

Institution: Cardiff University
Unit of Assessment 13: Architecture, Built Environment and Planning
<p>Section 1 (S1). Unit context and structure, research and impact strategy</p> <p>1.1. Unit context and structure</p> <p>The Welsh School of Architecture (WSA) is one of seven schools in the College of Physical Sciences and Engineering and has 32.3FTE category A staff. It has an ethos of collaborative, diverse research and dialogue with communities of practice. The School has a strong relationship with the Welsh Government (see SOLCER, Section 1.5), underpinned by a long-standing reputation for sustainability research and impact-delivering projects. Since REF2014, in which we submitted 14.80 of 20FTE category A staff, the WSA has grown, recruiting 21 researchers and expanding our key research areas into urbanism, heritage, and architectural computation.</p> <p>In 2019, the School secured ~£20M investment from Cardiff University (CU) for our ambitious plan for growth, WIDER-BE (Well Informed Design and Education through Research in the Built Environment – see S1.2), demonstrating the University's recognition of the central role we play in driving key research and innovation collaborations at Cardiff (see S1.4). The plan includes the further diversification of our research base and income, physical refurbishment, spatial expansion, growth in student and staff numbers and a new research facility. Consequently, WSA is more than doubling its space in Bute Building (from 2197 to 5685m²).</p> <p>In 2014, our research was organised in three research groups, each including 'special interest' clusters. In reaction to staff growth and diversification of specialisations, in 2018 the School undertook a major review of its activities to increase synergy between research and teaching. Following the review, we aligned activities and, to enhance the specificity of the research areas, developed a new group structure from the clusters. These inclusive Research and Scholarship Groups (RSGs) bring together staff on different contracts (Teaching and Research, Research, and Teaching and Scholarship) and postgraduate research (PGR) students, recognising the essential contribution they all make to generating knowledge, stimulating debate and creating impact. The groups sustain and support the WSA's research culture, mentor and nurture early career researchers (ECRs) and PGRs, organise research events (e.g. the WSA Research Lecture Series), run internal grant peer-review processes and joint applications. The groups are:</p> <ol style="list-style-type: none"> 1. Computational Methods in Architecture: The Group consists of two category A staff (group lead Jabi, Chatzivasileiadi) and five PGRs. Two others, Doe and Spaeth, have recently relocated abroad (we will recruit for these positions). The Group investigates generative design, parametric design, performance analysis, responsive architecture, digital fabrication, digital cultural heritage, building information modelling, virtual and augmented reality, and artificial intelligence. It has strong industry links, exemplified by projects studying robotically-controlled 3D printing of cob (EPSRC), and an innovative modelling software, Topologic (see S3.1), supported by Jabi's 2016 £287,000 Leverhulme Grant and integrated within industry (e.g. Buro Happold). 2. Design, Practice, Materials and Making: The Group includes six category A staff (Green, Forster, Gwilliam, McVicar, Salter, Wulff), five staff on Teaching and Scholarship (T&S) contracts and 11 PGRs. Members of the group engage in practice-based research, exploring the intersection of academic and professional domains. In the last years, key projects involved the study of affordable and sustainable housing (Green, Forster – see S4.4.3), the award-winning restoration of the Alhambra (Wulff, S4.4.4), and a work commissioned by the 2018 Venice Biennale (Salter). Key publications include the books <i>Walmer Yard</i> (Salter) and <i>Precision in Architecture</i> (McVicar). 3. Energy, Environments and People: WSA's largest RSG includes 13 category A staff (Patterson, Ampatzi, Bleil de Souza, Du, Knight, Lannon, Latif, Marchesi, Patel, Poortinga, Sharmin, Tweed, Zapata-Lancaster), eight non-category A academics and 32 PGRs. The Group focuses on the sustainability of the built environment and its impact on quality of life, working across scales from building components to national policy. It has secured more than £5M in research income in this period – funded by, among others, the European Regional Development Fund, Wales European Funding Office; EPSRC; ESRC; and

Horizon 2020. Key projects include SmartER (see S4.1), SOLCER (S4.4.1), SERL, SPECIFIC and EnergyREV (S3.1).

4. **Heritage and Conservation:** the group includes leads **Prizeman** and **Sibley**, Whitman, and six PGRs. The group's research on architectural and urban heritage and conservation spans externally-funded research and consultancy in the UK and globally. It is involved in sustainable retrofitting of heritage buildings through combining science, technology and humanities. Major projects in this period include Prizeman's AHRC-funded Shelf Life (S3.1), and Sibley's Eco-Hammam (S2.1; GCRF International Development Grant), as well as the key anthology *Sustainable Building Construction* (Prizeman).
5. **History and Theory:** Members of this group (**Kaminer**, Aelbrecht, Bowie, Lupton, Ntzani, one T&S staff as well as six PGRs) have published in this period key monographs about Medieval Indian temples (Hardy), architectural agency (Kaminer), architecture and shadows (Kite) and contracting (Lupton) as well as edited anthologies (Odgers, McVicar and Kite's *Economy and Architecture*). Following retirements and relocation, WSA has recruited new History and Theory staff (Aelbrecht, Bowie, Kaminer, Ntzani), expanding its portfolio to urban history, visual culture and social theory. Key funding included a £270,284 Leverhulme (Hardy).
6. **Urbanism:** The group consists of **Inam**, Davidová, Davis, Peimani, Talocci, two T&S and three research-only staff, and five PGRs. It interrogates urban theory, urban design and development, and urban sustainability. The group has studied in this period Cardiff, London, Las Vegas, Prague and Teheran, and works closely with the School of Geography and Planning (e.g. Peimani's co-authored outputs with Geography and Planning's Kamalipour). Inam, recently recruited as Chair, secured a Leverhulme Grant in 2019.

