Carbon Pasts, Low Carbon Futures
Industrial Heritage and Architectural Pedagogy

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1. Introduction

At the peak of their productivity in 1913, the collieries of the South Wales Valleys formed the largest site of carbon extraction in the world (Hughes 1994). Their decline and eventual cessation (ibid) have subsequently led to wide-spread multiple deprivation, which continues to characterize the area to this day, and a socially and geographically uneven shift to a post-industrial society. As we look to transition to a low-carbon economy, the industrial heritage of the region provides a rich resource for pedagogical activities that seek to address historic carbon debts, whilst providing creative solutions to sustainably and sensitively meet the needs of the associated communities left behind. This paper for session 2, presents the conception, development and delivery of a final year Master's in Architecture (MArch) design thesis unit, "Carbon Pasts, Low Carbon Futures". Created in direct response to student demand to study conservation, adaptive reuse and retrofit, now in its fourth year, the unit challenges students to design sympathetic and sustainable futures for specific examples of industrial heritage associated with the South Wales Coalfield. Sites to date have included both sites of extraction and the social infrastructure that emerged to support them. The use of these sites has focused the students' minds on the challenges of both the climate and ecological emergencies and has inspired them to develop a plethora of programmatic and tectonic proposals. Whilst the outcomes are purely academic, they have been shared with the site owners, curators, local communities and local government, with the hope they will provide new ideas and inspiration for a low carbon future.

2. Reshaping Architectural Pedagogy

Despite the fact that an estimated 50%-70% of construction work across the globe involves working with existing buildings (Cramer and Breitling 2012), in the UK architectural education predominately focuses on new-build

design (Grant 2020; Waite 2022). Equally, faced by the climate emergency created by anthropogenic carbon emissions, the UK construction industry is increasingly recognizing the need to reuse the embodied carbon of our existing built environment (Harrabin 2023; Hurst 2019; Gove 2023). Reflecting this, in 2021, students of the Master's in Architecture at the Welsh School of Architecture ranked "Conservation and Retrofit" as the third most important area of interest for their final-year design thesis closely following "Atmosphere and Experience" and "Zero/Low Carbon Design," a preference also echoed in their open-ended comments, where "Conservation" comes second only to "Sustainability" (Figure 1).

Figure 1. Free-text comments from MArch students 2021 regarding preferred topics for final year design thesis, showing dominance of conservation and sustainability.

In response, the corresponding author was invited to develop a design thesis unit focusing on the integration of reuse, retrofit, and passive/low-energy design. With the involvement of the co-authors, this was first delivered in the academic year 2021/22 and is just completing its fourth year at the time of writing this paper (June 2025). This pedagogical opening provided the authors the opportunity to explore the hypothesis that design thesis projects centered around industrial heritage sites related to historic carbon extraction, specifically those of the South Wales Coalfield, could increase the students' engagement with the issues of the climate and ecological emergencies.

3. The Industrial Heritage of the South Wales Coalfield

With an area of approximately 2,600 square kilometers, the South Wales Coalfield is the largest uninterrupted coalfield in Great Britain. Whilst there is evidence of coal mining dating back to Roman times (James 1993), the areas dominance in global coal markets dates primarily to the late 19th and early 20th century (Hughes 1994), reaching a peak in 1913 at which point it had one of the largest outputs of coal anywhere in the world (ibid). As a consequence, up until 1887 the UK was the highest emitter of carbon dioxide, the principal contributor to anthropogenic climate change, remaining in the top five highest emitters until 1969 (Vigna 2024). However, this carbon debt cannot be laid at the door of the proud communities who gave so much to power the world's first industrial revolution and have subsequently faced multi-faceted and widespread deprivation following the industry's decline, and widespread closure of mines in the 1980s. Indeed, their livelihood and prosperity were tightly linked with the demand for coal in the world. The decline of the coal industry, which started as early as the 1940s, was also synonymous with the decline of many former mining communities in South Wales (Curtis 2013).

