Carnegie libraries of Britain: Assets or liabilities? Managing altering agendas of energy efficiency for early 20th century heritage

After over a century of service, many Carnegie library buildings in Britain are at risk, often condemned for presumed poor energy performance with heritage protection perceived as a further burden to negotiate. Although most now have heritage status, saving them from demolition, demands to meet changing agendas for efficiency mean that increasingly these buildings are being sold and re-used. A more nuanced reading of measures of performance is necessary. By interrogating operational data in context and establishing indicators for life-cycle analysis, this paper aims to offer generalisable steps to justify their continued service in promoting wellbeing.

Keywords: Carnegie Libraries; Heritage Life Cycle Analysis; Sustainable Building Conservation

Subject classification codes: include these here if the journal requires them

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Introduction

Within the 2030 United Nations (2015) sustainable development goals for cities, both SDG 11.7 "universal access to safe, inclusive and accessible, green and public spaces" as well as 11.4 "strengthen efforts to protect and safeguard the world's cultural and natural heritage" are immediately relevant to the maintenance public library buildings. With respect to social sustainability, Klinenberg (2018) has recently made the assertion that public infrastructure, in the form of public buildings is instrumental in confronting inequality. The Chartered Institute of Public Finance and Accountancy (2019) reported in 2018/19 that there had been a 29.6% drop in spending on public libraries since austerity measures in the UK began in 2009/10. Although it notes a small upturn in the last year, impacts on the least advantaged in society during the Covid-19 pandemic have highlighted inequalities in Britain (Horton, 2020; Paton, 2020), it seems inevitable that the pressure of reduced public finances will be even further compounded by increasing demand for social benefits of public libraries in the near future.

Questioning a values-based approach to sustainable preservation, Avrami (2016) makes a critical point, citing Hobsbawm's (2012) notion of the re-creation of heritage values. She argues that the defence of heritage as a non-renewable resource is countered by its very capacity for the application of values attributed to it to be renewed. A critical risk remains that ambitions for meeting one political agenda should not eclipse those of another. The Carnegie mission was to encourage local engagement with asset management, his gifts were contingent upon councils adopting the Free Libraries Act which enabled them to levy rates in support of maintaining the libraries. Today however, following library closures, a number of libraries are community managed. In 2018-9 it was reported that cuts to library funding were forcing libraries to rely on

51478 volunteer workers (*Chartered Institute of Public Finance and Accountancy*, 2019). The trend towards community-led regeneration is increasing. In this context of constrained resources running in parallel with increasing levels of heritage attribution and pressures to mitigate the impact of climate change, justifying the financial cost of operational energy use will often come ahead of anxiety over excessive carbon emissions.

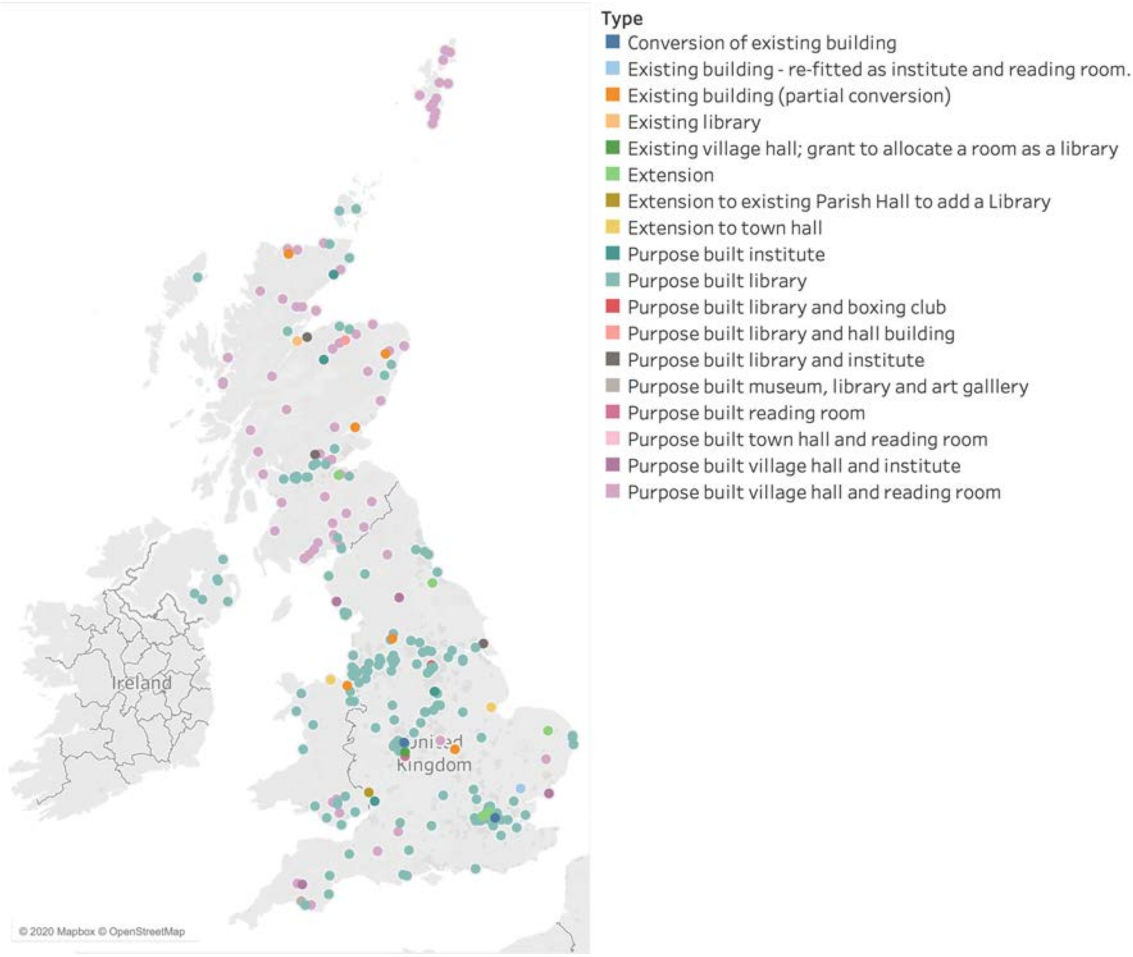

Figure 1. Map showing location and type of all surviving buildings funded with a Carnegie Library grant in the UK

There are 336 surviving buildings in Britain that were funded under Andrew Carnegie's library buildings programme illustrated in Figure 1, predominantly designed and built in a short space of time prior to the first world war. The accelerated standardization of their delivery creates a specific opportunity for considering their collective endurance and consequent indicators of their sustainability retrospectively as noted in previous work (Prizeman, 2012; Prizeman et al., 2020). These buildings are socially important in that they were at the vanguard of delivering newly devised ambitions for "open access" to all, they were also designed with a consciousness of standards evolving transatlantically.

Public libraries are an intensely designated building type, with spatial arrangements as well as fixtures and fittings that must withstand operation by users and at the same time remain manageable within limited budgets. Their continued performance demands in terms of delivering the public with means for navigation and accessibility and managers with capacity for surveillance and energy efficiency poses significant challenges and has resulted in changing attitudes towards their fitness for purpose but also their heritage value. Significant constraints on public funding for libraries make these concerns more acute.

Interrogating our recent complete survey of Carnegie funded library buildings in the UK, we aim here to consider the potential for reasoning critically with respect to reflections on life cycle from the particular to the general and vice versa with an aim of enhancing decision making tools for conservation management that should be relevant to these buildings and many more of the same era and or typology. Using historical analysis and current operational data, the research draws out deeper readings of shifting socio-economic agendas that have a bearing on how and why quantitative measures alone might be inadequate tools of assessment. The key feature of this work is to highlight the interplay of changing imperatives both of environmental resources and cultural heritage values leveraged by socio-economic weightings. The challenge of balancing these often-conflicting demands requires us to consider how we can best develop rules of thumb or principles that can assist stakeholders, managers and architects.

Whereas modelled projections tend to underestimate actual energy use for new buildings, operational data for 107 public library buildings here suggests the reverse to be true for a consistent cohort of buildings. Originally built to maximise daylighting for economic reasons, correlating data here suggests this characteristic may still contribute to reduced electricity use in these buildings. Reviewing these findings against contextual measures of deprivation further supports their current value as critical contributors to welfare, providing accessible and amenable public interiors.

The key mission for Carnegie library buildings of responding to an economic context of cheap heat and expensive light has been reversed by the advent of cheap and relatively low energy lights and increased concern with respect to climate change for lower carbon emissions. To some extent therefore, these buildings were all designed to achieve precisely the opposite conditions that current designers would emulate. In addition, their two-tier single-glazed rooflights are the cause of significant heat loss and vulnerable to leaking. These features are at once delightful and problematic. With libraries and councils short of funds it is not uncommon on wet days to see buckets collecting rainwater inside and to hear librarians complaining of their need to clear gutters, increasing a sense of vulnerability. Given the iteration of these same challenging conditions across the country, it is critical to draw together evidence in support of best practice for managing their future.

Figure 2. Walthamstow Central library Exterior (OP)

Figure 3. Walthamstow Central library Interior (OP)

The apparent opposing measures of performance for Walthamstow Central library, Figure 2 and 3, provides a good example of conflicting agendas. Valued for its success as a library and as a heritage asset, ostensibly it under-performs in terms of energy use. In 2019 Walthamstow ranked 13th of all the 3583 public libraries in the UK for the number of visits it supported (*Chartered Institute of Public Finance and Accountancy*, 2019). However, in terms of its display energy certificate it performs badly and is F-rated. Originally built in 1894, its extension pictured here was funded by Carnegie in 1909, both were designed by J. Williams Dunford. The building was given early Grade II listed status in 1973.

Hong (2015) has argued that the benchmarking of operational energy ratings by building type should be reviewed. Here, the implications of benchmarking are revealed against a substantive dataset, raising some further questions for publicly accessible heritage buildings that are also obliged to meet other pressing challenges. Arguably 126-year-old Walthamstow Central library's impressive ranking, providing members of the public to make 600,393 visits last year in an area with an Index of Multiple Deprivation decile of 3 (Ministry of Housing, 2019) should qualify of eclipse this measure of performance and is a greater determinant of its sustainability. However, the imperative to reduce carbon emissions by improving energy efficiency in buildings is unavoidable, balancing such demands is not a trivial task. The prevalence of this issue shared amongst a large number of closely matched circumstances determines the need for guidance.

Life cycle prediction methods variously suggest adopting an anticipated range of 50-100 years (Bull, 1993, 2015; Caplehorn, 2011; Ellingham, 2006, 2013; Flanagan, 1989, 2004; Langston, 2005; Mohamed Abdelhalim & Abouzid Sameh, 2011). The majority of buildings that are still functioning as libraries here are 110+ years old suggesting that they offer an opportunity for life cycle review that acknowledges changing imperatives at scale. With built heritage that is significantly protected, the threshold for determining the viability of alteration is high, however where built heritage has a lower or emerging designated value, the risk of inappropriate alteration or wastage is increased. The transition of a building from being perceived as a liability to that of an asset is influenced by various factors. A key component of this is the abandonment of old buildings justified by anticipated energy reduction. Technical director of CIBSE, Hywel Davies noted in 2013 "The performance of low energy designs is often little better, and sometimes worse, than that of an older building they have replaced, or supplemented"(Cheshire. D, 2013). It is essential therefore to seek means to balance the challenges of both maintaining socio-economic and heritage value whilst reducing carbon emissions through energy use and to better understand what we already have. Here, a range of evidence illustrates how intersecting values of changing socio-economic contexts and cultural sentiment over that last century have weighted political decisions impacting the extent of permissible physical adaptation of buildings in order to achieve greater energy efficiency. Official data compiling the measured energy use of 107 buildings is correlated here with measures of both heritage value and socio-economic context. Modelled estimations of energy use are also collated, inconsistencies in these underline the influence and risk of pre-judgement with regard to the presumed energy performance of early twentieth century buildings.

Towards Life Cycle Indicators: Research background

Appealing to instinctive sentiment for historic buildings amongst preservation architects, Elefante (2007) argued that "the Greenest building is … one that is already built" in 2007. Theoretically, a dense retrospective analysis of assets could provide valuable indicators for such decisions and was one intention of this research. The aim being to determine in principle that replacement was more wasteful than re-use or adaptation. However, it became evident through making a complete photographic survey of the Carnegie funded library buildings in Britain that more importantly than collating a historic database of embodied carbon (a somewhat ironic task for auditing the philanthropic legacy of a steel magnate in any event), collating evidence of how political and economic agendas have shifted is more informative in terms of qualifying the sustainable potential and future treatment of these buildings.