Whereas the RSGs take the lead in creating a vibrant research culture and providing peer-support and nurturing, their research is translated to external organisations primarily through collaborative **research centres** and **consultancies** and a key **University research institute**:

Design Research Unit Wales (DRUw): DRUw's work spans design-based research and consultancy commissions, addressing low carbon design, landscape and placemaking. Focus has been on innovative housing projects and buildings for care (Forster). DRUw will be closely aligned to the Design, Practice, Materials and Making RSG in the future and will enhance its industry-focus (e.g. expanding collaborations with Welsh housing associations).

Low Carbon Research Institute (LCRI), a networking group that brought together 120 contributors from different universities, led the development of a low carbon agenda. Its work has been taken forward in the **Energy Systems [University] Research Institute (ESRI)**, which is co-directed by Jones. LCRI and ESRI's research has contributed to impact through projects such as Microclimate Modelling (S4.4.1) and two of our Impact Case Studies, developing the 'whole house' approach and addressing carbon emissions and fuel poverty (S1.5, S4.4.1, S4.4.2).

Practice, Research and Advancement in South Asian Design and Architecture (PRASADA): The Centre integrates history research and design practice, focusing on South Asia and in particular on Indian temple architecture. The latter has led to research funding and consultancy work – Hardy's Leverhulme and AHRC/ICHR-funded Indian heritage projects (S4.4.4), the start of construction of a PRASADA-designed temple in India, and Hardy and Prizeman's Tamil Temple Towns project (S3.1). PRASADA hosted the 2016 conference of European Association of South Asian Archaeology and Art.

Centre for Sustainable Design of the Built Environment (SuDoBE): The Centre's main focus is the relationship between well-being, health and environments. Key successes include research on the health impacts of energy upgrades in social housing (Poortinga), on BREEAM ratings and comfort in non-domestic buildings (Zapata-Lancaster) and developing a Smart Energy Research Laboratory (S3.1; Tweed, Lannon). Marchesi and Tweed collaborate with Arup and Clarion Housing on a Marie Skłodowska-Curie Fellowship researching circular economy in social housing.

1.2 Research strategy

The WSA's plan for growth, WIDER-BE, presents a strategy for ambitious expansion and diversification. It articulates our commitment to research, teaching, the environment, and equality, diversity and inclusion (EDI), reflecting CU's *The Way Forward 2018-23* strategy – for example, the WSA aims to develop 'new research capacity in interdisciplinary design excellence across the built environment', and to engage 'communities and organisations who do not normally engage with the University through projects' (WIDER-BE). We will achieve both these aims through the **Living Lab**, a new research facility for working with external stakeholders being developed via WIDER-BE (S1.3).

In REF2014, we promised to develop our areas of expertise and to expand the scope of our research. We have now fully integrated the four key 2014 themes into our new RSGs - low carbon futures, people and buildings, architecture's cultural context and design research. In REF2014 we identified three areas of **potential growth** and have since invested in them, recruited 9 new staff with relevant specialisations (S2.1) and developed these areas into the Computational Methods in Architecture, Heritage & Conservation, and Urbanism RSGs.

Our new appointments have expanded the **ethnic diversity, range of specialisations and internationalism** of our staff (e.g. of the nine staff mentioned above, eight were born abroad and four are female; see more in S2). Strategic investment in new and existing staff has paid off in terms of the quality, range, diversity and quantity of our research (e.g. Marchesi's work on circular economy in the built environment, which opens a new avenue for sustainability research, brings new expertise to the School, and has created new collaborations with Clarion Housing, CU schools and a secondment within Arup).

To meet the target of 'strategic research national and international partnership' (The WSA Strategy 2014-17; a target also of its successor, WIDER-BE), the School supported through initial funding and time allocation projects such as the EPSRC-funded EnergyREV, a study of smart, local energy systems (Patterson, S3.1). Another strategic focus for WSA has been engagement 'with communities and cities to enhance quality of life', and has led to Community Gateway, a long-term project in Cardiff's deprived Grangetown (McVicar, S4.4.3), and to the widely disseminated study of means of developing sustainable, affordable housing in Wales (Green, Forster, S4.4.1).

1.3 Future research strategy

Our key objectives are informed by our commitment to securing engagement with, and impact on local and international communities, creative industries and policy communities, underpinned by rigorous research:

- In REF 2014, we promised an experimental research facility. We have scaled our ambition since then, now focused on delivering **state of the arts crafts workshops** for by-practice research and a **Living Lab**, both of which are being realised through WIDER-BE. The Lab will be a highly configurable space with sophisticated AV equipment and an adjacent observation room that will enable multimodal interaction between the School and external stakeholders and partners. It will be a hub for collaborating with communities, industry and the professions. The Lab will promote innovative research, such as co-production, recognising the need for user-oriented methods to achieve impact. The facility features in recent grant applications and will support the UK Government's ambition for innovative research, alliances with industry, and impact.
- In 2014, we promised 'a research end-user panel'. The School is materialising this in a new **External Advisory Board**. The Board will develop and formalise our industry relationships. It will be chaired by the Director of Design Commission for Wales and will bring together diverse external stakeholders (e.g. creative industries, building industry, NGOs). The Board will provide the School with an in-depth understanding of current needs and changing conditions within industry that require response via our teaching and research.
- We will take advantage of our expansion by sustaining excellence in **existing areas of expertise**. In parallel, we will continue supporting staff in the organic development of new and **complementary areas**, e.g. research on emerging technologies (artificial intelligence) and

issues relating to equality and inclusion (affordable and sustainable housing and well-being).

- We will prioritise the nurturing of **ECRs** through tailored research mentoring, the support of our RSGs, institutional and School support for career progression, and internal capacity-building aimed at grant capture and career development.
- We will grow our overall capacities by increasing **research funding**. WSA will develop specific policies and programmes to support grant applications (e.g. new research leave programme, enhanced reviewing processes, new research calendar).
- We will introduce a new **WSA research leave programme** and tighten the relation of teaching to research, both of which will be enabled by the WIDER-BE redesign of our undergraduate programme. The alignment of teaching and research and WIDER-BE-driven expansion in student recruitment will support further staff growth and diversification.