Along with the process of decline, and eventually forgetting, commemorating and heritagization emerged as a response to it. Despite wholescale attempts in the 1980s and 90s to eradicate evidence of the region's mining past, approximately 377 listed buildings identified as "industrial" survive in the area, and one World Heritage Landscape (Cadw 2025). The broader question, however, is how these former industrial legacies can be integrated into a sustainable future for these communities in a post-industrial era, not just as monuments, but as anchors for place-making and education that connect the past and future. Many of the tangible traces have yet to find a purpose and remain at risk of disappearing and being forgotten. These powerful legacies of our carbon past, together with their potential for renewable energies such as wind power and mine water heat recovery (Farr et al. 2016), and the need for meaningful social, economic and environmental regeneration, make them prime locations for achieving Wales's low carbon aspirations through just transition as enshrined in the *Well-being of Future Generations (Wales) Act 2015* 2015).

Within this rich context, each year for the past four years (2021/22, 2022/23, 2023/24 and 2024/25), a different site has been chosen to inspire the MArch design thesis unit, "Carbon Pasts, Low Carbon futures. The criteria used for their selection have been: i. historically linked to the coal industry; ii. substantial surviving built heritage; and iii. real and ongoing challenges currently leading to an uncertain future.

The first year the unit ran, 2021/22, Crumlin Navigation Colliery (Figure 2), a grade II* listed complex of colliery buildings, in the Ebbw valley was selected. Despite being considered by the Royal Commission for Ancient and Historic Buildings in Wales to be the best preserved colliery complex in South Wales, the buildings have been identified as buildings at risk by Caerphilly County Borough Council. Even with the active and passionate work of the current custodians, The Friends of the Navigation, the future of this iconic site of national importance remains in peril.

Figure 2. Crumlin Navigation Colliery (Whitman, 2025)

Another site of carbon extraction was selected for 2022/23, this time the grade II* listed Cefn Coed Colliery (Figure 3), in the Dulais Valley, in the west of the coalfield. Following closure of the mine in 1968, it reopened as a mining museum in 1986. However, as with many other heritage tourist attractions, it closed during the global pandemic and has failed to reopen. Faced with ongoing maintenance and financial issues, the site's current custodians, Neath Port Talbot Council, have yet to decide its future. The students were therefore challenged with proposing alternative complimentary uses to enable its sustainable survival.

Figure 3. Cefn Coed Colliery Museum (Whitman, 2022)

Equally important as the sites of extraction, is the social infrastructure that grew up to support the mining industry. An example of which, Pontypridd Market Quarter (Figure 4) was therefore chosen in 2023/24. Topped by an abandoned theatre, the working market faces the same socio-economic being experienced by high-streets across the UK and beyond, with the added complexities of the stigma and deprivation of a postindustrial society.

Figure 4. Pontypridd Market and Town Hall Theatre (Whitman, 2023)

This year the unit returned to a site of carbon extraction, focusing on the grade II* listed Penallta Colliery (Figure 5). Sunk in 1906, the colliery in 1939 achieved the highest weekly coal production in Europe (Price and Probert, 1995) and was the last deep mine to work in the Rhymney Valley, closing in 1991. Today part of the site has already been redeveloped for residential purposes, a Welsh speaking primary school, and a country park. However, the vast 1906 Engine Hall and 1938 Bath house remain derelict were added to SAVE Britain's Heritage's Building at Risk Register in 2024, and the Bath House listed as one of the top 10 buildings at risk by the 20th Century Society in 2025.

Figure 5. Penallta Colliery Engine Hall and Headframe No.1. (Source: Whitman, 2024)

4. Methodology

4.1. Pedagogical Methodology

As with many established teachers, the authors' methodology has incrementally developed over years of engagement with architectural education, however, there are models to which it can be compared, and pedagogical theories that have been influential in its formation. The use of the real-world problems of the existing sites, and the involvement of their owners or custodians, situates the teaching within the category of Live Project Teaching as discussed by Harriss and Widder (2014). The risk of this being an exploitative method is reduced by ensuring that from the outset there is transparency and clarity with all stakeholders engaged in the project (Almond 2023), and the sharing of the final proposals at the end. This benefits the students by immersing them in the complexities of an actual site, with specific strengths, weaknesses, risks and opportunities, whilst at the same time providing owners and authorities with solutions that often push the boundaries, and challenge conventional thinking. In 2021/22 and 2023/24 the sharing of the design proposals was done through a public exhibition, to which the site's custodians, the local community, and local and national policy makers were invited. In 2022/23 due to ongoing sensitivity over the site's future, a public exhibition was not possible, however a presentation was made to the local council, a situation that looks likely to be repeated this academic year 2024/25. The concept of Appreciative Inquiry (Hall and Hammond 1998) is also employed, encouraging students to build on the sites' positive attributes, rather than further demoralizing these community that already face significant prejudice.

