodied carbon a project.

This is an ongoing piece of research and further detailed studies exploring other elements such as services, theatre seating and theatre equipment is to be carried out. Further considerations should also be given to the relationship between embodied and operational carbon and the importance of operational targets. A list of proposed future studies has been included at the end of this report.

With thanks

CUNDALL

MAX FORDHAM

integral engineering design

Bristow

STRUER

November 2021

Introduction

Introduction

It shouldn't come as a surprise that buildings, and the activities that happen within them, form a huge part of the UK's carbon footprint (a little over twenty percent at the last count). These impacts are made up two main components:

- Embodied Carbon: The emissions related to a project's construction, maintenance and end of life. A major part of this is the "Upfront carbon" relating to the initial construction, including the extraction and processing of materials into building products and their transport and installation on site. Upfront carbon can make up a significant proportion of a project's total impact, and all happens in one big spike of carbon emissions. Unlike many other countries the UK does not have regulation surrounding upfront or embodied carbon.

- Operational Carbon: The emissions related to energy consumption within the building by the occupants, which can vary depending on the amount of energy used, as well as the source of fuel used and when the energy use occurs in time as the electricity grid in particular is decarbonising gradually as more renewables are added. Whilst there is a lot of regulation surrounding operational energy, a lot of this is of poor quality and leads to a difference in expectations and reality for many building owners called the "performance gap".

In the absence of policy or regulation of these impacts related to buildings, the built-environment sector has developed voluntary mechanisms that are designed to set ambitious Climate Change targets for buildings: Net-zero buildings.

What is Net-Zero

Whilst in general terms "net-zero" is often associated with climate delay and over-reliance on non-existent technologies long into the future, its use in the built environment sector is better defined and more science-based. In the UK, "net-zero buildings" are defined as the balance of the embodied carbon with high quality offsets (and later removals and storage and the operational energy use with renewable electricity. In addition, to acknowledge that both renewables and offsets are a scarce resource, buildings must use a "fair-share" of embodied carbon and operational energy, for which there are industry defined targets for key typologies (homes, offices, schools). For embodied carbon (and the upfront carbon relating to the initial construction of a project) there is also a voluntary rating scheme that indicates the level of ambition of a project, developed by LETI.

Though this is currently a voluntary framework, certification schemes will soon be available and at a local government level there is a move towards enshrining these targets within planning requirements.

How does this apply to Theatres

To allow designers and clients to align themselves with ambitious climate change action, it is useful to have targets which are based on the "fair share" principle described above. For some typologies, such as homes schools and offices, there is enough information to set benchmarks and targets, whilst some other typologies may be able to align themselves to one of these already defined targets due to similarities. For other typologies with very specific technical requirements (like hospitals) this may not be appropriate, and they require their own targets. Theatres, due to the variety of specialist requirements and technical equipment, fall into this last category. For such projects a more detailed analysis is required to understand the potential differences to establish what targets may be appropriate.

Our Goal

This report seeks to begin this analysis for the Theatre typology, with a particular focus on upfront carbon. Upfront carbon is the emissions source that is the hardest to decarbonise, the least studied and regulated, but arguably the most important.

The study analyses four completed theatre projects with varying levels of intervention, seat numbers and front and back-of-house area. It seeks to highlight the main differences between upfront carbon in theatres compared to other typologies, as well as potential differences between types of theatres, and spotlights the key areas related to theatres with suggestions of lower carbon alternatives. Lastly, it seeks to compare the relative impacts of the upfront carbon emissions with those related to operational energy over the life of a project and outlines future areas for research.

Lastly, the contents of this document are a summary of a large amount of research and calculations, which we intend to publish in more depth on our website in the near future. If you would like to receive an update when this is available, or are interested in any of the other areas of research we highlight please get in touch with us via sustainability@bennettsassociates.com

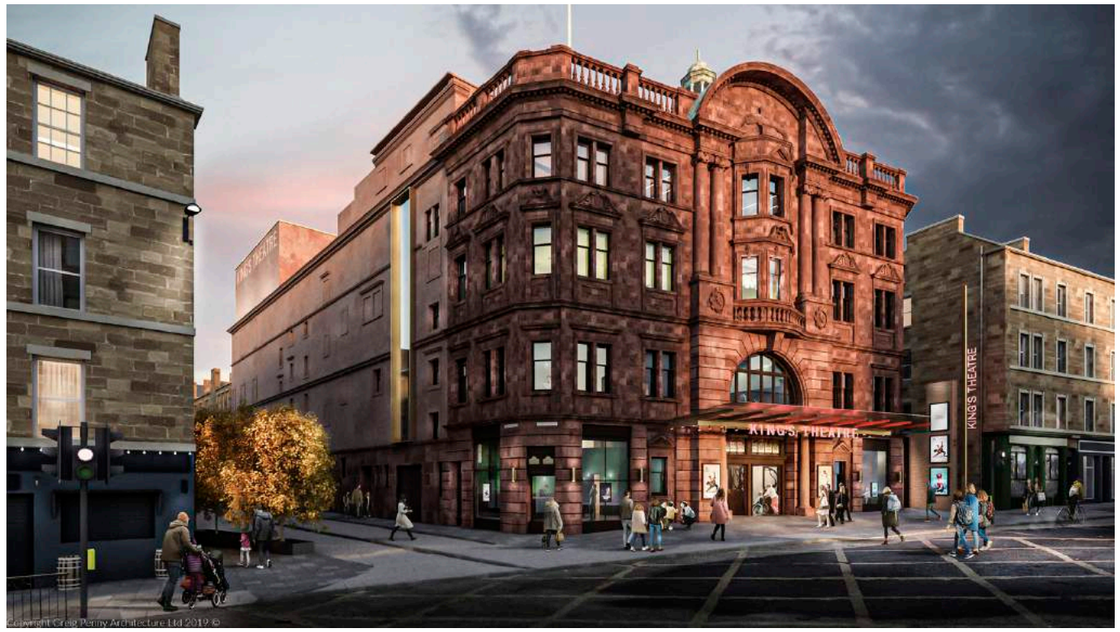
Methodology:

For each theatre a full embodied carbon assessment was undertaken, with quantities and specifications based off a cost plan or bill of quantities with a detailed review by the design team. The assessment was undertaken by Cundall in line with the industry standard RICS professional statement. For each theatre, a doughnut chart is provided showing the breakdown of the full upfront carbon by building element, with the text highlighting key findings. The embodied carbon of MEP was based on cost of various services sub-categories, and only Storyhouse and King's had cost data for theatre specific performance equipment, therefore MEP carbon is likely to be less accurate than other elements. It is also worth noting that Storyhouse is based on a Stage 2 cost plan for non-structural elements and so does not fully reflect the final project, but should be a good indicator of a newbuild theatre.

After reviewing initial findings, it was clear that one of the key differentiators for theatres was the structural upfront carbon of flytowers and auditoria. Alongside Integral Engineering, we took the 3D structural models of all studied theatres and organized all structural components into three zones: Stagehouse, Auditorium and Other. These quantities were then fed into the Institute of Structural Engineer's carbon calculator which allows us to report a breakdown of structural carbon by zone, shown in the second doughnut chart. As some zones have a much larger area, we also divided each zone's total by the area of that zone, which is a much better reflection of the relative impact of that zone [1].

1: As the IStructE calculator does not allocate A5a emissions per line-item we decided to omit this, as it was likely to be proportional to the A1-4 emissions. With more time we would reintroduce the more accurate structural quantities into the RICS assessment to align both analyses

King's Theatre, Edinburgh



Key Data

Operation type	Receiving house
Location	Edinburgh
RIBA Design stage	Stage 3
Year of design	2018-ongoing
GIA (sqm)	4739
GIA new build (sqm)	420
GIA refurbished (sqm)	4319
Number of seats in main auditorium	1100 (reduced from 1300)
Other building uses	Café, bars, event and learning spaces

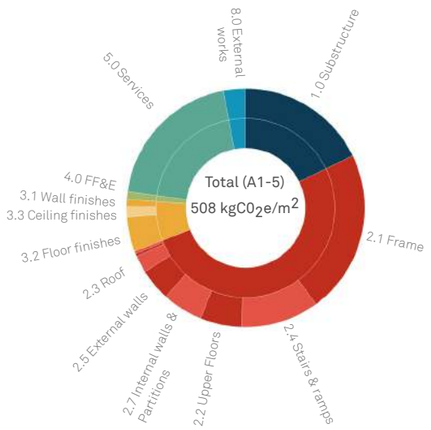
Description

Edinburgh's King's Theatre is one of the most important venues in Scotland's cultural and architectural history. Originally opened in 1906, it has undergone two major refurbishments, in 1950 and 1985. Now over 110 years old, the theatre identified a need for a major redevelopment to protect and enhance the 'A' listed built heritage and modernise the technical facilities to attract the top-quality touring productions. The redevelopment also upgrades the front of house areas to provide accessible and easy to navigate spaces.

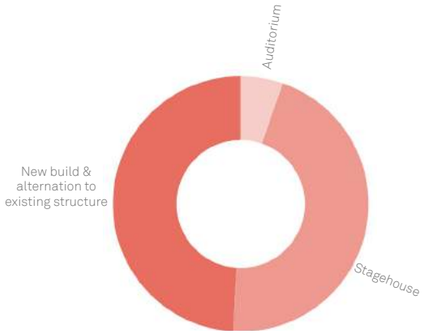
Scope

The project includes an extension and upgrade to the fly tower and remodelling of the get-in and dressing rooms. The number of seats in the auditorium is reduced from 1300 to 1100 to improve accessibility, comfort, and sight lines. Technical installations and services are replaced to provide new gantries, lighting positions, modern sound equipment and mechanical ventilation. Significant structural interventions within the front of house areas are required in order to create new circulation routes and to improve connections to street level. These interventions will provide access to a new bar, events space and a learning studio to support a wide-ranging programme of community and educational activities.

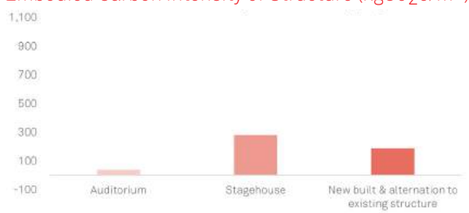
Total Upfront Emboided Carbon ($kgCO_2e$)



Total Upfront Carbon of structure ($kgCO_2e$)



Embodied Carbon Intensity of Structure ($kgCO_2e/m^2$)



Embodied Carbon at Practical Completion

The three building element categories with the highest upfront carbon are the frame (113kg ($113kgCO_2e/m^2$), services ($101kgCO_2e/m^2$) and substructure (90 $kgCO_2e/m^2$). The emissions related to frame are predominantly related to the steelwork used in the extension of the flytower, as well as the remodelling of the front and back of house circulation. Services carbon is generated by the full replacement of theatre specific equipment and ventilation, with the highest carbon elements being the stage's audio/visual systems. Finally, the relatively high carbon of substructure, despite the largely retained building, is due to the reinforcement of foundations below the stage and auditorium.