1.4 Interdisciplinarity

Our commitment to interdisciplinarity is illustrated by:

- (a) Poortinga, **a joint position** with the School of Psychology, works in the interdisciplinary space of environmental psychology and sustainable built environment on projects studying the success and/or impact of government policies (S4.3).
- (b) Employing staff from **diverse disciplinary backgrounds**, including archaeology (Bowie), engineering (Stevenson), urban design (Peimani), and architectural practice (Salter).
- (c) **Internal collaboration** on joint projects drawing on our **diverse expertise**, such as projects combining heritage, design, sustainability and computation, e.g. Maintenance scoping report (Prizeman, S4.2), funded by Historic England, Historic Environment Scotland and Cadw, later expanded to a collaboration with Knight, Lannon, and Latif.
- (d) **Research collaborations within CU**, with the School of Geography and Planning (Davis, Inam, Jones, Peimani, Tweed), with Engineering (e.g. the Energy Systems Research Institute; Jones), Business (Bleil De Souza, Marchesi), Computer Science and Informatics (Davidová, Jabi, Knight, Prizeman), School of Psychology (Poortinga), School of Chemistry (Jones, Lannon), The School of Journalism, Media and Culture (e.g. Creative Cardiff), The Water Research Institute (Poortinga) and Sustainable Places Research Institute (Davidová, Marchesi, Poortinga, Tweed); see S4.1.
- (e) **Collaborations across the UK and beyond**, encompassing **joint research across disciplines**, forming alliances and building new networks. For example, 'A Critical Regionalist Approach to Sustainable Urban Development' (Tweed, Zapata-Lancaster, Jabi; 2015-17) brought together institutions from three continents – the WSA and CU's School of Geography and Planning, University of Florida and University of Indonesia. WSA contributed knowledge in sustainability, computing and spatial expertise to the project, funded by a ~£150k Global Innovation Initiative award from the US State Department and the British Council.

1.5 Support for impact

The School has a strong track-record in delivering impact, achieved by in-house teamwork and collaborations with government, industry and NGOs. We have supported impact by securing University buy-in (e.g. Community Gateway), by funding initial endeavours (e.g. funding an away day with potential collaborators from which the Maintenance project (see above, S1.4C) developed) and by time allocation to staff (S3.1). Three projects have matured in this cycle to become **Impact Case Studies** (ICSs). Another, Poortinga's extensive research into the efficacy of the plastic bag levy, is an ICS in REF2021 subpanel 4.

One of our three ICSs proves that the continuous automated monitoring of individual building services' components is better for improving operational performance than undertaking physical inspections (Knight). The research has led to **a revised EU Directive, enacted in March 2020**. The underpinning research method is specified for use by the UK's **Department for Education** in their £4.4bn investment in new schools.

A second ICS (Jones, Lannon, Patterson) maps energy costs, carbon emissions, fuel poverty and health in housing. The mapping tools developed by our researchers **have been adopted by a community programme that has saved £1.5m for over 2,000 homes living in fuel poverty.** The research has informed the strategic approach of six local authorities in Wales and England.

Our third ICS, in which Jones, Patterson and colleagues have provided evidence that a systems-based 'whole house' approach can produce significant carbon reduction at lower cost, has stimulated **Welsh Government investment of £91M in 1,400 affordable, low-carbon homes as well as £19.5M in decarbonisation retrofits.**

1.6 Support for Open Access (OA)

Full text of all journal articles/conference proceedings are deposited into CU's OA digital publications repository (ORCA) within three months of acceptance. The School goes beyond standard OA obligations, hosting an OA online publication, the *Working Paper Series*, and providing OA publication opportunities for by-practice outputs through the *Design Research Working Papers*. CU encourages depositing all outputs as OA, including conference papers, book chapters and books when legally possible, by setting **OA as default**. Our staff are also involved in developing OA datasets and databases (e.g. Ampatzi's Scales datasets and Knight's IWA data available on ORCA, or Prizeman's Carnegie Libraries internet site, which includes an extensive database).

1.7 Research integrity and ethics

WSA has implemented CU's policies on research ethics/integrity, including compliance with the Concordat to Support Research Integrity, and staff are required to complete online research integrity training (see REF5a). The School's **Research Integrity Ethics Officer** (Whitman) provides guidance on ethics and data protection to staff and students. Common issues include gaining informed consent, gathering and storing personal data and working with vulnerable populations.

The **School Research Ethics Committee** considers applications that require full review. This includes dialogue to support the development of innovative or 'risky' initiatives, such as research in refugee camps, the study of homelessness, and monitoring with skin-mounted sensors. The School's Ethics Officer also facilitates **Research Integrity initiatives** focused on specific issues, such as conflicts of interest, authorship and intellectual property, research data and records management.

CU, a signatory to the San Francisco Declaration on Research Assessment, is committed to responsible and fair **research assessments**. WSA has followed CU's REF2021 Code of Practice, which emphasised inclusion, transparency and engagement with staff. The School's senior staff undertook REF-specific EDI training aligned to their REF roles.

A team of five with diverse expertise relevant to WSA research specialisations carried out the assessment of REF outputs. The material for the Environment Statement was assembled through communications with staff members and a staff survey. A draft Environment Statement was presented to the staff for consultation in Spring 2020.

Section 2 (S2). People

2.1 Staffing and recruitment strategy

WSA has 57 (49.8FTE) academic staff, of whom 35 (32.3FTE) are category A staff, as well as 31 (24.8FTE) support staff. Academic staff include 31 (28.8FTE) on Teaching and Research (T&R) contracts; 14 on Teaching and Scholarship (T&S) contracts, and 12 on Research-only (R) contracts. International staff comprise more than half of the WSA's academics (26 UK; 31 overseas), surpassing the CU ambition for 30% of academics to be international (*The Way Forward 2018-23*).