Overall, the general structure of the teaching shares similarities with the "Double-Layered Model" of architectural teaching, as envisaged by Goldschmidt (1983), and more specifically as an adaptation of that described by Salama (2015) (Figure).

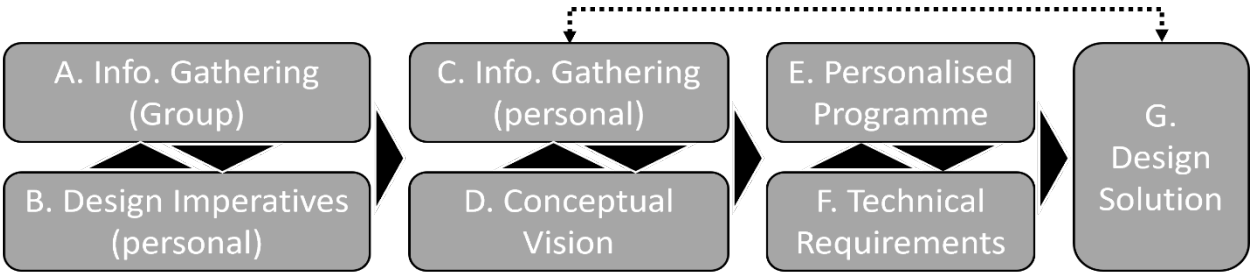

Figure 6. Pedagogical model, as adapted by authors from Salama's (2015) "Double-layered Asymmetrical Model".

At the beginning of the academic year, students begin in groups to build a comprehensive dossier of information of the site (A), using literature review, archival studies, building surveying techniques such as laser scanning and photogrammetry, and community engagement. Concurrently, commencing with the initial site visit, students are challenged to capture their initial personal response to the site through their choice of artistic medium, which over the years has included painting, printmaking, sculpture, creative writing and video. This is then critically analyzed as students are invited to form an individual, holistic understanding of the various elements and actors

within their sites. This was done through an interactive workshop that introduced students to a relational methodology to understanding sustainable heritage (Tam 2022). After an initial introduction to the methodology, students were split into groups to identify relevant actors and elements within the post-industrial sites through exploring their preliminary research and interpretation of the site's history. To scaffold the activities, students were asked to focus on specific categories, such as human actors, environmental or natural landscape elements, built elements on an architectural level, and built elements on a landscape level. They were then asked to identify historical or current connections between these elements and actors, both within their categories and between categories. By tracing the evolution of some of these connections, students were invited to consider how their proposed interventions might play a role in shaping these relationships in the future.

The initial personal response, and subsequent critical analysis is then further developed to form the basis of their individual design imperatives (B). The first semester concludes with the submission of a primer portfolio in which additional individual research (C), drawing on that gathered in groups (A), comes together as their conceptual vision and intellectual position (D) for the design thesis. This forms the starting point of semester two, initiating the formation of their programmatic brief (E), and associated technical requirements (F), which are tested through design iterations, resulting with a final thesis proposal (G). The model promotes individual student interpretations, supported by, rather than defined by the tutors (Salama 2015). As such the engagement with issues such as the climate emergency, or low carbon technologies, emerge from the students' own research and exploration, rather than being imposed.

4.2. Analysis of student outcomes - methodology

To explore the hypothesis that engaging with industrial heritage encourages a focus on sustainable outcomes, content analysis has been undertaken on the body of student work submitted during the academic years 2021/22, 2022/23 and 2023/24, to identify differences and commonalities in programmatic briefs and resulting architectural responses; to explore how students are engaging with the existing buildings and associate conservation philosophies; and to identify low energy strategies that have been explored and adopted. Five students work are presented in detail as part of this analysis to foreground the most successful examples of the potential offered by engaging with existing buildings with a common focus on low energy architecture.