Statistical outcomes of performance can be rendered meaningless if they are not properly qualified by nuanced contextual readings of design or operational intent. Janda's (2011) paper "Buildings don't use energy, people do" qualified how energy efficiency should be addressed for traditional buildings. There is an expectation that measured energy use in new buildings will generally exceed the modelled prediction. However, here, with a significant and cogent dataset of older buildings it is possible to draw together data indicating distinct measured trends in energy use and to hold these against modelled expectations and challenge this assumption. The aim is that these data provide a platform for decisions in principle.

Life Cycle Analysis (LCA) tools aim to enable decision makers to balance future outcomes against calculable risks when designing new buildings or deciding to adapt old ones. Data supporting observations of general practice and LCA of common components as opposed to charting complete data for individual buildings emerged as a more relevant tool. There is a frustration for attempting LCA for heritage buildings that the "sunk costs"(Brealey, 2020; Flanagan, 2004) of embodied energy and carbon are discounted. A report by Historic Scotland asserts that for historic buildings, the embodied carbon of the past has no mitigating impact on future consumption (Menzies, 2011). However, in the case of a large number of existing assets that may or may not be protected by heritage legislation and might be replaced with new buildings, finding some means to benchmark the comparative embodied energy between existing and new construction is still a relevant consideration as highlighted in Historic England's (2020) recent report. Dixit et al. (2010) highlighted that there were inconsistencies between parameters used for calculating embodied energy but noted that geographical distance of materials was the measure most universally incorporated in calculations. Therefore, although other parameters for the production of historic building materials, for example attempting to calculate the CO_2 emissions of horse drawn barge transport, would take some time and have little generalizable value, accumulating data demonstrating the simple measure of distance for principle building materials from cradle to gate is readily observed precisely from reports in the contemporary press and more generically from visual analysis of photographs and is therefore presented here.

Addressing relatively modern or marginal heritage, Berg et al (2018) have demonstrated the validity of life cycle analysis tools for evaluating refurbishment options for a single building modern heritage. Several life-cycle research studies using both LCA and Life Cycle Costing (LCC) argue that it is the operational life of buildings, as opposed to their construction that is most responsible for their environmental impact in terms of energy use with a proportion cited of up to 80% (Avrami, 2016; Cole & Kernan, 1996; Mudgal, 2009). The 2007 United Nations Environment Programme report (Huovila & United Nations Environment Programme, 2007) cited Smith et al (1998) stating that 50% of buildings' contribution to CO_2 emissions are accounted for by operational costs. It is argued that a combination of passive and active transformations to the supply and use of energy could have a significant impact on subsequent performance (Ramesh et al., 2010). However, Ibn-Mohammed et al (2013) have tabulated a range of cited proportions for embodied versus operational emissions which in the UK alone vary from a maximum 80% of life-cycle carbon being embodied carbon (Smith & Fieldsin, 2008) to an estimation of embodied energy as between 3-35% of 100 year life-cycle energy demand. They observe the complexity of comparing varied computational methods, however, the cautionary note is important as it indicates that the assertion highlighting the relevance of operational energy use can be misleading. Indeed, they go on to argue using cite research commissioned by British Land that were the grid to be de-carbonised to 0.2 kgCO_2e/kWh as anticipated by 2030 (Change, 2008; Hammond et al., 2011), the balance in estimation of embodied carbon for a building currently calculated at 42:58 could shift to 68:32(Battle, 2010). This anticipated shift of emphasis is relevant to considering how a substantial existing 'estate' such as that of these buildings, should be assessed in the interim.

Critically, the cost imperatives of efficiency for light and heat have reversed during the last 120 years. The first Carnegie Library to open in America at Braddock recorded in a 1916 annual report that the cost of heat was USD 225, 16% whereas that of light was USD 1200, or 84% (Taylor, 1916). Today, the normal expectation is for the cost of heat and artificial light is likely to be the reverse. Nevertheless, CIBSE still caution the underestimation of operational energy that is dedicated to artificial lighting (Cheshire. D, 2013). The CIBSE 2012 benchmarks note that for lighting, Public Libraries, under category 8, good practice is 5 w/m2 but typical practice is 9 w/m2(Ed. Butcher, 2012). Research in China derived from 54 surveys determined that library buildings without air conditioning built before 1990 that were under 10000m2 and benefitted from natural lighting, tended to use less energy, around 40 kWh per m2 per year, than later buildings over 20000m2 with mechanical ventilation and dependence on artificial lighting in the day which averaged 70kWh per m2 per year (Wang. Xuan, 2011). The majority of libraries here are heated with natural gas and naturally ventilated. During the last century energy sources have already been changed at least once. Interchanging the source of energy can be a relatively minimal intervention for a listed building. As has been argued by those highlighting the dominance of operational costs (Ramesh et al., 2010) as well as those highlighting the dominance of embodied carbon (Ibn-Mohammed et al., 2013), both note the potential to reduce operational costs through improved technologies used in appliances as well as in the CO_2 of externally supplied energy. In the case of a significantly large group of existing buildings, these indicators are important. The relative impact of altering the energy source is therefore an aspect of LCA that demands consideration here.

Key characteristics

The strictly prescriptive demands of the Carnegie library design briefs combined with the significant rapidity of the proliferation of buildings led to a high degree of standardisation as opposed to a wide variety of innovation in design. This is useful in terms of enabling the valid comparison of similar or even identical attributes with respect to differing contextual conditions. The standards are nuanced in so far as the buildings were generally designed by local architects, using local materials to deliver global standards. They achieved this by referring to detailed design briefs and clear, albeit limited technical guidance through a small number of authoritative sources and constant reporting in the architectural press. Ironically, although pre-dating stripped back modernist buildings that aesthetically removed tradition from the buildings of the mid twentieth century, the Carnegie aspiration had been 'TO OBTAIN FOR THE MONEY THE UTMOST AMOUNT OF EFFECTIV ACCOMMODATION, CONSISTENT WITH GOOD TASTE IN BILDING'[sic](Bertram, 1911). As has been discussed in related previous work (Prizeman, 2013), these aspirations are often obscured by the efforts of local architects to aggrandise the appearance of their towns and cities.

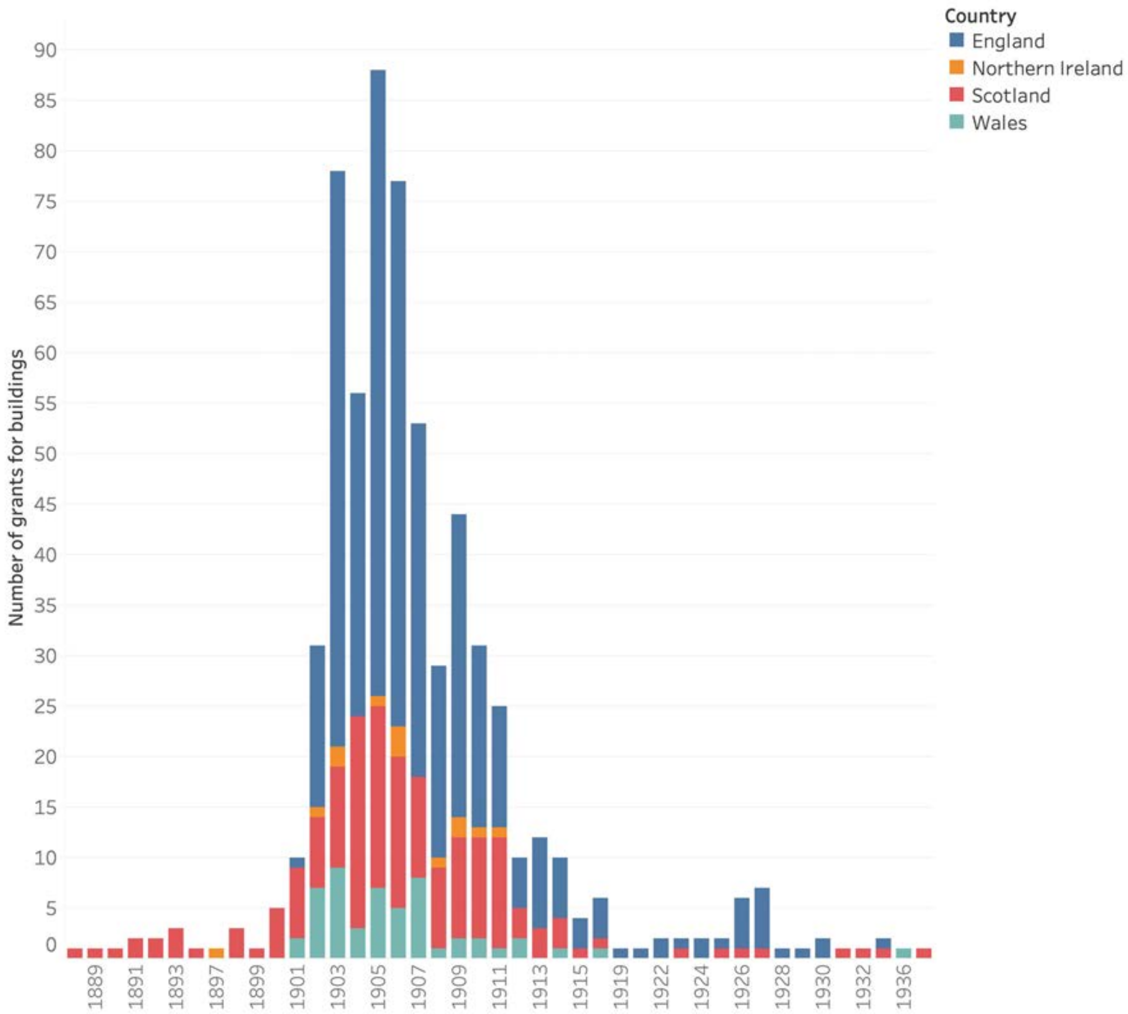

Figure 4. Histogram showing dates of all buildings funded with a Carnegie Library grant in the UK, colour-coded by country.

The legacy of Carnegie library buildings in Britain is a significant anomaly. His philanthropy transformed the Public library movement in Britain, yet it happened at such a pace that its assimilation is hard to distinguish from the Edwardian public domain as a whole. However, today we are used to the notion of chain stores, of global brands and of generic expectations of the basic constituents of the high street. The average lifespan including all buildings funded with Carnegie library grants in the UK has been 98 years. Our survey has determined that of 490 buildings built, 336 survive, 224 of which are open public libraries. Considering how quickly they arrived as illustrated in Figure 4 and how many other models have followed suit, it is critical to reflect upon how this substantial inheritance will survive or evolve and adapt. As these buildings become more widely acknowledged as a part of our heritage and are protected as such, they also become a part of the problem with respect to energy efficiency. This reflection is particularly important with respect to the similarities and common features of these buildings as there is an opportunity for measures of energy efficiency to be considered at scale and therefore to have a significant impact.

Brokering the relationship between emergent heritage value and its negotiation with imperatives of reducing CO_2 emissions is difficult, adding the weighting of these building's ongoing merits in serving socio-economic needs compounds this complexity further. However, considering that we can see that these standardised buildings have been re-iterated in waves by so many subsequent Twentieth Century buildings from fast food restaurants to cinemas, demands that such approaches are addressed. This paper sets out to quantify and qualify data surrounding the energy use of these buildings and to present it in such a way that these values may be considered against more nuanced values of social benefit and heritage value.

Materials and Methods

The results are structured three parts each using different datasets and varied methods of analysis:

Identifying fixed vulnerabilities:

Global and local knowledge transfer
Global components
Local materials

Identifying changing agendas:

Changing demands: Transformation of socio-economic contexts
Changing role: Heritage value and audit of re-use
Changing estimations of performance: Measures of efficiency

Drawing life cycle indicators

LCA: Toxteth Library
Suggested adjustments

Identifying fixed vulnerabilities:

The data derived from a recent survey is first presented in order to describe common "fixed" vulnerabilities and characteristics of the library buildings. These characteristics are tied to historical circumstance, original design imperatives which have been analysed in previous work (Prizeman, 2012; Prizeman et al., 2020) including a charting of their common features for HBIM.

Survey

As a whole the Shelf-Life project has included the first complete photographic survey of Carnegie library buildings in the UK (Prizeman, 2020). The data supporting the collation of the list of library buildings are various and previously incomplete. In the main, the card index of the Carnegie Corporation of New York's (1898) archive at Columbia University provides a list of grants offered, however, many of the grants are for a number of buildings and private grants are not included. The gazetteer of public library buildings in Britain included in Black et al's "Books Buildings and Social Engineering"(2009) together with Brendan Grimes' (1998) book on Irish Carnegie libraries which covers Northern Ireland together with the directories of the Carnegie UK Trust archives held in the National Records of Scotland are the principal sources. For verifying data on the location of architects, the RIBA Directory of British Architects 1834-1914 (Brodie et al., 2001), the various Pevsner guides, the Historic Scotland directory of architects (Walker, 2016) were used. Retrieval of online journal sources for The Builder and the Building News together with archival search for all journals that are not online at Cambridge University Libraries and the RIBA Library in London assisted with identifying the architects of the more substantial buildings, however, smaller and more rural grants required historic local media that is now accessible online.