The School's strong cohort of T&S staff aids disseminating research results through teaching and contributes to broader academic-industry relations, engagement and outward-facing research projects. These include collaborations on impact-delivering projects, public debates, conferences, working with disenfranchised communities and more (e.g. Almond steering the design of a hub for

Community Gateway via engagement with residents – producing material that contributed to the project's funding applications).

Our expansion since REF2014 added academics across career stages to bolster capacity in growth areas, while ensuring robust succession planning. The School's **recruitment strategy** aims at ensuring a balanced mixture of senior internationally leading scholars and promising early and mid-career researchers who complement our existing expertise while expanding our capacity in priority areas.

Several new posts over the REF period were created to strengthen areas of research and reflect **delivery on our strategic goals** regarding areas for growth targeted in REF2014:

- **Hiring Davidová, Inam, Peimani and Talocci enhanced our profile in urbanism.**
- **Sibley and Whitman strengthened the profile of heritage and conservation.**
- **Chatzivasileiadi, Doe and Spaeth strengthened architectural computation.**

Our REF submission demonstrates a cohesive and sustainable research culture supportive of staff at every stage of their career. Teamwork is a hallmark of our research – 65% of our returned outputs are co-authored with colleagues at the School and other institutions, nationally and internationally. The paper 'Emergency hospital admissions [...] meeting national housing quality standards', for example, was authored by eight researchers from three universities and the ONS, including two from WSA (Poortinga, Lannon) and one from Geography and Planning. The paper has been tweeted by 535 users and cited in *The Guardian*.

WSA's commitment to promoting a culture of equality and diversity has played a critical role in shaping staffing strategy. Since REF2014, we have hired 16 Lecturers - nine female and seven male; two Readers – one female and one male; one male Professor; two Research Fellows on externally funded grants - one female and one male.

There have been 18 promotions of academic staff over the period, **nine of which were of women**: nine Lecturers to Senior Lecturers (four female, five male); one Research Fellow to Senior Research Fellow (female); six Senior Lecturers to Readers (four female, two male); two to Professor (male). A recent promotion to Professor, effective after the period (1.8.20), is a female (Prizeman). These numbers evidence our progress on EDI since REF2014 – at the time we had no female Readers and only two of six Senior Lecturers were women.

Key leadership roles are occupied by women: Director of International (Sibley), Director of PGR (Prizeman), Director of PGT (Davis), and the EDI Officer (Bleil de Souza). The split on the WSA Executive Board is five women to six men. Overall, women occupy 46% of academic management roles (13:15).

Succession planning: Our promotions in this period and recruitment of ECRs have been designed to address forthcoming retirements and ensure the School's research sustainability. The School has provided **leadership role** opportunities to younger members of staff (e.g. Patterson's RSG leadership, in view of Jones's retirement, or Green leading the transition of the Design Research Unit Wales). Joint grant applications, with WSA staff as PIs and Co-Is, ensure continuity and nurture young researchers (see S3).

The internationalisation of our staff (currently originating from 20 different countries, ranging from Bangladesh to Ecuador) has reinforced our commitment to extend our engagement with the Global South (e.g. Eco-Hammam, in which Sibley, with Tweed, set-up stakeholder networks to develop Moroccan hammams' energy efficiency).

Our staff undertake mandatory unconscious bias and EDI training courses. Staff chairing recruitment panels undertake the Chairing University Appointing Panels course. WSA supports flexible working, encouraging the concentration of meetings on Wednesdays and their completion by 4.30PM. Staff are eligible to apply for career breaks of 6-36 months. We have implemented a Returners Support Scheme for staff returning from extended leave, offering reduced teaching and additional support to re-establish research. In the last period, WSA has organised sessions addressing academic work/life balance with invited speakers (e.g. Fiona McLachlan, University of Edinburgh).

2.2. Staff development

We foster a supportive environment through a range of staff development policies and opportunities, tailored to career stage and informed by our commitment to EDI. WSA adheres to the Concordat to Support the Career Development of Researchers, of which CU is a signatory. Annual **Personal Development Review** meetings involve guidance on promotions and development and promotions' sessions tailored to career stage are available. In addition to ECR support discussed below, our uptake of such opportunities includes the Professorial Leadership Programme (Knight participated) and career development training tailored to BME+ staff (two staff members participated). Category A staff have annual **Research Plan meetings** with the Director of Research in which their research, its development and required support are reviewed.

CU, in collaboration with its GW4 partners Bath, Bristol and Exeter, has developed **programmes for research capacity-building** and staff/research student development. Latif is a Co-I in a circular economy research funded by the GW4 Initiator grant. Welsh Crucible, a **research leadership programme** by a Welsh universities' consortium, has supported Du's research into damp and mould in Welsh homes.

Our **new T&R and T&S staff** take part in an academic orientation programme; staff on a **Research** pathway attend a dedicated programme. Staff on probation (Grade 6 and below) receive regular support through quarterly appraisals and are assigned a WSA mentor. The School has developed a **Research Guidelines** document to support the integration of ECRs into the WSA research community. It outlines our research strategies, policies and procedures.

Practice-based T&R and T&S staff play a vital role in our research culture and lead by-design research and high-profile projects, e.g. Better/More (Green, Forster) and the Alhambra renovation, winner of the Europa Nostra Grand Prix 2019 (Wulff). We have supported staff (including administrative, R-only and T&S staff) **pursuing PhDs** (Clark, Coombs, Lannon [R], McVicar, Munar Bauza, Odgers, Patterson [R] and Whitman in this period), enabling flexible and part-time working and have waived PhD fees (e.g. Patterson, see below). Clark, for example, was able to alter his FTE from 0.5 to 0.2 and vice-versa while pursuing a PhD.