5. Results

Analysis of the extent to which students engaged with existing heritage buildings reveals distinct differences over the three years (Table I). This can in part be explained by specific site conditions, with the first two colliery sites (2021/22 and 2022/23) having extensive areas of brownfield site where previous structures had already been demolished, thereby giving both the opportunity and precedent for new free-standing constructions. Whereas, in contrast, Pontypridd Market Quarter (2023/24) is a tight-knit urban fabric, with few clear sites for new build without demolition, and so no free-standing additions or solely new-build proposals were made. The final colliery site, like the first two had extensive areas of brownfield site, however all students engaged with the reuse of at least one historic structure. Possibly this may point towards a changing attitude amongst students, characterised by an increased willingness to question the need for new-build over reuse.

TABLE I. ARCHITECTURAL APPROACH TO EXISTING BUILDINGS AND PROPOSALS

Approach	No. of Students				
	2021/22	*2022/23*	*2023/24*	*2024/25*	*Total*
Reuse within existing volume	3	0	5	13	21
Reuse with extension	3	3	3	2	11
Reuse with freestanding additions	1	3	0	4	8
New-Build only	1	1	0	0	2

With regards to low energy and sustainable strategies that have driven the students designs, the frequencies of these are presented in Table II. Whilst a low-carbon agenda is implicit in the brief, the specific strategies to be adopted are not defined by the tutors, encouraging students to discover and adopt these through their own research and exploration. As such, it is the students' engagement with the existing buildings that has ultimately led them to adopt these specific low carbon technologies.

TABLE II. ARCHITECTURAL APPROACH TO EXISTING BUILDINGS AND PROPOSALS

Theme	No. of Students	Percentage of cohort over 4 years (%)
Reuse	38	90
Low Carbon Materials	29	69
Renewable Energy	26	62
Bioclimatic Strategies	37	88
Low Energy Retrofit	31	74
Design for Disassembly	18	43
Biophilia	7	17
Phytoremediation	6	14

5.1. Example 1 – MedTech Research Centre

David Lowenthal's heritage theories explored in "The Past is a Foreign Country" (Lowenthal 2015) inspired the student, Jordan Grady to explore the notion of heritage as a continuous narrative, perpetuating Crumlin Navigation's intangible heritage as a place of innovation and industry. As such she proposed the site's reuse for an emerging key industry for South Wales, Medical Technology, or MedTech. New insertions were envisaged as replacement "machinery", taking volumetric cues from the now lost large-scale engines and pumps that once filled these spaces (Figure).

Figure 7. Internal render of proposal at Crumlin Navigation Colliery for MedTech Research Centre, showing inserted "machinery" (Grady, J., 2022)

This created laboratory and research spaces as box-in-box units, meeting exacting the required technical standards with U-values of 0.1 W/m2K, excellent airtightness, controlled ventilation with heat recovery, acoustic separation and reverberation times of 1.2 sec being achieved without requiring substantial intervention to the historic fabric itself.

5.2. Example 2 – Renewable Energy Storage Facility

The concept of coal as an ancient form of solar energy storage inspired the student, Rowan Luckman, to propose the conversion of Crumlin Navigation Colliery into a novel battery for storing renewable energy. Challenging the current reliance on lithium batteries with their inherent environmental problems, and perpetuation of global resource extraction, Rowan explored alternative solutions, including, underground compressed air, pumped hydroelectric, the flooded mine acting as the lower reservoir, and a gravitational battery in the upcast mineshaft. Across the wider site a solar farm, wind turbines and micro-hydroelectric were envisaged as new landscape interventions. The incorporation of these mechanisms for both producing and storing power were woven into the historic fabric guided by Burke's notions of the sublime (Burke 2012) and subsequent ideas of the post-industrial sublime (Baptist 2016) (Figure 8).

Figure 8. “Wander above Crumlin”, Caspar David Friedrich’s “Wanderer above the Sea of Fog” is re-imagined in the Ebbw Valley (Luckman, 2022).

5.3. Example 3 – Mine Water Heat Recovery Research Centre and National Coal Archives

Example three is also from 2021/22 and this time the student, Alexander McCormick became fascinated by the underground heritage of the site. Using archival information from the Coal Authority (now Mining Remediation Authority), including plans of the excavations, borehole logbooks, geological data, in conjunction with personal histories of former miners and their families (Figure 10), he developed a proposal for a mine water heat recovery research centre, combined with a National Coal Archives (Figure). Earth sheltered buildings, constructed of

stabilised earth, were let down into the brownfield site in front of the historic colliery complex, whilst steel and larch, charred using the Japanese “Yakisugi” technique, climbed up through the heritage buildings with geometries taken from the underlying coal seams.