Determining what did not happen or when buildings closed was more difficult than finding what remained, this involved searching every missing library grant in national and local press through the British Newspaper Archive , Welsh Newspapers Online and for some, specific archival searches at the Carnegie UK Trust archive in the National Records of Scotland. Geographic locations and postcodes were verified through Google Earth™, and where possible on library websites. Edina Digimap® Historic Roam Ordnance Survey maps were used verify the age of the buildings and to generate latitude and longitude.

Identifying changing agendas and measures of performance:

Secondly, we trace the changing imperatives that have impacted the survival of the buildings and their performance. These data are collated from a range of sources and are variously correlated using geographic and numerical means. Interpretation also demands discussion and qualification to temper the bald conclusions of numerical results, using data visualization software, Tableau Desktop™, it has been possible to illustrate trends.

Drawing life cycle indicators

Finally, constituent elements that contribute to generic reasoning regarding an attempt towards life-cycle analysis are evaluated. A model of Toxteth library and parametric model represented by a 3D PDF was built by Mahdi Boughanmi in REVIT™ based on a laser scan survey by Camilla Pezzica and Giovanni Bruschi made using a FARO focus X130 3D laser scanner and registered using Faro Scene™ software. Using a REVIT™ plug-in to upload the take-off of elements, this data was exported to Oneclick LCA™.

Notes on data sources:

Socio-economic contexts:

The data include separate socio-economic measures drawn from the various Government data Indices of Mass Deprivation (IMD) for England, Wales (WIMD), Scotland (SIMD) and Northern Ireland. Postcodes of remaining buildings were correlated to Lower Super Output Areas separately for Scotland, Northern Ireland, England and Wales. IMD are used to target funding to small geographic areas. Whilst Indices of Mass Deprivation across the devolved nations in Britain do follow similar methodologies, they cannot be directly compared (ONS, 2010, revised 2013). The weightings for different domains of deprivation and timescales are not the same. It is therefore only possible to trace comparative measures using postcode look-ups within each of England (Ministry of Housing, 2019), Wales (Welsh Government, 2020b) (Welsh Government, 2020a), Northern Ireland (Northern Ireland Statistics and Research Agency, 2017) and Scotland (Scottish Government, 28 January 2020) independently. It is important to recognise that within each area, these are not absolute measures but relative ones. Also, as lower super output areas (LSOAs) may only relate to very small areas (e.g. the average population an LSOA in Wales of 1600), it should be borne in mind that the area which a library serves may cover a range of adjacent but different IMD scores. Nevertheless, the data is valuable in providing metrics to locate the resilient assets in terms of their indicative socio-economic contexts. The data all contain public sector information licensed under the Open Government Licence v3.0[1].

Heritage value and re-use

An audit of listing and heritage status was derived from current websites of Historic England (Historic England), Historic Environment Scotland (Historic Environment Scotland), Cadw (Cadw) and Northern Ireland's buildings database (Department for Communities). The various listing designations of each nation are different, however, in order to ease visual assimilation of data they have been colour-coded from red (highest) to yellow (lowest) to indicate the degree of listing.

Measures of efficiency

For collating measures of efficiency, Government Display Energy Certificates were collated manually through individual postcode lookups for each open library building in England, Wales and Northern Ireland and Energy Performance Certificates were retrieved by building type where available. As a result of Article 7 of the European Directive on the Energy Performance of Buildings 2003, amended in 2010, 2013 and 2015, it has been mandatory since October 2008 for Display Energy Certificates lasting one year for buildings over 1000m2 and for 10 years for buildings between 250 and

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[1] http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

1000m2 to be displayed for buildings partially occupied by a public authority in England, Wales and Northern Ireland, now requiring them for buildings with a "useful floor area" of 250m2 and above. In Scotland Energy Performance Certificates are used instead as are all UK buildings which are to be let, hence some of the community managed libraries are also included in the dataset. The certificates were individually downloaded from postcode searches on the Scottish EPC register (Energy Saving Trust), the Ministry of Housing, Communities and Local Government Energy Performance of Buildings Data England and Wales provides access to both EPCs and DECs (Ministry of Housing, 2020a) and The Department of Finance Northern Ireland Non-Domestic Energy Performance Register (Department of Finance, 2020). The most recent certificates up to 31 March 2020 were downloaded. Certificates were not available for every open library online and this is noted in the text.

Data for water usage is not readily available and as it is unlikely to be a significant aspect of library use, a benchmark was adopted. The UK watermark programme is cited by Arpke et al. (2005) giving a benchmark for water usage in a public building for libraries that is 0.203 kl/m2, best practice is 0.128 kl/m2 (Mudgal, 2009). The benchmark figure is used here as a presumed level of consumption.

Results

3.1 Fixed Vulnerabilities

3.1.1 Rapid standardisation: Global and local knowledge transfer

As noted above, the rapidity of the arrival of Carnegie Library buildings in Britain was remarkable. In just four years between 1903 and 1907, 268 buildings were built. The rapid taper of their inception and of their demise at the start of World War 1 compresses the potential for a reflective or iterative approach to their design. The news of the philanthropic opportunity spread very rapidly in the national press and within many local newspapers also. In parallel, the professional press, in the form of trade journals for both architects and librarians was chasing the phenomenon. This reporting effectively spread the common and technical understanding of what was to be expected of a contemporary public library building at an urgent pace. It is important because it enables us to plot the pace of "knowledge transfer". At the same time, the tendency of Carnegie and his private secretary, James Bertram to intervene and comment on design decisions became more intense.

A database of all the Carnegie Library buildings connects each to its architect or designer. Although some councils such as Manchester and Liverpool used the same architect to design a set of libraries each with the same plan but a completely different appearance, the majority of architects only designed one Carnegie library. Hence it is accurate to determine that these buildings as a group were largely conformist rather than innovative. The period of building in Britain leading up to the first world war can be regarded as a confluence of opportunity whereby industrial and colonial wealth provided high quality materials to be worked by tradesmen belonging to a well-established and organised working class with extreme skill. Such conditions provided a context able to interpret and deliver standard designs using well-versed building practices with energy. 1919 is commonly understood to be the end date of traditional building practices in Britain. This reflects the lives, knowledge and relationships lost in the first world war and the abrupt re-focusing of imperatives thereafter. It is also, coincidentally, the year that Andrew Carnegie died.

3.1.2 Global components

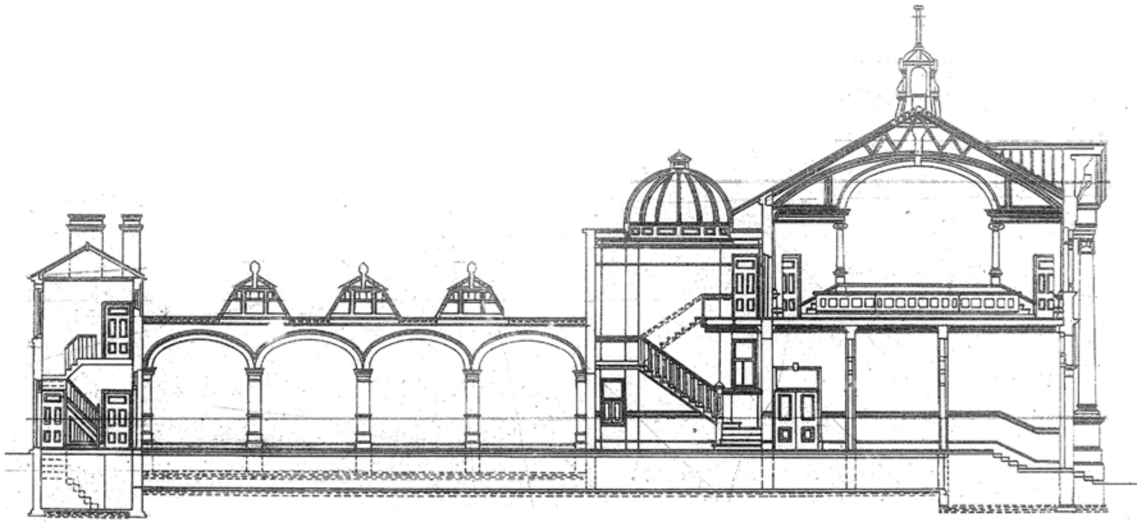

Figure 5. West Bromwich Library, Stephen J Holliday 1907 Long section. Schofield, H. Borough Engineer and Surveyor, 1949. Courtesy Sandwell Metropolitan Borough Council Architect's Unit

There are certain attributes of Carnegie library design that are almost universal. Firstly, the relatively high cost of artificial light and the low cost of heat meant that library buildings were commonly designed to admit as much natural light as possible to benefit readers. To do so, they generally relied on the use of skylights. It was often the case in towns that a two-storey imposing front would conceal a single storey rear in order to maximise the admission of daylight from the brightest point in the sky. Figure 5 illustrates a typical top lit deep plan building at West Bromwich library. In describing a bid for Hammersmith library, Maurice B Adams noted: "By this contrivance the cube, to save expense, was minimized, and the advantage of top lighting…is obtained"(Ed., 1903b). The nature of a public library was famously described in JW Clark's (1894) Rede lecture as either "a workshop, or as a Museum". This characterisation is literally reflected by a description of Kettering library as having a "stack room lighted from the north on the usual weaver's shed plan"(Ed., 1903a) to admit light to its rear. In related work the research team have identified and collated standardised elements for incorporation in HBIM and quantified the use of rooflights and glazed domes evident in open Carnegie Libraries in Britain today.

Liverpool's Toxteth (Southend Branch) is not a Carnegie funded library, however, it was opened by him in October 1902. This was the start (after Keighley) of his funding in England. Reportedly, he was so impressed by the £17000 building as an exemplar of his preferred model of branch library(Ed., 1902c) as well as Liverpool's "virility" as a city to the free library movement that upon return to New York in a letter dated 16.12.1902(Ed., 1902b) he pledged an almost unique unsolicited gift(Ed., 1905b) to the city for the complete cost to build their next planned £13000 branch at Tuebrook (West Derby) and later a number of branch libraries. Indeed, as an architectural model, designed by city architect, Thomas Shelmerdine, it is paradigmatic of a twin gabled arrangement that subsequently predominates. Toxteth library today is also relevant to this study because it is located in an area with an Index of Mass Deprivation that is in the lowest decile in England. It is in good condition having been refurbished in 2008. Figure 6 shows views taken from a 3d PDF which can be downloaded (Boughanmi, 2020a) and navigated in full. It is generated from the REVIT™ model used to perform the LCA discussed later. Here, the isometric of the exterior and the separation of glazed areas are used to illustrate the extent of exposed surface areas of the building. This design became immediately typical, being originally designed to capture daylight effectively as a priority but now serving to reduce its thermal efficiency (and risk water ingress) today.