ECRs, a large cohort at WSA (27% of category A staff), have access to the resources outlined above. ECRs can apply for participation in the prestigious ECR development programme Cardiff Futures (attended by seven staff: six female, one male). Support and training are also available to individuals when applying for external research funds. ECRs can access internal, competitively awarded schemes such as the EPSRC Early Career Research Capital Calls (2018). CU has a mentoring scheme to which seasoned WSA staff (Kaminer, Latif) contribute. Currently ten of our ECRs are programme mentees. The RSGs offer nurturing in a collegial, supportive setting, ranging from feedback to work-in-progress to advice regarding grants, potential collaborators or relevant journals. The nurturing and inclusive research culture in the School has led to ECRs' successes in obtaining external research funding and publishing key articles (e.g. Whitman's Historic England funding to develop his original PhD research).

2.3 Support for research-only staff

Researchers joining us are integrated into the research culture through the RSGs and invitations to our research events, and are given support in finding career opportunities. Research-only staff are fully involved in WSA management (e.g. Patterson leads the Energy Environments and People RSG; Lannon was Director of Research 2016-19).

CU employs a full-time careers adviser for research staff. In 2019, CU's promotions scheme was revised to incorporate a clear career path for staff on Research-only pathways, enabling advancement to Senior Research Fellow, Principal Research Fellow and Professorial Research Fellow (in the last period, **Patterson has been promoted, and Du regraded, to Senior Research Fellows**). The Cardiff Researcher Programme is designed specifically for Research-only staff and provides workshops, online modules and coaching in 65 topics (including grant writing, applying for fellowships, research leadership). **The School provides teaching opportunities** to RAs; research staff with contractual obligation preventing involvement in paid teaching (e.g. European Commission sponsored) have been provided unpaid teaching opportunities through the LCRI Low Carbon Summer Programme.

Joanne Patterson:

'Coming from environmental science, I was approached in 1996 by the WSA to consider applying for an RA position in an EPSRC-funded project. My work at WSA continued over the years, and I progressed to the position of Research Associate in 2000, Senior Research Associate in 2002, and a Research Fellow in 2008. In 2015, [...] I completed a part-time PhD at the WSA, in parallel to my work on demanding projects such as SOLCER and raising two children. The fees were waived and WSA allowed me to move to a 0.6FTE contract when needed and later to increase again my FTE. In 2019, I was promoted to Senior Research Fellow.'

2.4 Support for research

Our Workload Model includes 600 hours p.a. **research time** (40% working time) for full-time T&R staff. The School provides £1000 annually to every academic member of staff, *including* T&S, fixed-term, externally-funded researchers and Research Associates, for conferences, travel and other research and scholarship expenses (S3 for additional funding).

Research-active staff are eligible to apply for one year study leave every five years through CU's **research leave programme**. Up until 2018-19, the programme provided buy-out from teaching and £3,000 in research funding (in the last period Ampatzi, Davis, Gwilliam, Knight, McVicar, Poortinga – four female, two male). Its 2019-20 iteration, the Disglair scheme, has been designed to facilitate post-doctoral development, supporting the School hiring an outstanding ECR (Bowie) to replace staff granted research leave (Prizeman). The programme has enabled staff to develop grant applications, start new projects, and complete major monographs (e.g. McVicar's *Precision in Architecture*). In the next years, the School will develop a research leave programme to supplement the University's (S1.3) and strengthen its outputs, grant capture and impact.

2.5 Support for postgraduate research

The School is home to a diverse body of PGR students across our clusters of expertise and encourages applications globally, benefiting from institutional support through PhD scholarships and the resources (workshops, training courses and events) of the Cardiff Doctoral Academy (see REF5a). The School adopts a transparent equal opportunities approach, e.g. taking professional/voluntary work and career experience into consideration for applicants who have not recently been involved in academic study or have taken career/study breaks.

Our PhD programme is led by the **Director of PGR** (Prizeman). The School's current 60 PGR students are from 16 different countries, spanning four continents. Applicants' success rate since 2014 has been 55% for males and **82% for females**. Redesigned, tailored work and socialisation spaces and a meeting room will be provided to the PGR community through WIDER-BE.

The number of **doctoral degrees** awarded for 2014-20, in total, was **72.5**, including one by publication. The diversity of **sources of support** for our PGRs in this period demonstrates the prowess of WSA's research, and included the AHRC Collaborative Doctoral Award with the British Museum; BRE Studentships; EPSRC CASE award with BRE; EPSRC Doctoral Training Partnership award; EPSRC fees-only; Knowledge Economy Skills Scholarships award with BRE; Ser Cymru/Bangor Uni. We have recruited two PhDs (2017, 2020) through WSA-funded scholarships.

The School carries out an initial review for new PGR students followed by annual progress reviews. Since REF2014, the annual progress monitoring system has been enhanced by the involvement of independent reviewers. PGR students attend workshops designed to support disciplinary research skills. Interested students can gain **teaching experience** in our undergraduate (UG) programme.

The Postgraduate Research Experience Survey has consistently shown (2015; 2017; 2018) strong and increasing satisfaction among PGRs with the knowledge and suitability of their supervisors (90%; 91%; 96%) and strong satisfaction with feedback (90-92%). PGRs had highlighted, however, their limited interaction with other academics and researchers within WSA

(35-52% satisfaction) – in response, WSA has encouraged PGR involvement and leadership in the new RSGs. The School also launched 'PGR social', a weekly social event for PGRs, supervisors, PGR support staff and others. More recently, our first 'PGR International' event has taken place, celebrating with staff the diversity of our cohort by sampling homemade international foods and attending a guest lecture.

PhD students are thus increasingly **integrated into our research culture** through the RSGs, the new WSA Research Lecture Series and events, conferences, workshops and presentations. PhD students are part of the management structure of the School through representation on committees (e.g. the WSA Research Committee). Recruitment, diversity of research areas and geography of expertise has been supported by the growth and internationalisation of staff.