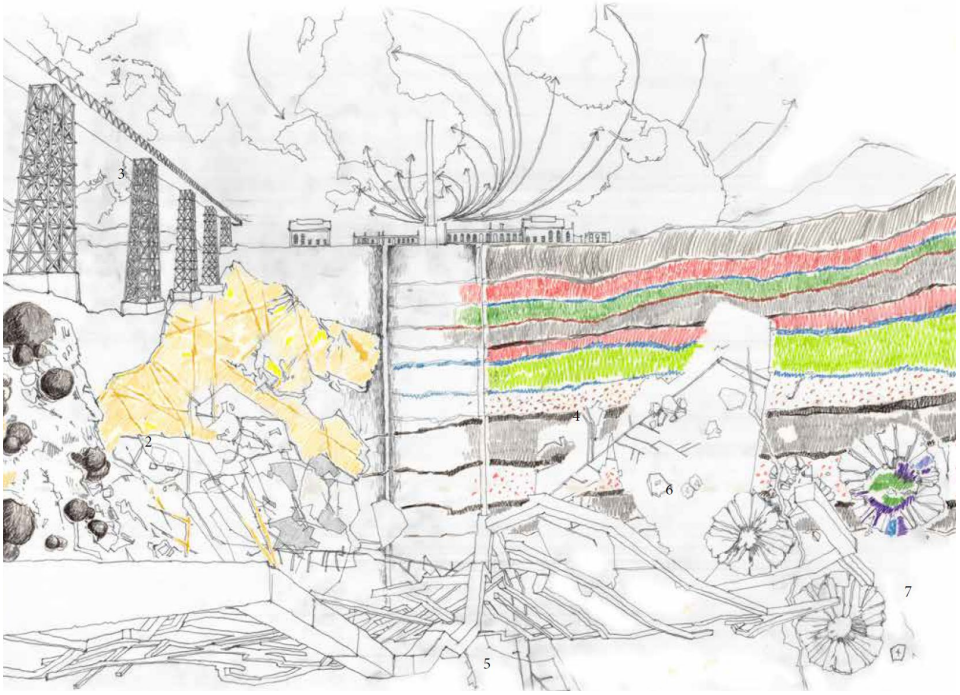

Figure 9. Conceptual collage of subterranean and global connections, leading to the proposal at Crumlin Navigation Colliery for Mine Water Heat Recovery Research Centre and National Coal Archives (McCormick, A., 2022)

Figure 10. Cross section of proposal at Crumlin Navigation Colliery for Mine Water Heat Recovery Research Centre and National Coal Archives (McCormick, A., 2022)

5.4. Example 4 – National Museum of Energy and Renewable Energy development Park

Moving on to Cefn Coed Colliery Museum in 2022/23, Morgan Taylor similarly took energy as his theme, this time proposing a renewable energy development park centred around the new National Museum of Energy, an addition to the Amgueddfa Cymru (National Museum of Wales) portfolio of museums that are situated across Wales (Figure).

Figure 11. Aerial axonometric of proposal at Cefn Coed Colliery for a National Museum of Energy and Renewable Energy development Park (Taylor, M., 2023)

Energy Past, the existing buildings, Energy Present, low-caron demonstration homes, and Energy Future, mine water heat recovery and future research form a sequence around the site, with one gallery forming a new context for the grade II* boilers, replacing a poorly maintained and not original asbestos shed. (Figure).