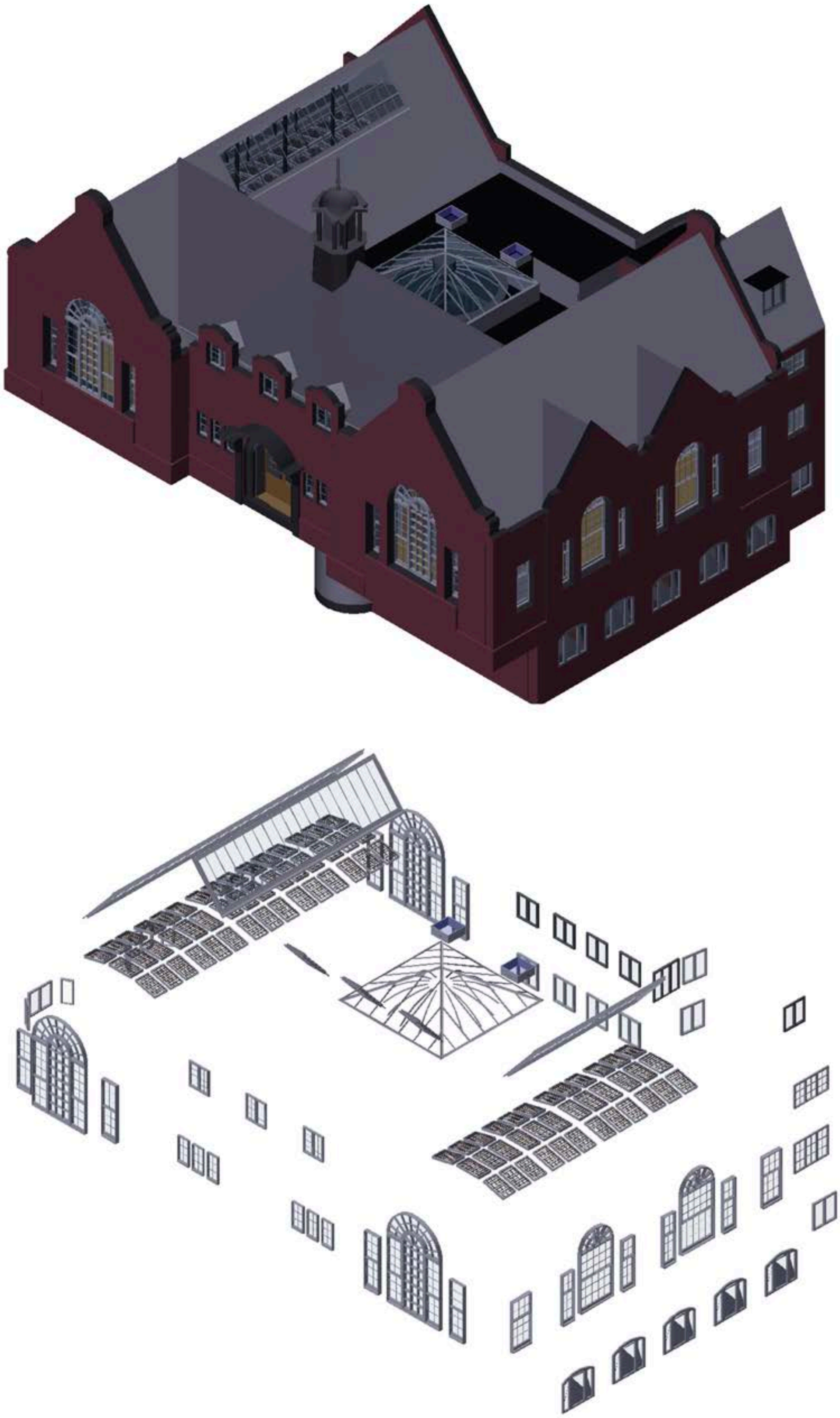

Figure 6. Isometric views from 3d PDF of Toxteth Library showing **(a)** building envelope and **(b)** exterior glazed elements

3.1.2 Local materials

It is relevant to consider transportation distances with respect to current ambitions to acknowledge the embodied energy from existing buildings (Historic England, 2020). In visually reviewing the external wall materials used for British Carnegie libraries, it is clear that they were, in the main, locally sourced and regionally clustered. The map, Figure 7 below indicates the range of materials which, grouped by colour to indicate type, indicate their geographical spread. With few exceptions, the buildings are of solid masonry construction, predominantly built of either brick or stone. The materials chosen reflect their local availability and to an extent the geology of available building stones and clays of the ground. Evidence for this observation is backed up in detail through innumerable mentions in the architectural press. Lincoln library, for example is one of the largest in England at 3044m2 (Ministry of Housing, 2020b) and was built of local Ancaster stone (Ed., 1917) whereas the Aberdeen central and branch libraries are clearly constructed of its local granite as those of Glasgow are predominantly of its red sandstone. Noting that with few exceptions, architects tended also to be local to their buildings will account for some of this preference. They and their contractors are likely to have been familiar with the local materials and transportation costs would generally preclude the importation of heavy building material from distant sources. When considering the life-cost of these buildings as a group, this factor should be acknowledged more generally with respect to the quantity of embodied carbon that they represent.

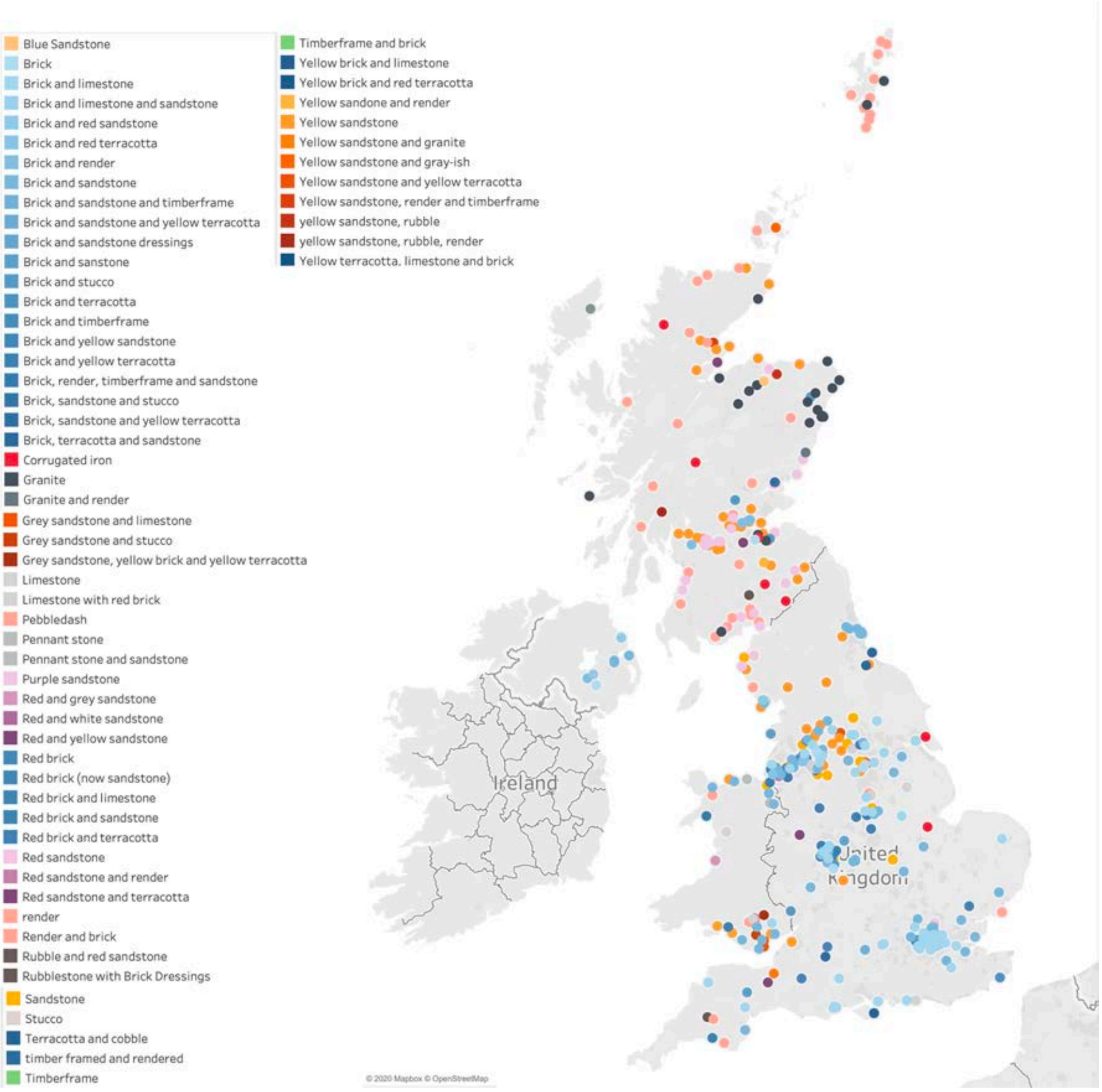

Figure 7. Map of Carnegie library grant funded buildings colour-coded to illustrate distribution of exterior building materials

3.2 Altered values:

3.2.1 Changing demands: Transformation of socio-economic contexts

The predominance of Carnegie libraries located in areas with low indices of mass deprivation today is not a coincidence but a direct reflection of a recognized crisis of post-industrial decline that divides society (Martin et al., 2016). The Scotch-American steel magnate favoured supporting the working man to help himself through the provision of public libraries in what were then industrialised areas. Today, particularly in England, the context of a service-dominated economy has determined that the majority of these library buildings now serve some of the country's most deprived communities. Our research has identified that in England, of a total of 147, 118 are located in areas with IMD deciles of 5 or lower. In Wales, of 14 open libraries remaining, 9 are in the WIMD decile of 5 or lower. Of those 19 buildings which have closed, moved or been re-purposed, 13 are in WIMD of 5 or lower. In Northern Ireland the 890 Super Output Areas are ranked from 1 (most deprived) to 890 (least deprived). The three open Carnegie Libraries are ranked within Northern Ireland's 2017 NIMD measures at 174 (Bangor), 55 (Falls Road), 54 (Lurgan). Notably, Old Park library, currently closed but previously volunteer run, sits in the second lowest area of all 890 in the whole of Northern Ireland. In Scotland, by contrast, the balance across deprivation areas is weighted towards the less deprived areas. This more even distribution is likely to reflect the higher proportion of buildings per capita that native Scotsman Carnegie funded there.

These data are crucial to include in this discussion because they underline the continuing, in fact enhanced importance of the buildings and of their critical social role. It also highlights that the affordability of choice is likely to be limited and indeed that the pressures of sustainable management are significant.

3.2.2 Changing role: Heritage value and audit of re-use

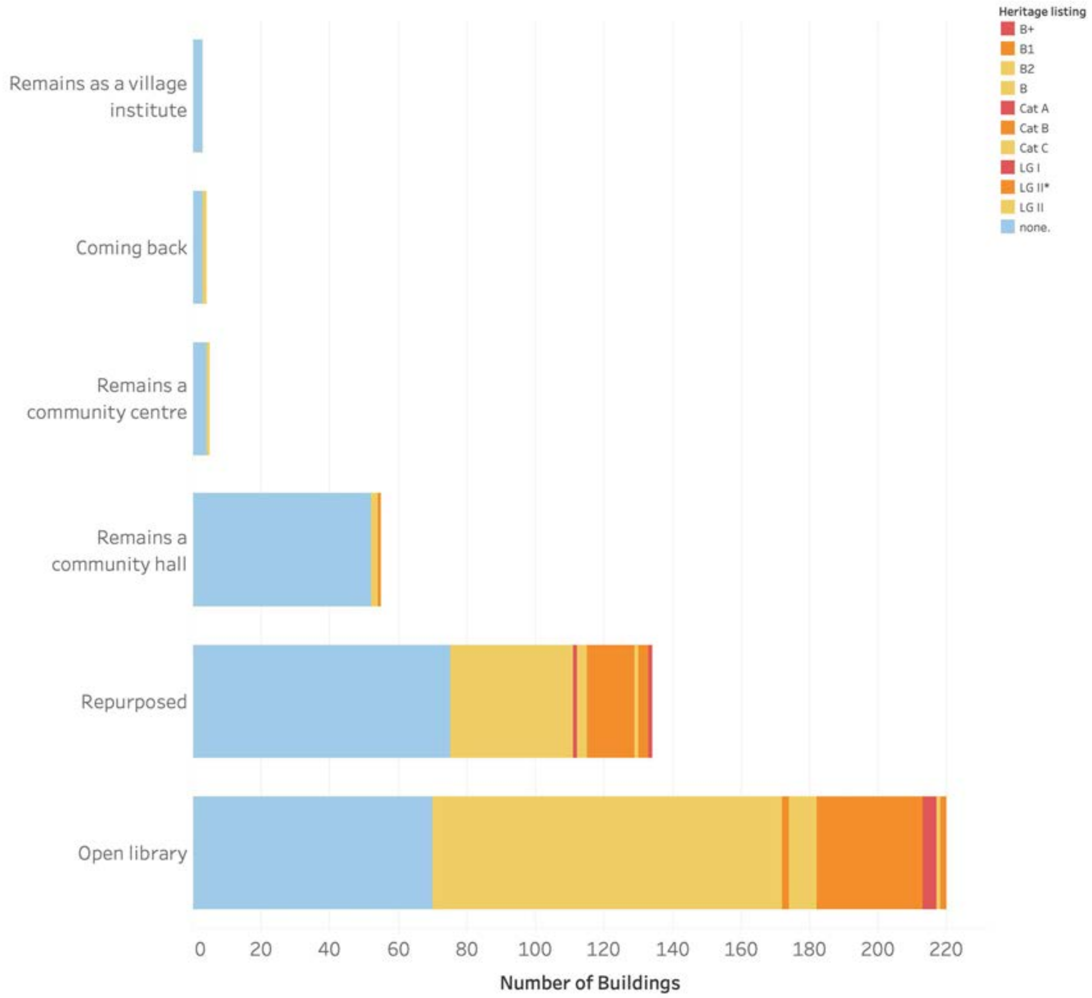

Figure 8. Bar chart quantifying functional status and heritage designation of buildings in the UK funded with Carnegie library grants in 2020

Since 1950 and accelerating from the 1980's onwards, the majority of the remaining buildings are now designated as heritage assets as plotted in Figure 8. This serves to both protect them from demolition but also at times to frustrate councils who perceive the upgrading of older buildings to meet new standards of wheelchair accessibility and energy performance as insurmountable. In addition to this, a willingness to adapt and move away from the designated purpose of the building may further enhance the prospects of its survival.