PhD students make wider **contributions to the discipline**, presenting their research at national and international conferences, receiving recognition (e.g. Akhimien's prize at ICEESD conference, San Francisco 2019; Coombs' RIBA President's Award for Research 2017; Wyatt's IHBC Gus Astley Award 2019). PhD students have also taken an active role in organising events at WSA and beyond (e.g. Drozynski and Tam's work on the 2018 Generosity conference, a three day conference with 60 papers).

The strength of our PGR programme is highlighted by the success of our graduates in **gaining academic posts** (e.g. Drozynski at the University of West of England, Jones at Birmingham University, Stravoravdis at Liverpool University). Ampatzi, Chatzivasileiadi, Whitman and Zapata-Lancaster, previously WSA PGRs, have become lecturers at the School in this period. Whitman, who had an Association of Prevention Technology (APT) Student Scholarship, won the APT Martin Weaver Award as a PhD student.

Section 3 (S3). Income, infrastructure and facilities

3.1 Research income

In this REF period, the School has sustained long-standing, high-impact programmes of research (e.g. SOLCER). The School won **88 research awards**, providing income to the School of **£12,934,574** – a 23% growth compared to REF2014. The diversity of funding sources, which include the EU, the Welsh Government (WEFO), UKRI, industry and non-government funders, ensures a robust, resilient portfolio. Our funding trajectory over this assessment period demonstrates the sustainability and innovation of our approach.

Income generation is spread across the School. 82 awards went to teams headed by a WSA PI, and 18 to teams that included more than one of our researchers, typically comprising of senior and junior researchers. 25 staff across career stages have been PIs in this period.

Major grants won in this REF cycle secure the sustainability of research through large-scale investment and leadership in disciplinary and interdisciplinary collaboration. Examples include, in this period:

- SPECIFIC2 WP3.5 (2016-21): **£2.5M** for WSA from the Welsh European Funding Office (Jones, Patterson, Lannon). The project develops knowledge from earlier projects: the energy positive SOLCER House, Five Low Carbon Retrofits and the Sustainable Building Envelope Centre, all funded under the LCRI programme (2010-16). Its ambition is to create 'buildings as power stations' – the idea that 'active' buildings can generate, store and release their own heat and electricity. The project is a major collaboration with Swansea University. The WSA team's contribution is in modelling and monitoring 16 demonstration projects across Wales to create a low-carbon built environment that is replicable and affordable.
- EnergyREV (2018-22): **£729,000** for WSA from EPSRC (Patterson). Research into smart local energy systems and the transition towards their widespread application, involving more than 60 researchers from 22 universities. Applying the themes of digitalisation, decarbonisation, decentralisation, and democratisation, and disseminating the findings through reports and scholarly articles, the project takes the lead in identifying a viable route towards widespread adoption of better energy systems. EnergyREV is one of the three key

components of the UK Industrial Strategy Challenge Fund's 'Prospering from the Energy Revolution' programme.

- Smart Energy Research Lab (2017-22): **£391,047** for WSA from EPSRC via UCL (Tweed, Lannon). Developing a world-class research portal that will provide vital access to energy data for the UK research community. The project aims to transform UK energy research through the long-term provision of high-quality energy data necessary for intervention, observational and longitudinal studies.

By providing funding for RAs, conferences, and equipment over an extensive period, these projects have sustained our research capacity and infrastructure. Such grants have allowed WSA to continue employing key RAs in subsequent projects (e.g. Perisoglou, employed since 2013 on the projects SBED, LCRI, Ser Cymru, SPECIFIC 2) and benefit from their growing expertise and skills. Grant income has **contributed to capacity-building through strengthening areas of priority**, building the scope of clusters of excellence and cultivating research networks/interdisciplinary collaborations.

Smaller grants have been particularly effective in supporting humanities and social science research. Examples include:

- Shelf-Life (2017-21), £162,000 for WSA from AHRC (Prizeman): developing HBIM tools supporting rehabilitation and networking for public library buildings at risk of demolition. It addresses the urgent issues of heritage buildings' use/redundancy and energy performance. The project delivered scholarly publications, an OA website database containing GIS mappings for all UK Carnegie Libraries, Life Cycle analyses and more.
- Tamil Temple Towns (2018-20), £147,000 for WSA from AHRC/ICHR (Hardy, Prizeman), a collaborative international project developed from previous research into Tamil temples, including a graphic representation of 25 ruined medieval temples in Ashapuri, India, which has led to impact (S4.4.4). The project intervened in a case of contested heritage that has included litigation among the disputants and required UNESCO involvement. It developed a conservation strategy acceptable to the competing stakeholders.
- Care and the City (2015-19), £130,000 for WSA from Grosvenor Estate Management Ltd (Davis), a follow-up to a previous collaboration regarding the contribution of urban form and governance to resilience, focused on the concept of 'care', and leading to scholarly articles and forthcoming monograph (Bristol University Press, 2021).

The School has used funding to **maximise impact**. The WSA has received impact funding of £114,501 for three projects (Eames; Jones & Patterson; Tweed) through the EPSRC Impact Acceleration Account (e.g. supporting the development of energy monitoring kits for housing associations by Tweed and Zapata-Lancaster). Community Gateway, launched by McVicar in 2014 and addressing sustainability, participation and deprivation in Grangetown, Cardiff, secured CU funding of £100,000 annually. CU was also the conduit, and is currently the Asset Guardian, of £1.9M received from the National Lottery, Welsh Government, and multiple charitable funders to support creating a community hub as part of the project. These supports have enabled the development of ambitious work that involves interdisciplinary research, engagement and impact (S4.4.3).