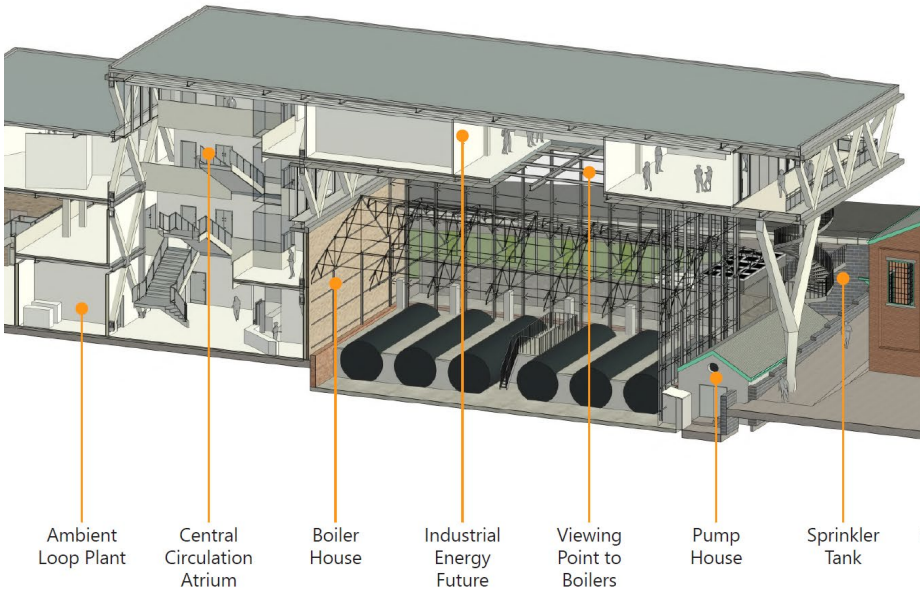

Figure 12. Sectional axonometric of the “Energy Futures” gallery, sheltering the grade II* listed range of boilers, as part of the proposal at Cefn Coed Colliery for a National Museum of Energy (Taylor, M., 2023).

5.5. Example 5 The Memory Collective a story telling archive for a Sustainable Future

The final example, from last year (2023/24) by Connor Bryan, takes a different approach to tackling the climate and ecological emergencies, addressing the need for societal behavioral change, rather than more technical building-based solutions. This is possibly due to the shift in site from a source of carbon extraction to the social infrastructure that supported the coal mining industry surrounding Pontypridd. The project proposes the restoration and adaptation of the former Townhall Theatre as a story telling archive (Figure 14) and explores recapturing the art of communal storytelling in 21st Century, with the aim of aiding our transition to a low carbon society (Solnit and Young-Lutunatabua 2023).

Figure 13. The Memory Collective a story telling archive for a Sustainable Future (Bryan, C., 2024).

Whilst not the principal programmatic driver for the design, low carbon strategies were still incorporated with waste heat from the datacentre meeting 45% space heating demand, the specification of cross laminated timber, a low carbon material, for principle new structural elements and the integration of photovoltaics in the new replacement roof design.

6. Discussion

Over the past four years, it has been noted by technical examiners that students in the Carbon Pasts, Low Carbon Futures unit have a higher engagement with low carbon technologies and strategies when compared to other final year MArch design thesis students. As unit leads, the first and second authors can confirm that this is principally is driven by the students, and naturally arises from their study of the selected industrial heritage sites. It is heartening that this success has been recognized with the capacity of the unit in 2024/25 being doubled, requiring the employment of the second author as co-unit lead. As a result, 19 students have recently completed proposals for Penallta Colliery in the Rhymney Valley. Whilst the marking of this is still being completed, there is an evident increasing emphasis on social sustainability, and a greater acknowledgement of the ecological crisis, rather than focusing purely on mitigating our changing climate.

The importance of engaging with existing buildings is also being incorporated into the redesign of the Welsh

School of Architecture's undergraduate BSc Architectural Studies, with the inclusion of "adaptation" as one of the suites of thematic studios. Heritage buildings are no longer being seen as only an area for postgraduate specialization, but an important element of our built environment that all young architects should be encouraged to engage with and be inspired by.

7. Conclusion

This paper underscores the importance of engaging architectural students with industrial heritage, particularly those sites directly related to carbon extraction and carbon intensive industrials, in the context of teaching low-energy design. By working with sites tied to the UK's historical carbon legacy, students are inspired to develop innovative responses to the climate and ecological crises. Encouragingly, the growing recognition within both architectural pedagogy and the profession of the need to question demolition and new-build practices is beginning to take root. To meet ambitious climate targets, it is imperative that the industry shifts its focus toward reusing and optimizing existing built assets, thereby preserving and leveraging their embodied carbon. Industrial heritage has an exciting part to play in achieving this goal.

8. Acknowledgements

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