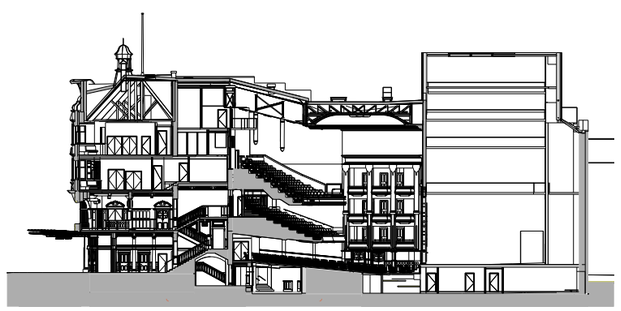
As the refurbishment had a focus on the improvement of accessibility and connectivity, it's not surprising that the fourth highest carbon impact were stairs (54 $kgCO_2e/m^2$) with most of the carbon coming from feature steel stairs in the front of house areas. In contrast, the impact of internal finishes ($35kgCO_2e/m^2$) appears relatively low considering the amount of redecoration, with the most significant contributor being floor finishes (24 $kgCO_2e/m^2$), largely due to the carbon intensity of new carpets.

Looking at the impact of technical areas, upper floors (29 $kgCO_2e/m^2$) stand out, which is mainly due to the steel gallery walkways. For internal walls (28 $kgCO_2e/m^2$) the highest contributor are foam acoustic panels.

Upfront Carbon of Structure

Reviewing the impact of the structure in relation to the three set areas, stagehouse (including flytower), auditorium and other spaces, starts to highlight where theatres as a typology may diverge from others. For King's there is very little intervention in the auditorium proposed, at least structurally, and so the carbon impact is fairly minor. Most of the embodied carbon is split between stagehouse and other areas. However, the relative sizes show that the flytower has around double the carbon intensity per m^2 due to the amount of additional steelwork, grids and technical gantries.

Distribution of embodied carbon across the structure of King's Theatre suggests that auditorium works have the lowest impact, this is due to small amount of refurbishment works needed in that area.



Citizens Theatre, Glasgow

Key Data

Operation type	Producing theatre
Location	Glasgow
RIBA Design stage	Stage 5
Year of design	2012-ongoing
GIA (sqm)	7300
GIA new build (sqm)	3200
GIA refurbished (sqm)	4100
Number of seats in main auditorium	655
Number of seats in studio theatre	140 -
Other building uses	Café, bars, event and learning spaces, offices, rehearsal rooms, workshops,

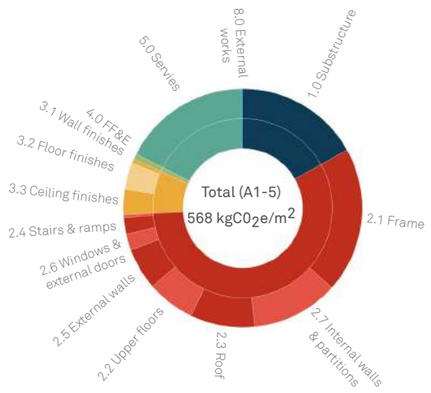
Description

The Citizens Theatre occupies an iconic venue in the Gorbals area of Glasgow consisting of a Grade B listed auditorium and an amalgamation of buildings built over a period of 120 years. After several decades of piecemeal alterations, the redevelopment seeks to take a holistic approach to repair, refurbish and rework the building to secure the theatre's future and help meet its aspiration to be creative, activity-packed organisation with extraordinary heritage where artists and audiences can come together to be entertained, challenged, and inspired.

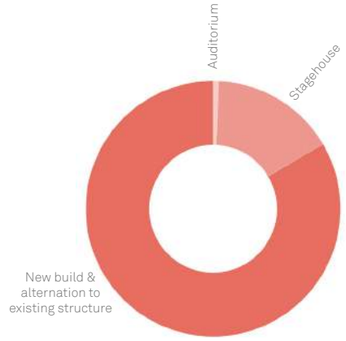
Scope

New flytower and improvements to the historic auditorium and stage house ensure that their condition, comfort, safety and technical capabilities are fit for the future. Audiences will enter the refurbished auditorium through its iconic stone gable via new street frontage and dramatic foyer spaces that will create a vibrant and accessible gathering place that properly supports the breadth of work and inclusive ethos of the theatre. The upper galleries will connect with new spaces for flexible studio theatre, rehearsal, and learning spaces. Actors' facilities and backstage areas are being improved through reorganisation and refurbishment, whilst public access will extend further into the building where the public can see the inner workings of the theatre and its heritage.