Research income has led directly to **major outputs**, e.g. Jabi's Leverhulme Grant (£287,000), for example, enabled developing software, Topologic, aimed at improving existing Building Information Modelling. By establishing connections between each of the individual spaces within a building, the software can map the thermal flow of energy throughout spaces. This information can be used for buildings' energy performance simulation. The software has been adopted by **Buro Happold and other leading firms**. The research has led to 11 articles and conference papers, including papers in the *International Journal of Architectural Computing* and *Architectural Science Review*. Poortinga and Tweed's Health Impacts of Structural Energy Performance Investments in Wales, funded by the National Institute for Health Research (£739,551 in total), has led to five outputs, including Poortinga's research output in *the Lancet* (2016) and a key publication in the journal *Public Health Research* (2018).

Relatively **small sums** can provide a boost to a diverse range of staff. In addition to the Individual Development Allowance of £1000 (S2.4), WSA offers further support (£4,500 in total in 2020) through an annual competitive process (e.g. in 2019, £2,231 won by Peimani to complete a strong output and £300 by Aelbrecht for image sourcing for an article). The School strategically uses small sums to enable research grant development, events and workshops, and impact and engagement. Such School funding has been particularly important for building capacity and confidence for ECRs, using the funding as the basis for larger bids and supporting the development of RAs. For example, the School provided monetary support and staff time for a series of preliminary meetings from which the EnergyREV project was developed and for which UKRI's Industrial Strategy Challenge Fund support was secured.

A notable success story is the School's strategic use of the innovative Cardiff Undergraduate Research Opportunities Programme (see REF5a). This provides bursaries for summer placements for students working on staff-defined and supervised research projects (e.g. Poortinga's plastic bag charge project – the contributing student has progressed to become a CU PhD student). In this REF period, these awards provided **support for 34 WSA research projects**. The scheme has benefited staff across career stages, with opportunities identified as particularly vital for ECRs who have used the scheme to build towards grant applications (e.g. Whitman). Similarly, collaborations with industry have produced small yet impactful sums via diverse service projects with industry funding (30 projects, £300,000) and prepared the ground for expansion of the collaborations - e.g. Monmouthshire Housing Association feasibility study that led to an experimental housing project (Forster, S4.2), recently followed by another.

3.2 Research infrastructure/facilities

CU is investing in the refurbishment of our Bute building as part of WIDER-BE (~£20M). A key feature of the project is the **Living Lab**, which will enhance the visibility and impact of WSA's interdisciplinary research (S1.3). It will have an easily accessed, dedicated facility adjacent to the entrance, and will be used for meetings, presentations and workshops with external collaborators. The Lab will be a test-rig for studying behaviour in different interiors. Its flexible space could be configured, for example, as an office, a school classroom, or a retail space to simulate different settings in which participants can be observed from an adjacent room. It will also serve as a studio for co-design. The Lab will be outward facing, supporting innovative forms of research, collaboration and engagement, fostering relationships with the community, with the profession, and with industry.

The building redesign includes the relocation and expansion (by 50%) of the workshops with upgraded equipment, dedicated wet cast and spray rooms and capacity for additional CNC machines and laser cutters – providing state-of-the-art facilities for **by-practice research**. The redesign provides dedicated space for PGRs and for research teamwork and will offer opportunities to showcase research material within the School via tailored display furniture and in changing exhibitions in the new Exhibition Hall. Refurbished rooms and auditoria will offer high-end facilities for hosting symposia and conferences. Break-out and rest spaces will support informal and social activities.

Our **Architecture Library**, home to the largest collection of architecture books and journals in Wales, is staffed by dedicated subject librarians (Pryor, Davies), and includes the Rare Book collection, specialist information resources such as the Bloomsbury Architecture Library, Digimap, materials and buildings' costings databases, British Standards online and Construction Information Service. The Adrian Gibson Slide Collection (19,000 slides and 900 papers regarding British vernacular architecture, 1100-1700) and the CIBSE Heritage Group Archive (created in 1973, recording building engineering services history) have been donated to WSA in this period. Both collections are of significant national interest. Our building is also home to the **Bute Library**, covering social sciences, planning and geography. Together, these two libraries cover many of the research fields pertinent to WSA staff, offer easy access, extensive research support, and bring together researchers from different schools.

Our research culture, internal organisation and research support are led by a **Director of Research** (Kaminer) and supported by a specialist **Research Manager** (Lewis) and a **Research Officer**. Researchers also receive advice and support from central staff regarding grant and

fellowship applications, and grant management (REF5a). This support includes tailoring funding opportunities, planning budgets, and submitting applications. The Director of Research chairs the **Research Committee**, which includes representatives of the RSGs, our centres, and the PGR community, the EDI Officer, and the PGR Director. An **Impact Champion** (Knight) coordinated the development of Impact Case Studies (ICS), and WSA provided ICS authors time to develop them (S1.5).

To enhance the visibility and accessibility of our research, WSA has introduced a **research annual**, collating current research projects into a single, reader-friendly booklet. The **WSA Research Lecture Series**, initiated in spring 2019 and replacing earlier initiatives (e.g. ReseARCHI lectures), hosts leading scholars and provides a vibrant monthly forum for academics and PGR students (e.g. Christoph Linder). It is jointly organised by the RSGs.

Distinctive support for research is provided by our **Centre for Research in the Built Environment** (CRiBE), a Knowledge Transfer Centre. It is a conduit for research-support and a first point of contact for external organisations. CRiBE advises and assists other centres and large-scale research projects, both external or internal to WSA, with project and financial management – e.g. a commission to evaluate Premier League stadia's daylight (Lannon).

School, College and University technical administrators provide vital assistance with workshops, research software, research web pages, and research events. Support includes a workshop manager and a technician, a digital labs manager, two operations assistants, two staff who support research, impact and engagement events, as well as two IT Officers stationed in our School. **Investment in IT** at WSA has grown from £23,000 in 2016-17 to £96,000 in 2017-18 and £151,000 in 2018-19, renewing WSA's technological infrastructure and providing additional support for research, including new software licencing and new hardware. WSA has invested over this period in **specialised research equipment**, such as £78,041 of externally funded grants and £17,826 of School funding for energy monitoring equipment (sensors, data loggers, etc.). Our robotic arm (purchased in 2013), extensively used for specialised research, has been critical to the emergence in this period of computation as a key research area.