Figure 9. Treemap quantifying current use of former Carnegie library buildings that have been re-purposed

It is relevant to note the array of purposes for which these highly designated buildings have been re-deployed as illustrated in Figure 9. Although a substantial number of re-used library buildings have effectively been taken onto the private domain by being re-purposed as residential, and a large number have made use of the comfortable illumination and generous spaces of reading rooms to become offices, the majority of buildings have been re-used for purposes that can still be identified as serving the public interest. Although heritage officers might have opinions and planning departments may limit, for example the adoption of high street space for residential use, there is no regulation that can actively direct such outcomes, in effect, the re-use of a building is open to the developer or owner's imperative much more than that of the planning authority. Such movements are subject to much wider levers, predominantly these are economic, so the vulnerability of once publicly accessible library buildings to be replaced with something much less amenable to the communities they once served is high. Nevertheless, the table of re-use does show a tendency in the case of the Carnegie library buildings in Britain that have been re-purposed, to be understood as socially beneficial environments. It is clear that they have generally been re-deployed for uses that might be associated with the role of a public library in its wider sense, as a place that served the community. Thus, there are numerous educational uses such as schools and nurseries, but also a number of rehabilitation related community centres. The identification of the qualitative environmental factors that stimulate such a coherent response is a subject for further research.

3.2.3 Changing estimations of performance: Measures of efficiency

As noted above, there are assumptions that heritage assets are liabilities with respect to energy use as their adaptation can be complex, however the evidence collated here suggests this is not the case, indicating that political will or bias may still have a greater impact. Using newly accessible data for all Display Energy Certificates in England and Wales (Ministry of Housing Communities & Local Government, 2020), it is possible to compare the measured operational rating bands of 107 of the open Carnegie Library Buildings with DECs that have been logged to date in Northern Ireland, England and Wales. Asset ratings on Energy Performance Certificates (relevant here to libraries which are rented spaces and those in Scotland) are calculated values whereas Operational Ratings on DECs are based on metered data benchmarked to a target for the building type. They are not directly comparable yet are both designed to deliver unambiguous measures of performance to stakeholders and managers. There is leverage in evidencing poor energy performance in support of either closing or moving a library service.

The benchmark given to all is “Cultural Activities”. The typical building in the UK is expected to be rated between D and E (Davies & Chartered Institution of

Building Services, 2009). Figure 10 shows there are 6 libraries here which achieve an Operational Rating Band “B” in their display energy certificates. This is impressive in so far as all 6 are listed grade 2, all are at least 110 years old, none have been significantly modified and all are predominantly naturally lit. They cover a range of attributes: of these only Malvern (1906) is a fully detached building. Ilkley (1907) is attached to the town’s public offices and assembly hall (News., 1905). Kayll Road (1909) is community managed and although it does have a suspended ceiling it retains a large rooflight, Folkestone (1910) is an extension to an existing building and Leicester Central (1905) is also attached to council offices. Northampton Central Library (1910) is one of only 4 of all the Carnegie Libraries to be terraced. At the other end of the scale, only 3 Libraries received a G rating, Harlesden, Pontypool and Brentford and only 4 are F rated but have no data so this would appear to be a default setting.

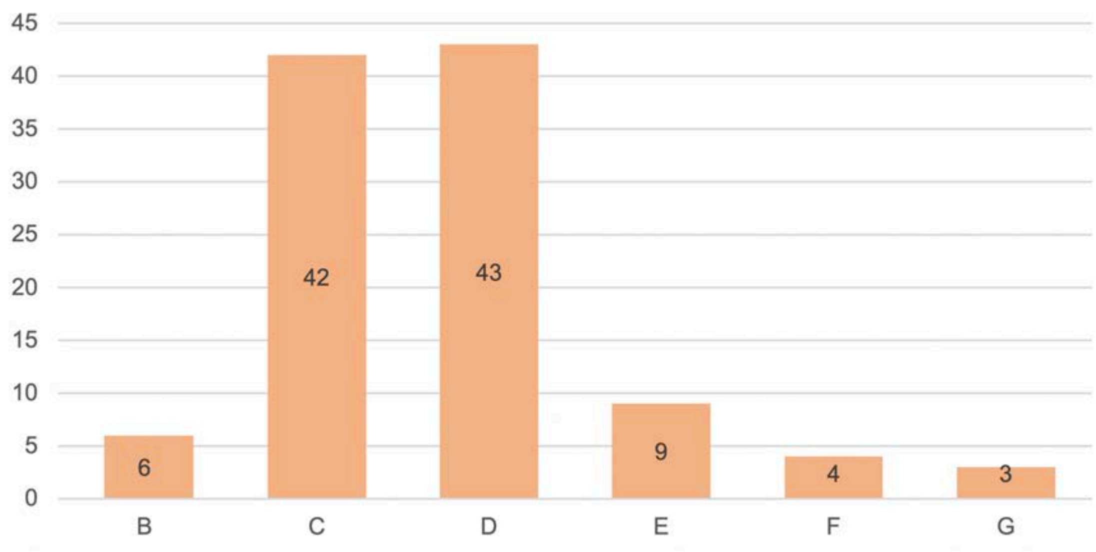

Figure 10. Chart plotting Operational Rating of all open Carnegie libraries England Wales and Northern Ireland with DECs 2020

In terms of heating fuel, Leicester Central is the only building here to have district heating, Abergavenny and Meadows Library in Nottingham are the only two to list renewable sources (solar and solar PV). 23 have air conditioning, only 8 list Heating and Mechanical Ventilation although it is known that the majority were designed to incorporate it. 95 are all listed as Heating and Natural Ventilation, one as “Mixed-mode with mechanical ventilation” and three Mixed-mode with natural ventilation. Floor areas range from 109-5000m2.

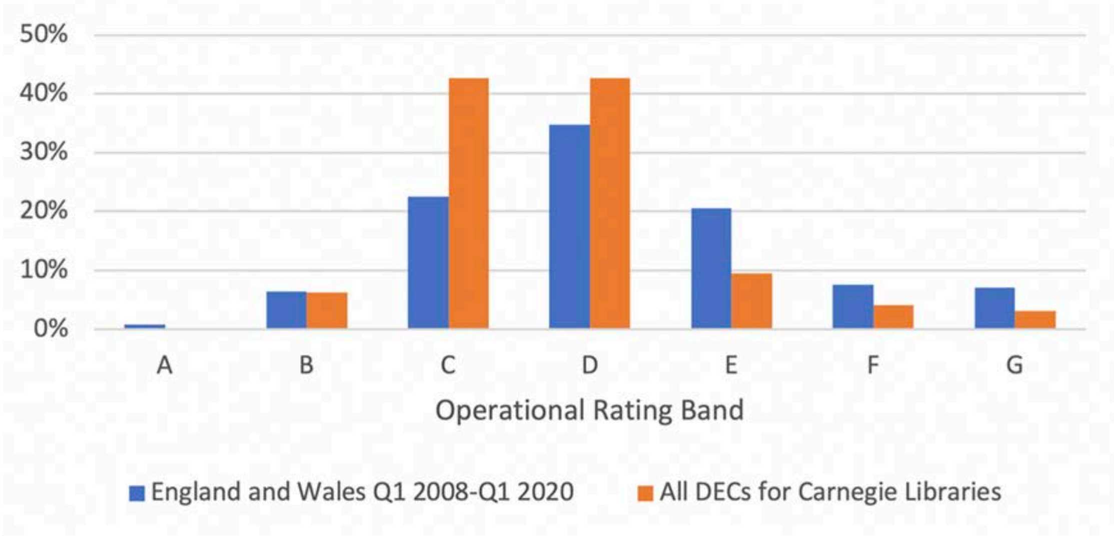

Figure 11. Chart plotting all public buildings with DECs in England and Wales Q1 2008-Q1 2020 and all DECs for Carnegie Libraries

Figure 11 demonstrates that 84% of the Carnegie Library Buildings here are deemed to be D or above, whereas the score for all public buildings with DECs in England and Wales rated above band D is only 65%. In contrast with DECs for all public buildings in England and Wales Q1 2008-Q1 2020 (Ministry of Housing Communities & Local Government, 2020), the profile of the Carnegie Libraries is not radically worse as might be anticipated.

The Operational Rating can be expressed as:

$$OR = \frac{100 \times \text{Building } CO_2 \text{ emissions/building area}}{\text{Typical } CO_2 \text{ emissions per unit area}}$$

However, in our sample the operational bands are not correlated to the same typical usage benchmarks, although all but one (under “office”), cite the same overall benchmark property type; “cultural activities”. The research observed that the “typical” measures of fossil fuels used as benchmarks range from 138 – 257 kWh/m2 per year with a few extreme exceptions (39 and 307) which are assumed to be errors. This correlates closely with latitude, however, measured thermal energy use did not. This observation is important as it highlights the risk of presumption in benchmarks. Whereas latitude can be seen to correspond closely with the gradual adjustment to benchmark data applied for thermal energy use, Figure 12 illustrates that it has no discernible influence on either actual electrical or thermal usage across the range of varied sizes of building. For electricity, the “typical” measures on the DECs for Carnegie libraries ranged from 47-124 kWh/m2 per year.

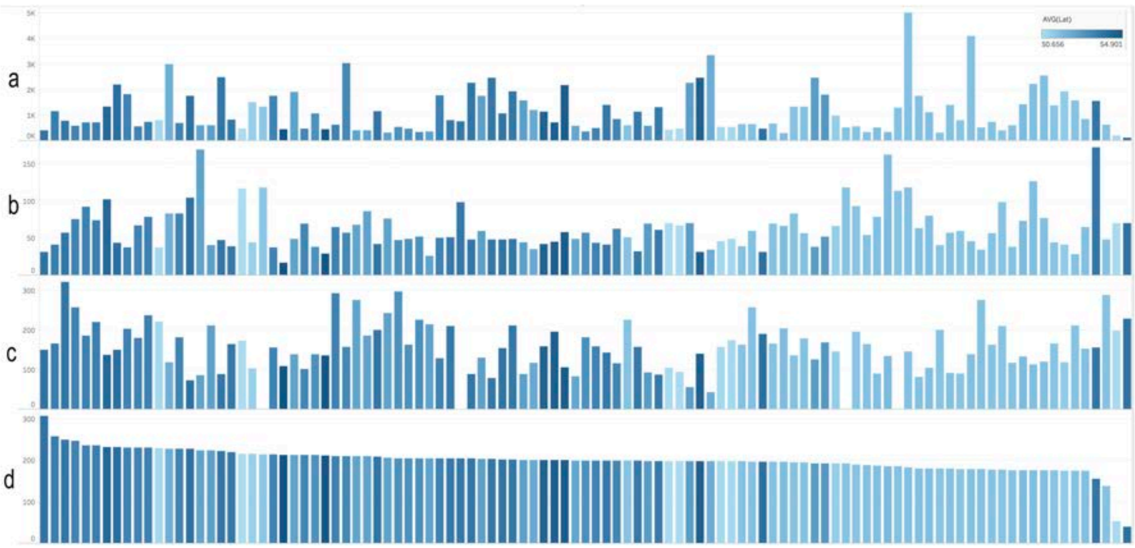

Figure 12. Chart shaded to indicate Latitude (darker is further North) against data for all open Carnegie Library buildings with DECs in England, Wales and Northern Ireland aligning **(a)** Total Floor Area m2 **(b)** Annual Electrical Usage kWh/m2 per year**(c)** Annual Thermal Fuel Usage kWh/m2 per year **(d)** Typical Thermal Fuel Usage kWh/m2 per year benchmarks used in each DEC

CIBSE Guide F benchmarks set in 2012 for existing public library buildings suggest that good practice is fossil fuels 113 kWh/m2 per year and electricity: 32 kWh/m2 per year but that typical practice is 210 kWh/m2 per year fossil fuels and 46 kWh/m2 per year electricity(Ed. Butcher, 2012). The inadequacy of CIBSE building type benchmarks was highlighted in Hong's PhD research (2015). Subsequently, tools being developed in collaboration with UCL and available from CIBSE (2020) have created a dynamic energy benchmarking tool dashboard, currently in BETA, which to date includes data for 275 existing public library buildings nationally based on DECs. We might presume that our 107 DECs found for Carnegie library buildings alone form a substantial part of this set. The benchmarking figures based on these DECs differ from the last published set in 2012: Effectively, the benchmarks for electricity have been raised and those for heating lowered. They note that good practice is fossil fuels 85 kWh/m2 per year and electricity: 54 kWh/m2 per year but that typical practice is 117 kWh/m2 per year fossil fuels and 76 kWh/m2 per year electricity. Against these later data the average of the buildings here is above the "typical" at 160 kWh/m2 per year fossil fuels but below typical at 62 kWh/m2 per year for electricity as illustrated in Figure 13.