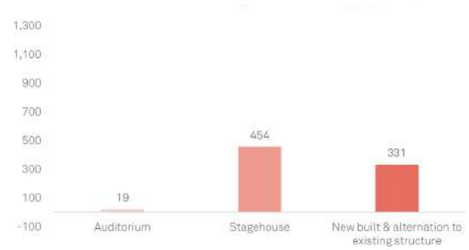
Total Upfront Embodied Carbon ($kgCO_2e$)

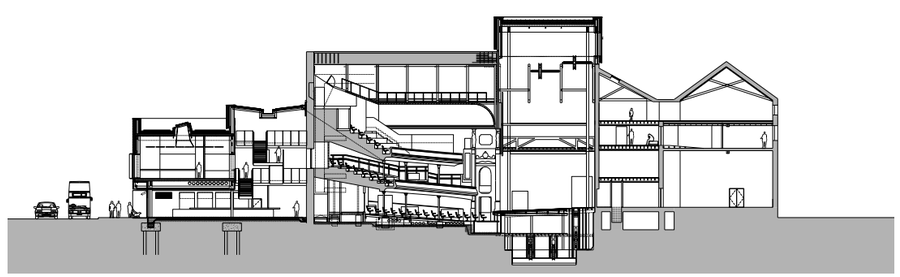


Total Upfront Carbon of structure ($kgCO_2e$)



Embodied Carbon Intensity of Structure ($kgCO_2e/m^2$)





Embodied Carbon at Practical Completion

Similarly to King's Theatre, the building elements with the most significant impact on the upfront carbon are frame (112kgCO_2e/m^2), services (98kgCO_2e/m^2) and substructure (96 kgCO_2e/m^2). The frame and substructure upfront carbon is mostly associated with the upgrades of the flytower and the new building extension steel frame.

The scope of work for the Citizens Theatre involves new build extension and replacement of structures which were not suitable for refurbishment. As a consequence, building elements such as internal walls (67 kgCO_2e/m^2), roofs (50 kgCO_2e/m^2), internal finishes (43 kgCO_2e/m^2) and external walls (32 kgCO_2e/m^2) have a proportionally higher impact on the overall embodied carbon. The highest amount of upfront carbon associated with internal finishes is again floor finishes (21 kgCO_2e/m^2), this time containing predominantly vinyl finishes and a demountable stage floor. Those are closely followed by ceiling finishes (20 kgCO_2e/m^2) which needed to be replaced in most areas. The emissions from wall finishes (4 kgCO_2e/m^2), external works (2 kgCO_2e/m^2) and FF&E (4 kgCO_2e/m^2) are much less significant for the overall embodied carbon of the Citizens Theatre project.

Upfront Carbon of Structure

Similarly to King's, the stagehouse has the highest structural carbon intensity (454 kgCO_2e/m^2). The difference between intensity in King's and Citizen's stagehouse values could be down to the flytower capacity or the condition of the existing structure.

The largest contributing zone to structural carbon is the area containing all non-performance spaces with carbon intensity of 331 kgCO_2e/m^2. This is around 80% higher than that of King's non-performance zone and is a result of large amounts of new-build extension formed predominantly using new steel frames.

The structural carbon intensity of the auditorium zone (19kgCO_2e/m^2) is also comparable to King's due to the relatively light-touch intervention within the auditorium.

Hertford Theatre, Hertford

Key Data

Operation type	Receiving house
Location	Hertford
RIBA Design stage	Stage 4
Year of design	2019-ongoing
GIA (sqm)	3228
GIA new build (sqm)	861
GIA refurbished (sqm	2367
Number of seats in main auditorium	550
Number of seats in studio theatre	150
Other building uses	Café, bars, cinemas, dance studio, event rooms, offices,

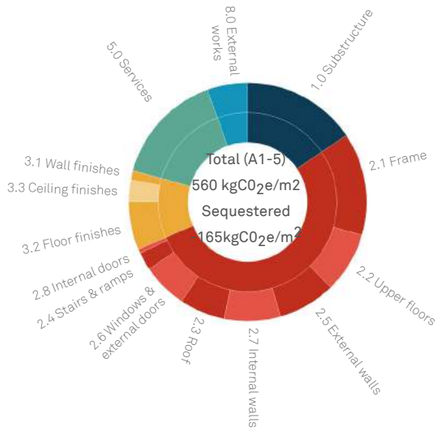
Description

The redevelopment of Hertford Theatre is integral to the future economic and cultural life of Hertford and East Hertfordshire. The theatre plays a central role in the lives of the people in Hertford and the wider district, and the emerging scheme seeks to build on the work the theatre already does, providing a building that can enhance this offer and sustain itself in the future.

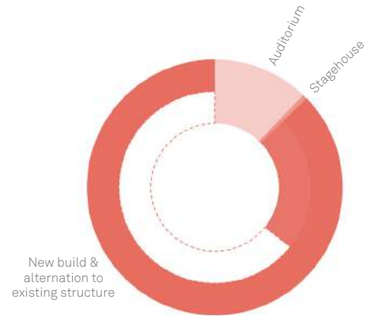
Scope

The core objectives of the redevelopment include making the most out of the theatre's unique location in the centre of Hertford alongside the River Lea as well as growing and diversifying the theatre's audience base. To do so, the proposal increases main auditorium capacity to 550 by introducing a new balcony structure. The existing single-story front of house spaces will be demolished and replaced by 150 seat studio theatre, three cinemas with combined capacity of 200, dance studio, community room for hire and new front of house spaces comprising double height foyer and cafes.