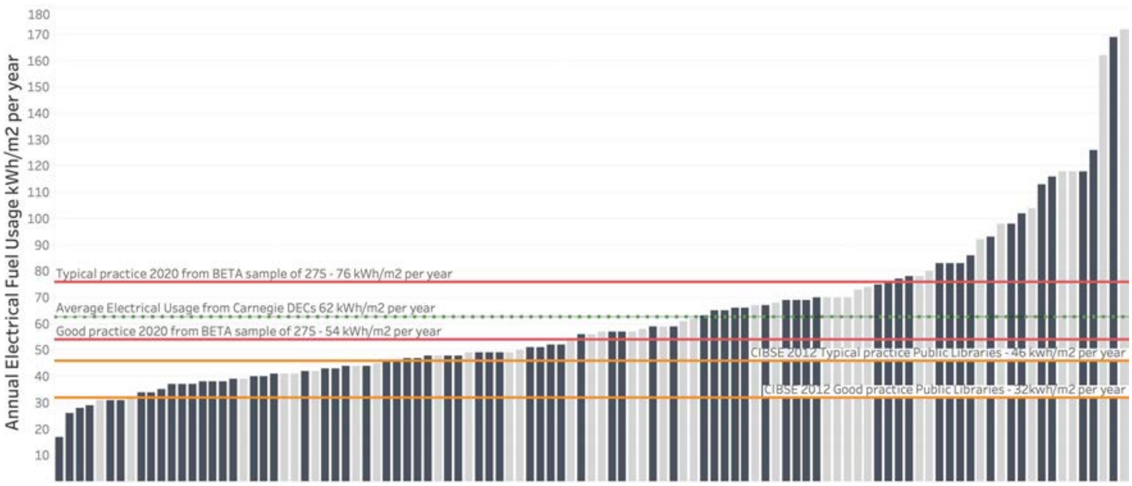

Figure 13. Chart plotting annual electrical fuel usage for open Carnegie libraries with DECs against 2012 and emerging 2020 CIBSE benchmarks for public libraries. Presence of Skylights indicated by darker bars

Despite the number of visible lights switched on in daylight hours, it is possible to speculate that the predominance of relatively high levels of daylighting contributes to the relatively reasonable use of electricity in the Carnegie library dataset. 44 of the 107 libraries that are below average electricity use have skylights, whereas only 25 of those above do as indicated in Figure 14. In addition, several others below average have either highly glazed walls, glazed domes or clerestory lights.

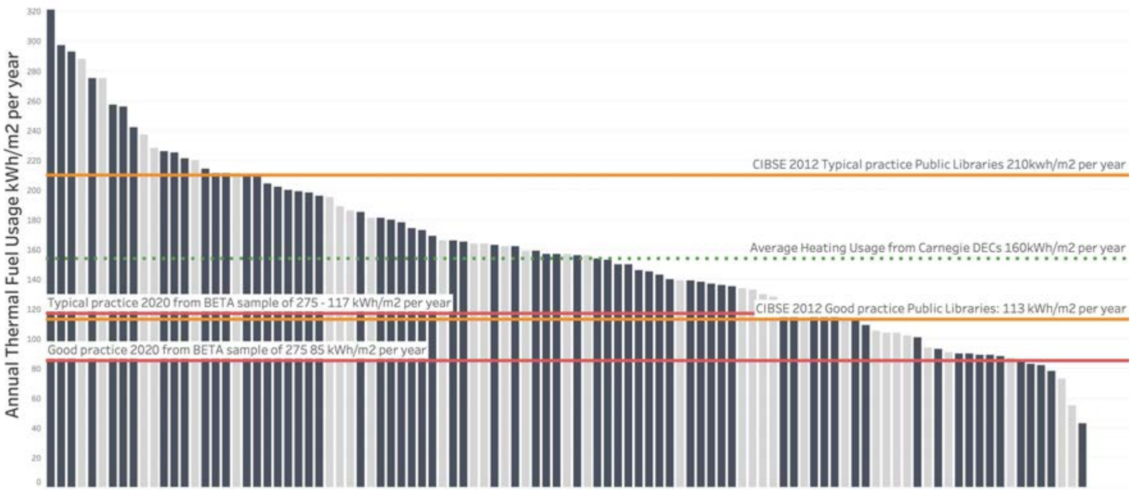

Figure 14. Chart plotting annual thermal fuel usage for open Carnegie libraries with

DECs against 2012 and emerging 2020 CIBSE benchmarks for public libraries. Presence of Skylights indicated by darker bars

For heating the correlation is not as distinct, 36 below average have skylights, whereas 32 above average have them - see Figure 14. This may indicate that skylights are not as great contributors to heat loss as presumed because of the solar heat gain they enable. The higher thermal figures from the DECs of open Carnegie libraries here indicate the margin of improvement required to match the most recent standards of good practice.

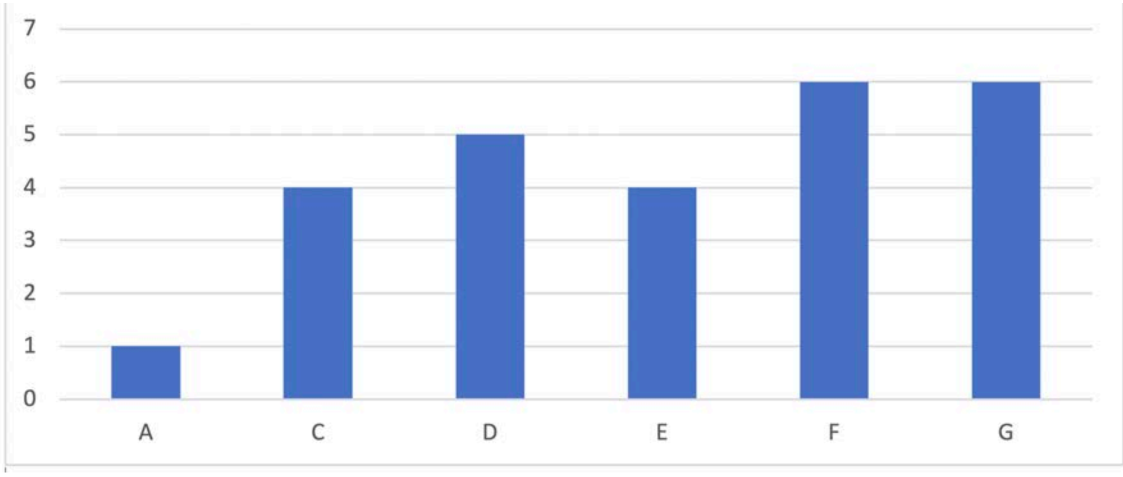

Figure 15. Chart plotting numbers of open Carnegie library buildings by 2020 in Scotland, England and Wales with Energy Performance Certificate within Asset Rating Bands

Although EPC Asset Rating Bands and DEC Operational Rating bands are not directly comparable, the graphic impact of the colour-coded range, A-G is illustrated in such a way as to give an unambiguous impression of best to worst that is potentially persuasive to decision makers. When looking for modelled estimations for the energy performance of these buildings, there are obviously fewer available since the DECs are the standard requirement for public buildings in England, Wales and Northern Ireland.

However, Energy Performance Certificates are mandatory instead of DECs for public buildings in Scotland. Nevertheless, using postcode lookups only 12 could be found of the 56 open Carnegie libraries there. A further 14 are also available for Carnegie libraries in England and Wales. Using this dataset of only 26 buildings it is evident in Figure 15 that the calculated energy use of these buildings appears to be higher on the scale than the measured energy use determined in the DECs. The data include 7 buildings for which no Primary Energy Value has been entered, indicating that these are presumptive figures. It is assumed that the one library that is A rated (Wombwell) is an error as it has no obvious significant modifications.

Nevertheless, overall the data illustrate that for existing buildings, the EPC method of modelling tends to indicate relatively higher levels of energy and CO2 emissions than the measured data provided through DECs does. This is concerning precisely because the opposite has been demonstrated to be true for new buildings that are being designed based on models that turn out to be over optimistic relative to their measured data of consumption. The comparison indicates that there is a bias evident in modelling tools which favour projected performance of new building products and workmanship over existing materials and workmanship for which there is a significant potential to generate more accurate observations. They also indicate that frugal management can have as great an impact as significant alterations to a building’s fabric or services.

3.3 Drawing life cycle indicators

As noted above, attempts to calculate the life cycle of an existing building completely are not feasible, owing to a lack of data and also not helpful in determining future expenditure, for the purposes of projection, it is conventional to strike off previous expenditure as “sunk costs”(Flanagan, 1989). However, it is still relevant to seek to derive indicators from a reference model for a set of buildings which share so many attributes. Using Toxteth library, which was identified by Carnegie as an exemplar, we are able to provide some signposts.

3.3.1 LCA: Toxteth Library – materials and components

Figure 16. Toxteth Library: Cross-section of laser scan (CP and GB)

A parametric model of the existing Toxteth library derived from a laser scan Figure 16 was built in REVIT™ and using the OneClick LCA™ plug in, the take-off of elements was imported in an attempt to create a Life-cycle assessment projected for 60 years in accordance with EN-15978. Assuming that historic means of transportation, by boat, train or horse drawn barge or carriage were beyond the scope of calculation, the aim was to model the building as if constructed today, using materials as closely matched to the actual building as possible. The immediate challenge lay in the selection of appropriate equivalent materials. For example, although the substantive quantity of brick might be readily identified from the UK, there is no option for a lime mortar or lime plaster that is manufactured in the UK, only from Germany or France. It was not possible to locate natural slates, so roof tiles from Germany were used. In addition, of course the quantities and types of fuels used and the processes of manufacture for steel, glass, kiln drying, lime-slaking, timber seasoning, slate mining, stone quarrying or tile-firing are all more or less incomparable in terms of their energy or carbon costs. Added to this the chemical composition of finishes; paints, varnishes, polishes and stains is generally completely altered. The outcome was therefore fairly unsatisfactory as it was so reliant on substitutions some of which are quite eccentric owing to the changed standards of building technology today.

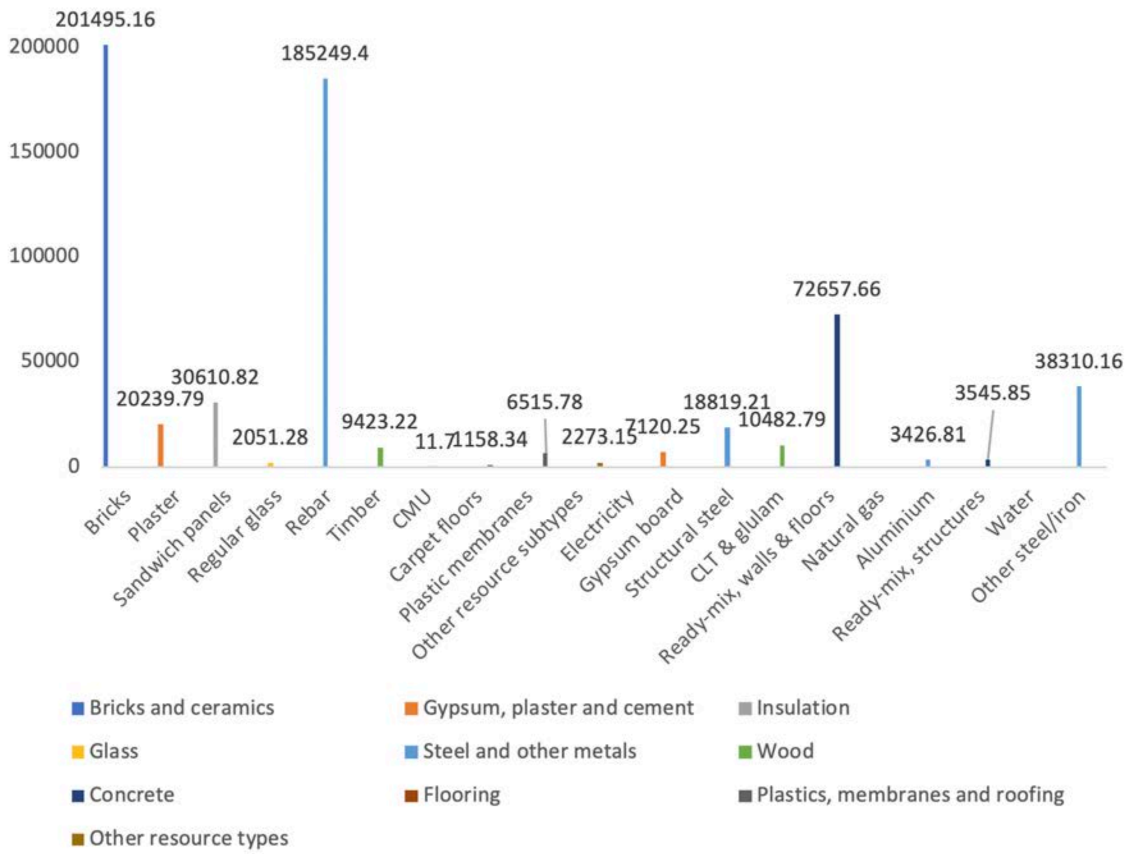

Figure 17. Toxteth Library: Total life-cycle impact by resource type and subtype, Global warming $KgCO_2e$ excluding energy and electricity use

There are, however, some critical details to highlight. The analysis, which can be accessed here (Boughanmi, 2020b), obviously showed 60 years of energy use to be the greatest contributor to future projected emissions. However, excluding that data, Figure 17, above sets out the embodied carbon in attempting to construct a similar building today, albeit including some unusual choices as noted above, there are some relevant lessons in principle. Excluding Rebar (steel reinforcing bar in concrete is not a known constituent in any event just a presumption from the modelling software REVIT™), the quantity of embodied energy attributed the large volume of masonry stands out. Since both the form and the method of construction are typical to a significant number of buildings, it is worth reflecting on the impacts of this.