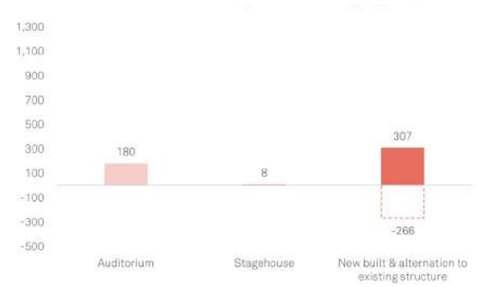
Total Upfront Embodied Carbon ($kgCO_2e$)



Total Upfront Carbon of structure ($kgCO_2e$)



Embodied Carbon Intensity of Structure ($kgCO_2e/m^2$)



Embodied Carbon at Practical Completion

From the analysis of total upfront carbon for Hertford Theatre the three elements which contribute to the largest amount of upfront emissions are substructure (87 $kgCO_2e/m^2$), services (86 $kgCO_2e/m^2$) and frame (78 $kgCO_2e/m^2$ excluding sequestration). Even though the three most carbon intensive categories are the same as for the King's and Citizens Theatres, the use of Cross Laminated Timber on Hertford's new building extension lowers the embodied carbon for substructure and frame. If sequestration is included, upfront carbon of the frame decreased by nearly a half (40 $kgCO_2e/m^2$).

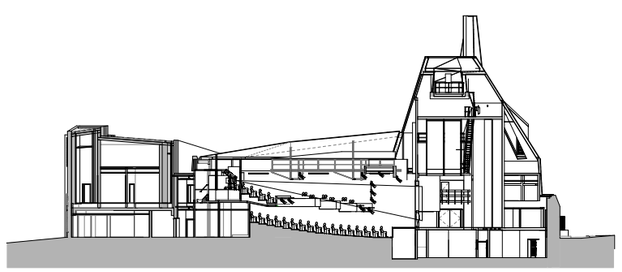
Use of timber also has a significant impact on the upper floors (46$kgCO_2e/m^2$ excluding sequestration & -45 $kgCO_2e/m^2$ including sequestration), internal walls (43$kgCO_2e/m^2$ excluding sequestration & 38kgCO2e/m2 including sequestration) and roofs (35$kgCO_2e/m^2$ excluding sequestration & 14$kgCO_2e/m^2$ including sequestration). These are all significantly lower than their equivalents in Citizens Theatre's new build extension when sequestration is taken into account.

External works (31$kgCO_2e/m^2$) and internal finishes (60$kgCO_2e/m^2$) are the categories with the lowest carbon emissions. It is worth noting that floors (37$kgCO_2e/m^2$) are associated with the largest carbon emissions within the finishes, mainly due to use of carpet used within the cinemas.

Upfront Carbon of Structure

Unlike within the theatres analysed previously, the Hertford Theatre flytower is not extended, hence its impact on the upfront carbon is minimal. However, the main auditorium is remodelled to include a new balcony level to increase capacity. This is reflected in a higher proportion of total upfront carbon and the highest $kgCO_2e$ per m^2.

The newbuild extension comprises majority of upfront carbon. The area of works covers 2,367m^2 and the carbon intensity of the extension excluding sequestration is 307$kgCO_2e/m^2$. When sequestration is included the impact of this area drops to 41 $kgCO_2e/m^2$, lower than the auditorium which is only 560m^2. It is apparent that use of CLT in those areas has a major impact on the upfront carbon totals.



Storyhouse, Chester

Key Data	New-built only
Operation type	Producing Theatre
Location	Chester
RIBA Design stage	Stage 7
Year of design	2012-2014
GIA new build (sqm)	3459
GIA refurbished (sqm	Not included in study
Number of seats in main auditorium	806 489 in Thrust mode
Number of seats in studio theatre	150
Other building uses	Library, cinema in the refurbished Odeon

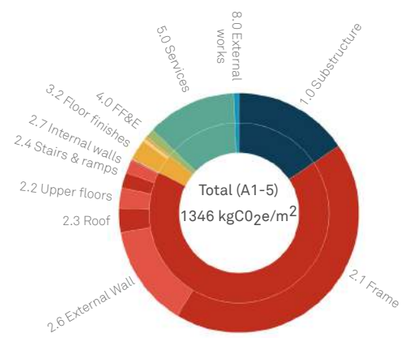
Description

Storyhouse is a mixed use cultural centre partly housed in the redundant shell of a 1930s Odeon in the centre of Chester. The project presented an opportunity to create an innovative public building which will be open 12 hours a day, re-occupying the art deco cinema interiors and re-inventing the way a city library is used and perceived. The project aims to connect people through storytelling and brings theatre and cinema back to Chester after a decade-long absence.

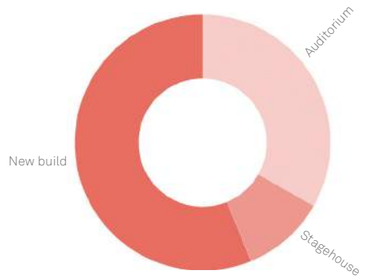
Scope

Although the project includes a significant amount of refurbishment works to the existing Oden building, the main auditorium, studio theatre and performance support spaces are located in the new extension of the building. For this reason, only the newbuild part of the Storehouse was considered in the in the embodied carbon study and any existing substructure was assumed as newbuild. The extension is predominantly clad in brick and the steel-framed audience circulation walkways flank the brick auditorium enclosed by glazed cladding.

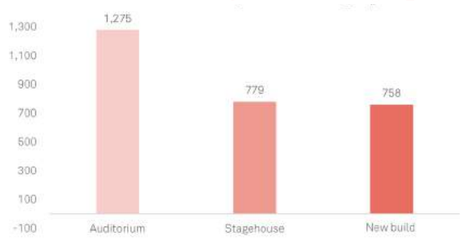
Total Upfront Embodied Carbon ($kgCO_2e$)

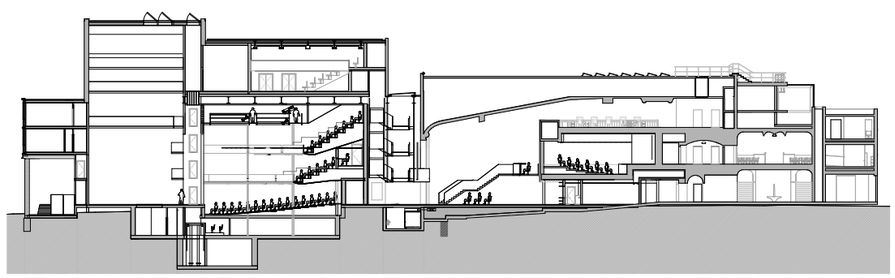


Total Upfront Carbon of structure ($kgCO_2e$)



Embodied Carbon Intensity of Structure ($kgC0_2e/m^2$)





Embodied Carbon at Practical Completion

In contrast to the previous theatres, the study of Storyhouse focused entirely on the newbuild part of the project. As anticipated, the upfront carbon of the new performance spaces is significantly higher than previously analysed refurbishments. The highest uplift is seen in the frame (411 $kgCO_2e/m^2$) which together with substructure (184 $kgCo_2e/m^2$) comprises over a half of all upfront carbon emissions, closely followed by external walls (185$kgCo_2e/m^2$) and services (163 $kgCO_2e/m^2$).

Even though the proportional distribution of upfront carbon emissions remains similar to the refurbishment projects, the proportional impact of internal finishes in comparison to other building elements is smaller. Interestingly, the floors (38$kgCO_2e/m^2$) are once again the most significant among finishes.

Upfront Carbon of Structure

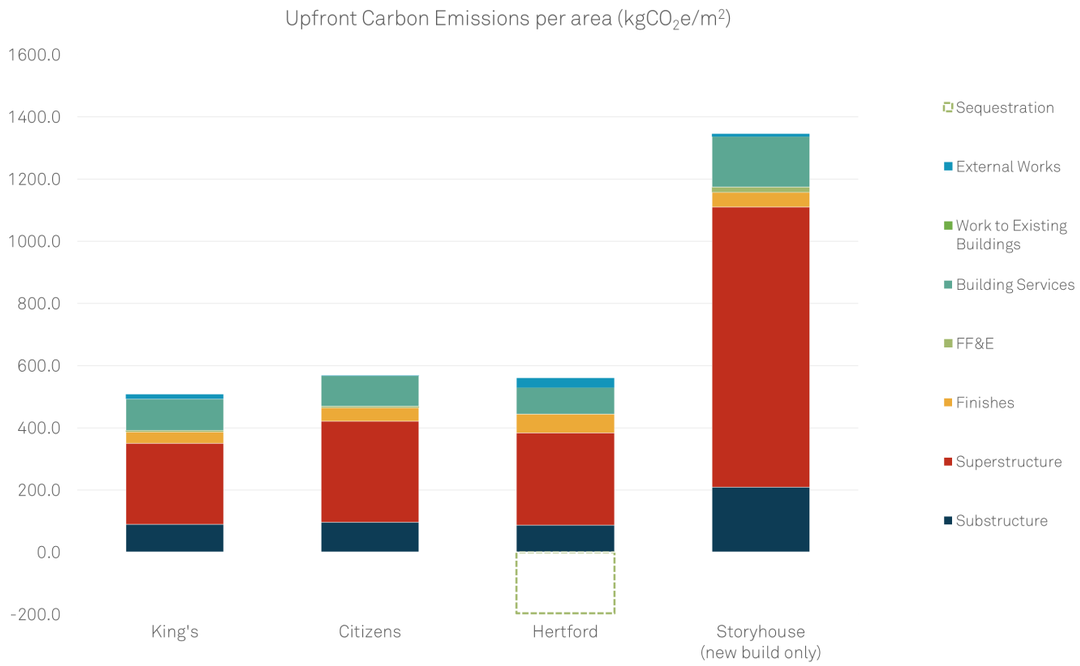
The analysis of the newbuild part of Storyhouse highlights that the non-performance spaces make the highest proportion of embodied carbon. This could be due to non-performance spaces tending to be quite tight with a lot of vertical structure per m2, as well as including walkways and large structural stairs. As demonstrated by the Herford Theatre project, there is potential to significantly lower the structural embodied carbon by using other materials, such as CLT, where possible (e.g. areas requiring shorter spans). However, additional embodied carbon from elements required to achieve fire and acoustic performance should be considered. A reduction of the fly tower impact can be achieved but requires an early engagement and coordination between structural engineer and specialist theatre consultant.

The zone with the highest structural carbon intensity is the auditorium. This is primarily due to large spans needed for optimum seating capacity and unobstructed sightlines, as well as the vibration performance requirements. Since the auditorium comprises a significant proportion of the overall upfront carbon, it is an area where incorporating low carbon solutions will have a major impact on the total project emissions.

Conclusion

Having assessed all four theatres using the same RICS methodology and detailed investigation of the structural carbon emissions we can look to draw conclusions from the similarities and differences.

Relative Carbon Intensity



When comparing the four projects on a per m2 basis, the proportional split between various building elements is similar across all projects, with superstructure (frame, external walls, internal partitions etc.) forming the main source of emissions. It is also clear that the main driver of carbon savings is the extent of newbuild vs retrofit; whilst all theatres had a similar level of finishes and MEP carbon intensity, as these elements are replaced in all projects, the superstructure and substructure for the three retrofit projects is substantially lower than on new-built development of Storyhouse.