3.3.2 Suggested adjustments

External walls

The record of the building's opening in the architectural press (Ed., 1902a) determines its key materials – this was a common practice in reporting so such data are frequently accessible. We know that its external walls were constructed of Ruabon bricks with Cefn stone dressings, these are adjacent sites near Wrexham in North Wales, 58 miles south of Toxteth. The slates on its roof were Green Cumberland slates, presumably from Borrowdale, 102 miles north of the site. Furthermore, looking at the map, it is likely that the weight of these materials on these journeys was likely to have been at least partly water borne. These short distances from cradle to gate are accounted for here only in part, however, their contribution to the weight of materials used is quantified – with external walls accounting for 39.7% of the overall mass of the building. It is not unreasonable, regarding the map of exterior materials used for all Carnegie libraries in Britain and acknowledging the similarity of their construction methods (refer back to Figure 7), to extrapolate that the distance of building materials from the sites was generally kept to a minimum and that the use of local stone, which was frequently praised, if nothing else because it benefitted the livelihoods of local men.

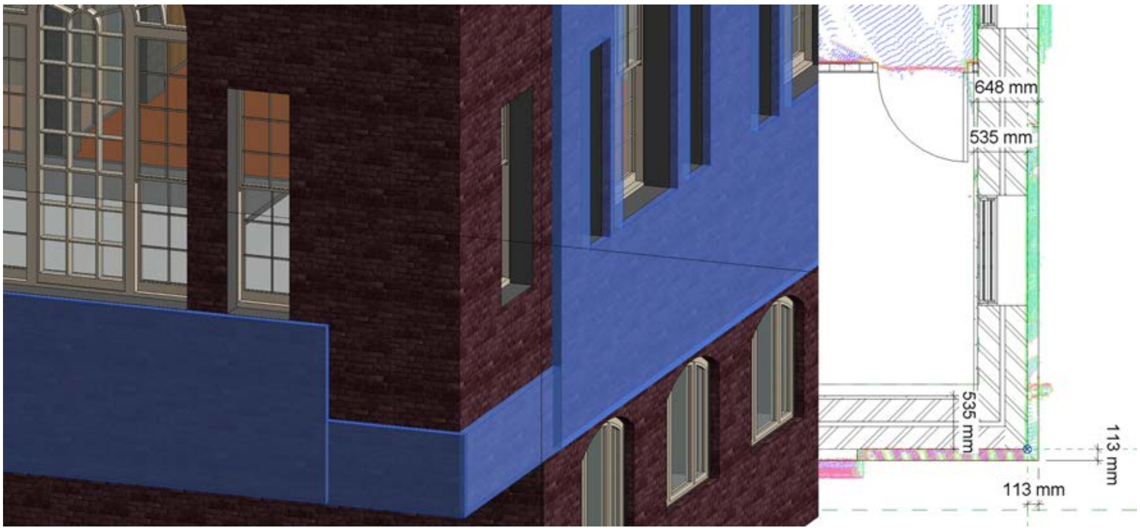

Figure 18. Toxteth Library: Parametric model detail and plan detail showing external wall construction (MB)

The greatest volume of material used is for the wall construction. These measure 535mm thick and are deemed to be built of two 225mm skins of solid-bonded brickwork finished internally with lime mortar and plaster Figure 18. Providing a small cavity between the two skins was an emergent practice used to prevent direct ingress of moisture, “hollow walls” are described in contemporary specification guidance (Macey, 1898). Based on the BR 443 the U-Value of each 225mm skin would be 1.52 whereas Rye and co have monitored a similar construction (no 20a) and found a figure of 1.48 p.36 (Rye, 2012). As the difference is not huge, BR 443 U-value of 1.52 which is based on BuildDesk™ calculations was used. The modelled U value of the whole wall assembly in REVIT™ is 0.3448 W/(m2/K). The walls’ thermal mass is calculated as 57.72 kJ/K and is likely to benefit the thermal comfort of the building year-round. Upgrading the thermal efficiency of the walls further is generally not the optimal solution, firstly external insulation would be ruled out for aesthetic reasons relating to listing status. Cavity insulation is no longer deemed advisable, internal dry lining might in some cases be possible without damaging the historic fabric, however, the benefit of thermal mass would also be lost.

It should be stated that the standard use of this quantity and quality of material whilst technically possible, was an extravagance not repeated after the economic contraction post-First World War. It would never be specified today simply on grounds of cost and the use of floor space given over to non-profitable structure. The durability of such practices of solid masonry construction is evident in the physical survival of every building. In order to meet modern standards, such walls would only be faced in a single skin of brick for aesthetic reasons, otherwise, they would be composed of a frame only substantial enough to meet structural requirements and insulated to meet the modelled energy performance targets of today together with an anticipated service life of perhaps 60 years. Taking into account the additional service life of the stone dressings and sills around the window openings that have also endured, it is hard to anticipate that aluminium, concrete or timber alternatives that would be chosen today would not require significantly more frequent maintenance and replacements.

Floors

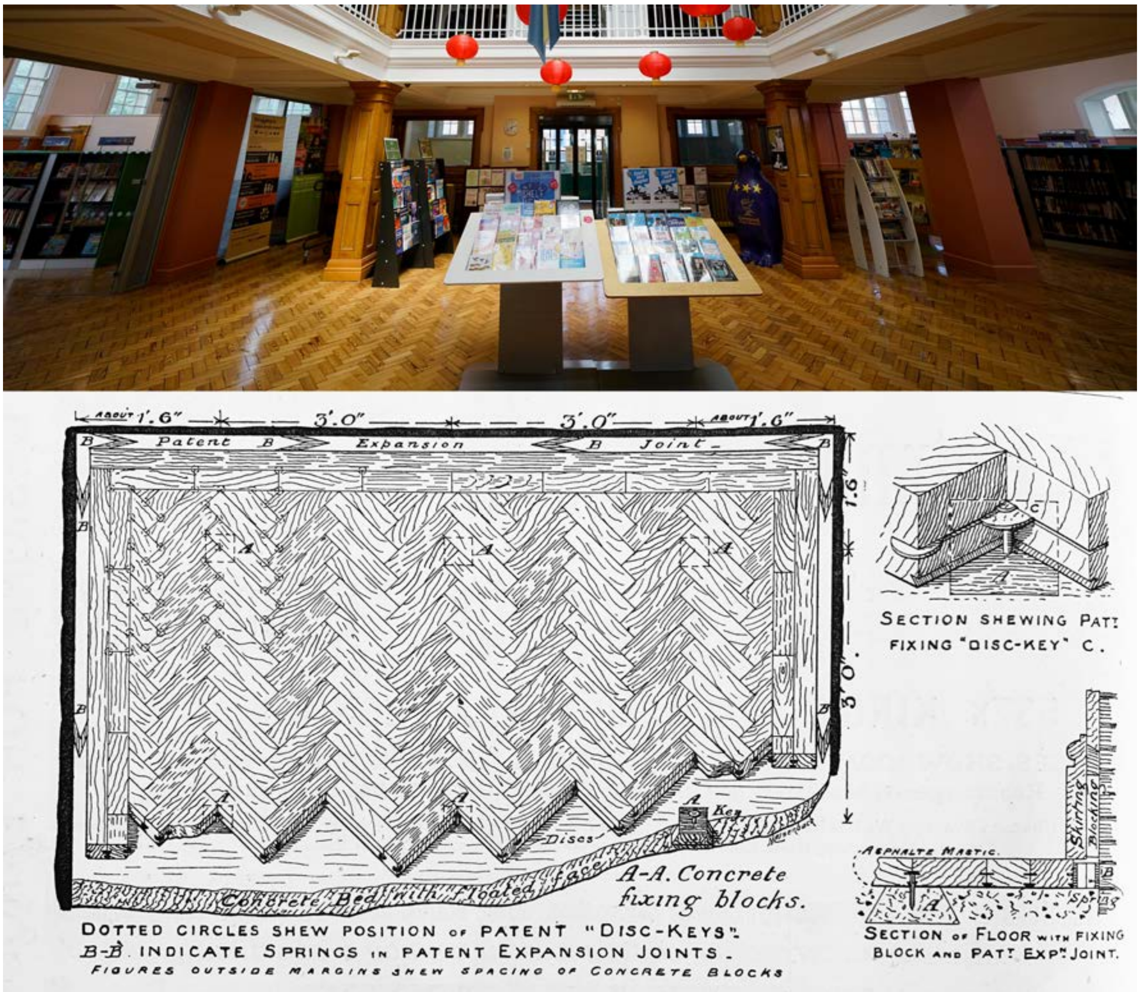

Figure 19. Toxteth Library: Interior showing parquet floor (OP) and detail of typical construction (Sears, 1893)

Floor finishes that require frequent replacement have significant impacts on life cycle assessments. With the exception of the first-floor gallery and carrels, the interior floors at Toxteth are of solid wood block parquet, a typical solution of the era, Figure 19. The floors require polishing and have evidently been sanded and re-finished in the 2008 refurbishment, however, other than general cleaning, they have survived for 118 years. The quality and colour of their finish is also a recognisable visual asset. As with the wall material, today, such solid construction is unaffordable and could not be justified for a building of this type except if specified in a laminated and therefore more vulnerable form. Requirements for acoustic attenuation in libraries would generally dictate that a softer floor finish were specified, perhaps a carpet, a vinyl or linoleum floor. These would have the same cleaning and maintenance demands as the woodblock floors but an anticipated service life of 5-10 years.

Rooflights

Figure 20. Toxteth Library: Laser scan cut away showing internal and external glazed layers in top-lights (CP and GB)

Toxteth library has a footprint of 620m2, its roof slopes are typical in including 124m2 of rooflights, see Figure 20. It is understood that all glazing was draught-stripped an updated in 2008. The critical vulnerability of the top lights as being the source of valued daylight but the most direct exit of heat is obvious. To this end the replacement of the external components of the rooflights with triple-glazed sealed units has been considered. It should be noted that as at Toxteth, the larger rooflights and glazed domes were not simply a single construction in the line of the roof, they commonly had a lower layer internally, often with decorative stained and obscured glass leaded lights. These served to diffuse the unwanted over-heating of direct sunlight. Having observed librarians in the North of England sheltering beneath a plastic gazebo that they had erected to shade themselves from the unprecedented heat of summer 2018 inside their refurbished library, it is important for managers and architects to note that the obscured glass layer that had been replaced with a modern clear rooflight did not simply serve an unnecessary decorative purpose.

Services

By far the greatest contributor to the CO_2 emissions of Toxteth Library modelled over the next 60 year is its projected energy use. Fossil fuel heating is calculated at 31272t or 67% and electricity use at 929t or 20% of the total CO_2. Swapping the source of heat for the most efficient available option in the model, (Biodiesel, vegetable oil based, SAP) reduces its contribution to 268t or 15%. Were the source of electricity to be decarbonized by, for example, connection to the world's largest offshore windfarm, at Burbo Bank adjacent to Liverpool, these figures could be amended further with little or no physical impact on the library building. Whilst this is not a universally available opportunity, it is illustrative of the increasing potential to set the problem in context.

Discussion - Balancing goals and generalisable implications

4.1 Balancing goals and relative measures

Data collated here relates to quantified economic, social and political conditions but also to related implicit qualitative measures of cultural heritage values, environmental wellbeing and regional socio-economic inequality. The force by which these imperatives are addressed through political policy and ultimately fiscal decisions is often distanced by levers informed by unilateral goals. Nevertheless, a significant number of community projects demonstrate that there are also bottom-up forces at work which are likely to innovate through improvisation. Observing the distinction between global and local drivers for change is thus utterly critical when applied to a set of buildings despite their apparently being erected with such uniform aspirations.