Within the retrofit projects the differentiators are potentially more complex and relate to the types of intervention. Citizens and King's Theatres both have flytower upgrades, which come with a higher carbon cost due to the significant amount of steelwork. Citizens and Hertford have large amounts of new-build extension, but the use of timber within Hertford's structure lessens this impact (even before considering the "sequestration" benefit of the carbon locked within the timber).

Comparison to other typologies and the potential for Targets

One of the aspirational outcomes for this study was to compare the Theatre typology to others and propose embodied carbon targets. Whilst four data points (and only one newbuild project) is not ideal, the results of the study do allow us to propose some indicative targets based on the LETI embodied carbon rating system methodology.

Using Storyhouse as a "current practice" baseline, on the basis that it is fully new-build, we can see that this sits around 1300kgCO_2e/m2, or around 200kgCO_2e/m2 above the "current practice" for offices. Considering what the study is showing around the carbon intensity of structure in theatre-specific zones, such as the stagehouse and auditorium, as well as the typology's inherent area:volume efficiencies, this uplift seems reasonable. Taking this as the "current practice" F rating, and applying similar percentage reductions as other typologies, we propose a LETI upfront rating banding as per the below.

Upfront Carbon, A1-5 (exc. sequestration)

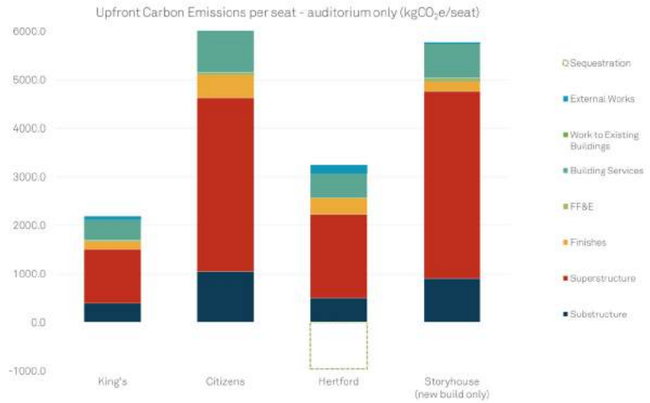
Band	Office	Residential	Education	Retail	Theatre (proposed)
A++	<100	<100	<100	<100	<125
A+	<225	<200	<200	<200	<270
A	<350	<300	<300	<300	<400
B	<475	<400	<400	<425	<550
C	<600	<500	<500	<550	<700
D	<775	<675	<625	<700	<900
E	<950	<850	<750	<850	<1100
F	<1100	<1000	<875	<1000	<1300
G	<1300	<1200	<1100	<1200	<1575

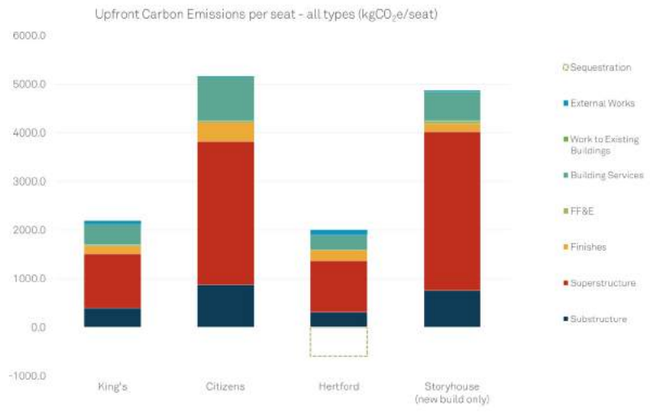
Alternative intensity metrics

Energy and Carbon targets have typically focussed on gross internal area. For commercial offices is closely related to the product being sold, but there are no theatre projects where increasing area alone is the key driver for a project. Therefore, alongside the standard per m2 assessment, we also considered the carbon intensity of each project based on the number of main auditorium seats as well as the total number of seats (including studio theatre, cinema etc.).

Using this assessment, the amount of space (front of house and back of house) that is associated with the performance spaces becomes one of the main differentiators. Though this is partly about efficiency, it is mainly related to the type of theatre. Storyhouse and Citizens are both producing theatres which require more rehearsal and production space, versus the King's and Hertford being receiving theatres, and the carbon intensities reflect this. Older city centre theatres like King's are also likely to benefit in this metric from having tight front-of-house areas associates with large main auditoriums, whereas once all types of seats are taken into account the benefit of retrofits like Hertford can be seen, where significant numbers of ancillary performance seats are added as part of a retrofit project, dramatically improving the viability of a project.

A lot of our theatre projects are not just about seat numbers but about increasing utilisation of space and reducing dark periods. Further metrics such as ticket sales or overall visitor numbers could also be considered, though these are inevitably linked to the operation and management of the theatre. Additionally, the data for this is harder to obtain and publish publicly.





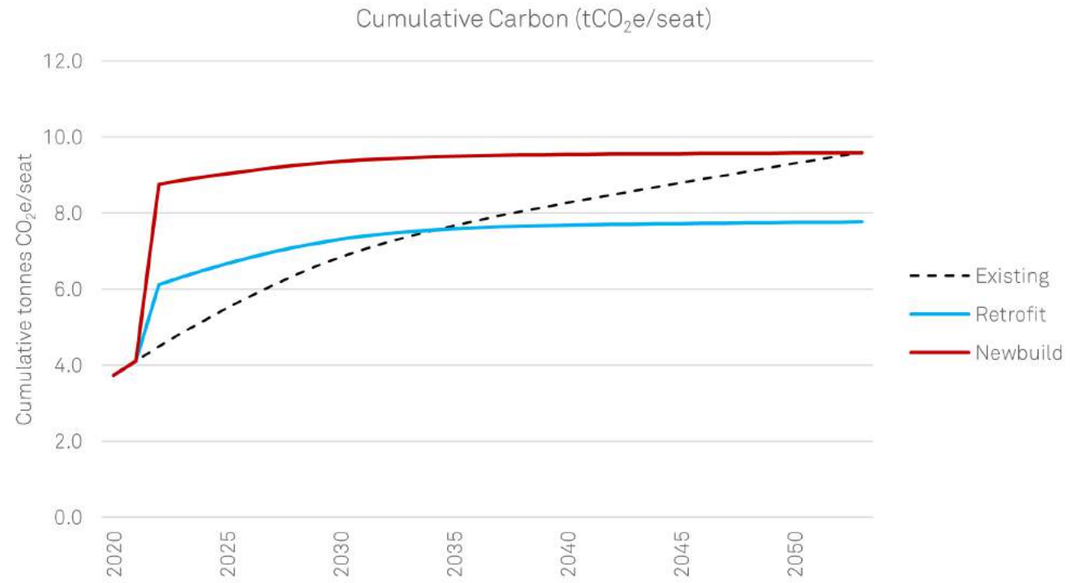
Upfront Carbon Versus Operational Carbon

In a Climate Emergency it is important that we understand the importance of our actions in relation to carbon emissions. As noted in the introduction, operational energy has been the focus of sustainability discussions on most projects, but as energy sources decarbonise, the carbon emissions related to the construction can dominate a building's whole life carbon. Following the assessment of projects we wanted to test this by comparing three option for Hertford Theatre.

01. 1. Existing: Assuming the theatre does nothing, continuing with its current energy usage and fuel supply, and does not improve its cultural offer.

02. 2. Retrofit: Assuming the upgrades shown within this study, with a spike in upfront carbon related to the construction works, and a switch to lower energy and electric only systems. The number of seats available is also dramatically increased energy usage is based on a non Part L estimate of actual energy usage.

03. 3. New build: Assuming a new-build of a similar carbon intensity to Storyhouse. We have assumed the same number of seats as the retrofit option, but with half of the energy use of the retrofit (which is likely an overestimate of the impact of a newbuild on energy usage considering that both have almost entirely new services).



As can be seen from the graph, the initial spikes of upfront carbon from the construction are the most significant impact and also happen on day one of the project. Reducing energy usage means a less steep trajectory initially for both projects compared to the existing building. Electrification means that the cumulative emissions quickly level off, whilst the existing building's gas usage continues to add to its carbon total.

Whilst it can be tempting to use this graph to see the carbon payback of a project by seeing what year the cumulative emissions of both options cross the existing line (13 years for retrofit and not until beyond 2050 for the new-build), it is important to remember that not all of the upfront carbon emissions are related to the improvement in energy efficiency. In many of our projects the "do nothing" option just isn't viable, neither would an option where only the energy improvement features were undertaken, as the ongoing viability of the theatre is often firmly tied to some form of performance upgrade (more seats, improved front of house, flytower capacity etc.).

Routes to Improvement

One of the reasons for undertaking this study was to identify hotspots of carbon where we could focus reduction efforts through design and material specification. The most obvious carbon saving is re-using an existing building and particularly an auditorium/flytower if at all possible. Beyond this there are some clear opportunities for further investigation:

Structural Frame: Hertford shows that using timber can reduce carbon emissions, though this is often challenging when designing acoustically sensitive spaces.

Flytower: Flytower capacity is often inherently linked to a project brief, and whilst it may not be possible to reduce this, it should be discussed in terms of its impact on the carbon emissions of a project. The brief for flytower grids and infrastructure often asks for maximum flexibility and adaptability, which can lead to high volumes of steel being incorporated into the design. The quantity, locations and capacity of technical infrastructure should be interrogated as early as brief stage to set out optimum requirements and avoid overspecification. Lastly, just considering the carbon impact of materials and design of the flytower may lead to a lower carbon design.

Services Equipment: Some of these emissions are unavoidable and some are related to specialist equipment which is integral to performances but for elements like ductwork, lower carbon non-metalic options could be considered. Natural ventilation should also be considered, but only if this reduces the wholelife carbon of the project.

Technical gantries: We found that these can be a surprisingly high carbon building elements, mainly due to their use of large amounts of steel. Considerations should be made on how they can be constructed from low carbon materials and their extent.

Internal Partitions: Due to big spans and high acoustic requirements these can often turn into high carbon elements. Considering timber framing or use of high-mass low carbon materials like compressed earth blocks to be considered.
Finishes: Carpet and acoustic linings to soffits and walls can have a high impact due to the use of large amounts of plastics.

Seating: Though not as significant as we had initially imagined, theatre seating still has a large carbon footprint. Where possible reuse of the main body of the seats should be prioritised.

Next Steps

This report summarises key findings of a larger study which we hope to publish alongside the background data that has informed it. We also plan to undertake several further studies to continue this work, including:

- Net-Zero Operational Energy targets for theatres
- Embodied carbon analysis of theatre specific services using CIBSE TM65
- Detailed embodied carbon assessment of services, internal finishes and FF&E within a theatre specific zone
- Design of a prototype performance space which significantly reduces upfront carbon based on the findings of this report.

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