With such small numbers of top-ranking libraries - Figure 10, it is possible to consider each case in turn. Sunderland's Kayll Road library faces specific challenges, the library service was closed by the council and the building has been given to the local community, it is now one of a growing number to be run by an entirely voluntary group. In this area, where the median income is in the 4th decile and employment in the 3rd(Ministry of Housing, 2019), it is a reflection of the perceived value of the facility that its six computers available were provided by local contributions. The probable cause of Kayll Road's inclusion in the highest ranking is the frugal nature of its management. Malvern, by contrast rests in the 9th decile for deprivation, its inclusion in the least resource consuming band is probably an error based on the computation of its floor area which stands out as one of the largest Carnegie Libraries in Britain on the DEC at 5000m2, from Ordnance Survey it would appear more likely to measure around 1100m2. It is likely that the unusual embedding of the building (together with district heating at Leicester) account for the better reported running costs in Folkestone, Leicester and Northampton central libraries. Ilkley is a more typical building and its high score perhaps reflects a degree of frugal management. In common with many buildings it benefits from "strong top lighting"(News., 1905) and was typical in being designed with mechanical ventilation and vaulted ceilings.

The libraries at the bottom of the performance scale are not discernably different in their physical characteristics from the main. However, it is noticeable that a disproportionate 5 of the 7 in categories F and G are in Greater London; Lea Bridge, Harlesden, Walthamstow, Brentford, Willesden and Teddington. Given that the buildings are not particularly different physically from others in the UK, an observation may be either that being frugal with heating is at a lower priority than in other parts of the country or that as with Walthamstow's example in the introduction, they are simply very intensively used. Teddington is in the least deprived area of any open Carnegie Library and is one of only two to be in the top decile for IMD in England. It is a fairly typical double gabled design and is only different from its peers in terms of its internal decorative plasterwork which is unlikely to significantly impact its energy use. Notably two of them (Harlesden and Walthamstow) were not originally Carnegie Library buildings, they were built earlier and had extensions funded by Carnegie. The original part of Willesden library is dwarfed by an enormous extension so the data relating to it have little bearing on the old building.

These relatively small numbers of extremes are exceptions, rather it is the consistency of the cluster of median values around C and D ratings that are important to acknowledge. These measured data of actual operational energy consumption are impressive for a building stock of this age, especially with respect to the challenges outlined above that are inherent in the original aspirations of their designs. Bearing in mind that these data are comparative with all other buildings of all ages of this type, they would appear to reflect efficient management practices. It may also suggest that the almost universal preponderance of high levels of natural lighting within Carnegie library buildings is still a benefit to operational demands even though the energy consumption of artificial lighting appliances has been so reduced in recent years.

Generalisation

The findings regarding the relationship between measured energy use and current as well as emerging benchmarks confirm robustly that this cohort of buildings are not performing as badly as presumed for their age, particularly for the use of electricity. Reducing the consumption of energy for heating from 160 kWh per year (the current average of this cohort of 107 Carnegie library buildings) to that 85 kWh/m2K per year attributed to the emerging "Good practice" benchmark from the CIBSE's project in BETA, is more challenging.

Figure 21. Existing Carnegie library buildings with DECs exceeding emerging CIBSE 2020 "Good practice" benchmark for heat energy use of 85 kWh/m2K per year in public libraries (a) Kings Heath - Arthur Gilbey Latham, 1906 (b) Rushden - William Beresford Madin (Town Surveyor), 1905 (c) Mile End (James Knight originally 1862, Extension by MW Jameson, Borough Surveyor funded by Carnegie), 1906 (d) Burnley - George Hartley and Arthur Race (Borough Engineer), 1930 – Carnegie UK Trust (e) Harrogate - Henry Thomas Hare, 1906 and (f) Walsall - James Glen Sivewright Gibson, 1906. (OP) -all images

However, six buildings in our dataset with attributes that are shared and of very different scales, appear to achieve this already, all are fuelled by Natural Gas. They are Kings Heath, Rushden, Tower Hamlets Local History Library & Archives (formerly

Mile End Library), Burnley, Harrogate and Walsall. All are Grade 2 listed and Figure 21 illustrates their varied scale and appearance. Of particular note is the exemplary recent refurbishment of Walsall library, which has achieved annual energy consumption for heat of just 55 kWh/m2K. That this is possible for one, should, by virtue of all the observations made during this research of common features, make it feasible for others to follow.

Table 1. Heat sources.

Natural Gas	Oil	Grid supplied Electricity	District Heating
98	3	5	1

Table 1 indicates the current predominance of Natural Gas as a heat source for these buildings. It could be presumed that external factors will influence this in coming years. As noted initially, there is potential for increased reliance on lower tariff forms of energy to benefit their operational usage and increasing reliance on renewables which can be delivered at district level is not detrimental to the visual setting of the building. As the photograph of Walthamstow at the beginning illustrates, many libraries still operate artificial lights even though their levels of natural illumination are more than adequate. The comprehensive installation of sensors to time artificial lighting would be a low-cost adjustment to make. The iSERVcmb project has demonstrated through monitoring how calibrating the timing of heating controls in buildings with significant thermal mass can initiate energy savings of up to 43%(Knight).

Table 2. Building Environment.

Air Conditioning	Heating and Mechanical Ventilation	Heating and Natural Ventilation	Mixed mode with Mechanical Ventilation	Natural Ventilation Only
4	7	90	4	1

Another potential is to re-design the mechanical and ventilation systems taking note of their original intentions. As Table 2 indicates, 90 of these 107 buildings are listed on their DECs as being naturally ventilated. However, our survey identified ventilation turrets or towers associated with mechanical ventilation systems on 90 of 224 open library buildings, including Toxteth, a further 71 have external vent grilles visible which may indicate that they also had the same system but that the turrets have been removed (Prizeman et al., 2020). They were typically designed to use mechanical ventilation with fans in turrets over vaulted ceilings with inlets drawing warm air through the wall behind the radiators below as modelled in principle in recent work (Prizeman et al., 2020). The principle is neatly described for Montrose library: "the building is heated by low-pressure hot water, and pure air is secured by two electrical fans – one above the lending library, the other in the flèche above the recreation-room, which effect a complete change of air every fifteen minutes without draught" (Ed., 1905a). Although drawing in such quantities of fresh air is counter to common ambitions of air tightness, it is possible that modern heat recovery systems could be devised to systematically make use of these existing features.

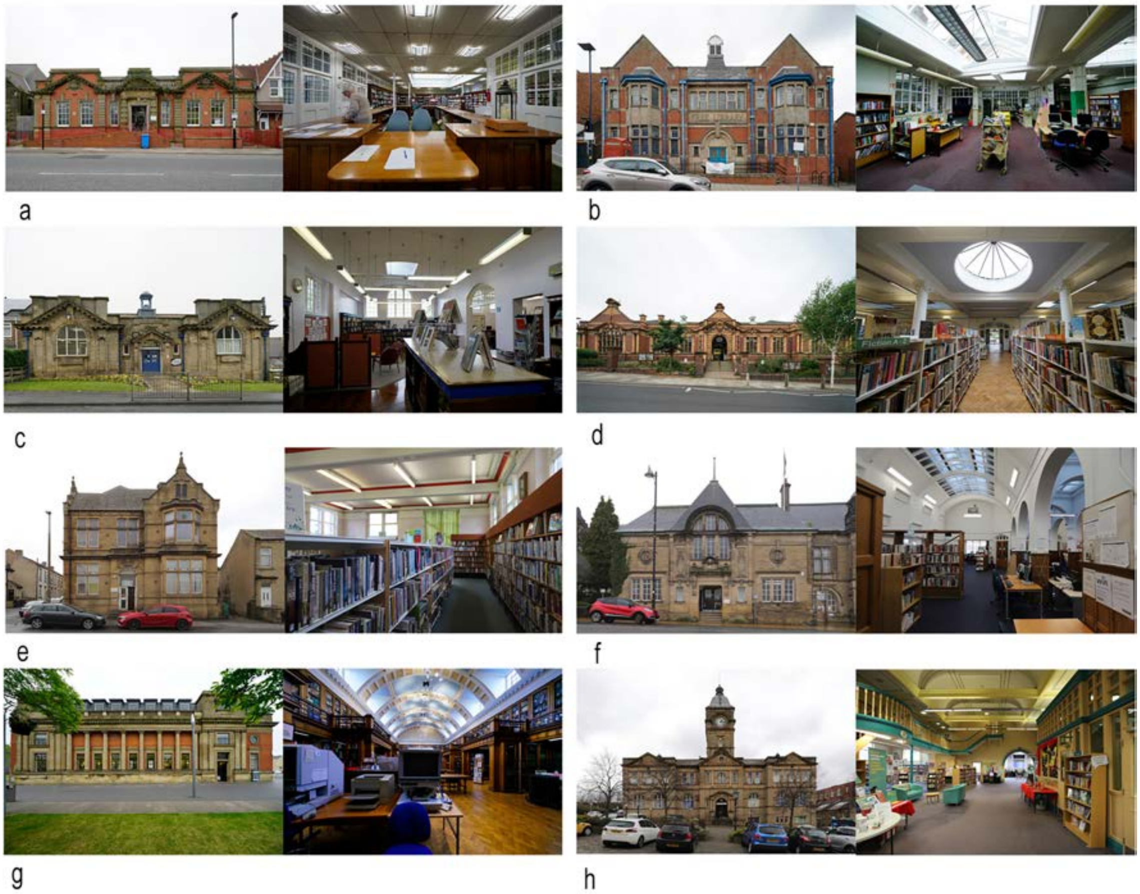

Figure 22. Existing Carnegie library buildings with DECs exceeding emerging CIBSE 2020 “Good practice” benchmark for electrical energy use of 32 kWh/m2K per year in public libraries (a) Kayll Road - Hugh Taylor Decimus Hedley, 1909 (b) Stirchley - John P. Osborne, 1908 (c) Annfield Plain - Edward Cratney 1908 (d) Herne Hill - H. Wakeford & Sons, 1906 (e) Heckmondwike - Henry Stead, 1911 (f) Ilkley - William Bakewell, 1907 (g) Middlesbrough - Sir Thomas Edwin Cooper, 1912 (h) Batley - Walter Hanstock & Son, 1907. (OP) -all images.

In seeking to meet the lowest of the various benchmarks for electricity consumption, the CIBSE 2012 Good Practice level of 32 kWh/m2K per year from the current average of 62 kWh/m2K per year, there are more exemplars in our sample already below this level. These are the previously mentioned Kayll Road together with Stirchley, Annfield Plain, Herne Hill, Heckmondwike, Ilkley, Middlesbrough and

Batley. All are Grade II listed except Heckmondwike, which has no heritage designation. They are variously council and community managed and cover a wide range of economic contexts. Again, the potential for generalization is self-evident.

Conclusions

Modelling and measuring energy use here identify a reverse principle of normal assumptions of performance. The metered data reveals consistent thrift in management and durable economic operation learned over time. Identifying the use of local materials in these proto-modern early standardized buildings is a significant finding. Mapping the local and the global paradigm demonstrates some irony in that the specific was generic (American furniture fittings and library plans) and the generic was specific (the use of local stone).

Whereas Hong (2015) noted that establishing benchmarks for the energy use of a typology is generally difficult, with the large quantity and limited era of building during which the Carnegie Library programme was delivered in Britain, it is possible to make steps towards offering informed statements in principle since the buildings demonstrably deploy a range of standardised components and features. There is potential for these methods which have been based on historical research and computer vision tools, to be expanded to other sets of buildings or specific technological practices. The importance of considering ambitions for lowering carbon and energy is undeniable, however, reasoning through the imperatives of original design intentions is paramount to better decision making.

For these buildings, their potential social value, current heritage listing status and universal conditions of operating under tight financial constraints are also shared circumstances in addition to requirements to maintain accessibility and meet lower emissions targets. These mutual conditions can readily be assumed to have similar impacts on future attempts to reduce energy and carbon costs. Here, using a single but exemplary building as an archetype, key components and opportunities have been identified whilst common traits with respect to the use of materials are mapped to provide evidence in support of generalizing these findings with confidence.

The findings suggest that a cautioned approach to decision making should be adopted which seeks to make use of existing potentialities:

- Future research to develop generic ventilation and heat recovery strategies relating to existing equipment and built forms could be developed
- to prioritise the replacement of fossil fuel sources of energy with low carbon or renewable alternatives as they become available
- to consider the installation of additional insulated glazing over rooflights

and not to:

- drastically alter the daylighting design of these buildings or
- consider that they do not compare favourably with newer buildings in terms of energy performance.

Where it is necessary to move the library service on, the findings demonstrate that future uses are most successful that are aligned to celebrate the particular environmental qualities of publicly accessible environmental conditions offered. Fundamentally, this paper calls for decision makers not to discount the durable quality of materials and workmanship and the ongoing contribution to wellbeing of these civic buildings as a given.

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