3.3 Covid-19

WSA has supported staff during the Covid-19 pandemic in relocating required University equipment to their homes, and permitting direct purchasing of necessary equipment, to allow for continuation of research. The Bute and Architecture Libraries have purchased dozens of e-books and expanded online subscriptions to architectural collections (e.g. Bloomsbury Architecture Design & Practice Online and De Gruyter). On the cusp of what may become a major transition in UK academia (Brexit, Covid-19) and in the midst of our own transition (WIDER-BE), our investment in WSA's research infrastructure is necessarily also an investment in the School's **resilience**, understood as a key guarantor of the overall health and prowess of our research.

Section 4 (S4). Collaboration and contribution to the research base, economy and society

The School's ethos of 'grounded creativity' underpins our research and teaching. It captures an ongoing commitment to engaging with real world problems. Collaborative work is a key vehicle for these ambitions, manifested in our emphasis on collegiality and mutual support, and in our research and impact involving industry, public bodies and communities.

4.1 Local, national and international research collaborations

Collaborations with other CU schools have strengthened our interdisciplinarity in the last period (S1.4). National-level research collaborations have helped produce impact, while many international collaborations have enhanced the reach, prestige and visibility of our research. A **national-level project** completed in this period was the EPSRC-funded Retrofit 2050 (Eames, Lannon), which identified pathways to expand and enhance systemic retrofit of UK regions. The project was a collaboration with the universities of Cambridge, Durham, Oxford Brookes, Reading, and Salford, a wide array of government agencies, industry bodies and NGOs (ICS, BRE, TATA, ARUP, Core Cities, DEFRA, Welsh Government, Manchester City Council, Cardiff Council, Carillion, Environment Agency Wales and Neath Port Talbot Council). Scenario and modelling techniques developed for the project were later used for the 2019 'Independent Review on Decarbonising Welsh Homes' report for the Welsh Government. The **global expansion** of our

collaborations is demonstrated by the Smart Energy Regions project (Jones), which was a H2020-funded collaboration of 70 researchers from 28 countries. It studied the drivers and barriers regarding the implementation of low carbon technologies in the built environment.

4.2 Collaborations with and contributions to industry and public bodies

Industry collaborations have been vital for the WSA's impact (see S4.4). The School's forthcoming **External Advisory Board** and **Living Lab** will enhance and expand these relationships by providing channels for sustained and long-term partnerships (S1.3).

WSA's productive collaborations with **industry** include Forster's work for the Monmouthshire Housing Association (2017-19) – the realisation of two sets of experimental urban 'infill' housing. The collaboration enabled the funding (contract value £1.1m) and testing of innovative approaches to long-term and multi-generational living in the context of low-cost and sustainability.

Others have collaborated with public bodies: Prizeman developed a scoping report (with Whitman) for Cadw, Historic England and Historic Environment Scotland (£7.5K) in 2016, which demonstrated the importance of traditional buildings' maintenance in reducing their energy costs. The report was presented to the Welsh Government Housing Committee, the Welsh Government Tourism and Environment teams, the Heritage Environment Group Wales, and to the UK wide Historic Environment Adaptation Working Group. Du worked with the microbiology team at Public Health Wales, Adult Cystic Fibrosis Centre at NHS Wales and Swansea University on mould and damp's impact on vulnerable patients (Welsh Crucible funded).

Our extensive collaborations have led to diverse **contributions to industry, public bodies and third sector**, such as Chatzivasileiadi's Institution of Engineering and Technology Standards Technical Committee membership, Knight's membership of a steering group at the Institute of Welsh Affairs, Patel's reports (2019) for the Higher Education Design Quality Forum, Kaminer's directorship at the Edinburgh Old Town Development Trust, and Prizeman's advisory role for the Heritage Lottery Fund and UNESCO. Latif is a senior member of the influential International Union of Laboratories and Experts (RILEM). Prizeman is an Association for Preservation Technology International board member; Tweed is a member of the advisory board to Welsh Government on Decarbonisation of Homes in Wales. These contributions have developed from and enhanced our role as leaders in the wider field and extend the outreach and impact of our research.

4.3 Wider academic contributions and research dissemination

We have helped sustain the vitality of our research fields through an array of critical activities. Such contributions are encouraged through the promotions process and enhance the esteem of the School.

A key role is played by staff who are members of **reviewing & assessment panels** for REF2021 (Tweed), EPSRC (Bleil de Souza; Lannon; Tweed), UKRI Future Leaders (Lannon), and RIBA President's Medal for Research (Tweed). Others, contributing as **editors, members of editorial boards, guest editors and peer-reviewers** of academic journals, have supported vital research processes and enhanced their own networks and the prestige of WSA. In this period, Davis has been an **editor** for *Planning Perspectives*, Hardy for *South Asian Studies*, and Sibley for *Global Built Environment Review*. Our staff serves on the **editorial boards** of journals such as *Architectural Science Review* (Jabi); *Architecture and Culture* (Jabi); *International Journal of Architectural Computing* (Jabi); *International Journal of Contemporary Urban Affairs* (Latif); and *Journal of Sustainable Smart Behavior* (Davidová, Tweed).

Guest editorships included *Architectural Research Quarterly* (Davis); *Architectural Science Review* (Spaeth); *FORMakademisk* (Davidová); *Indoor and Built environment* (Jones); *International Journal of Architectural Computing* (Jabi); and *Journal of Building Performance Simulation* (Bleil de Souza).

Our staff **review** papers for leading journals by major academic publishers (Sage, T&F, Elsevier) and book proposals for Ashgate, Bloomsbury, RIBA Publishing, T&F, and Palgrave. Latif received three **Outstanding Reviewer** awards, from the journals *Construction and Building Materials*, *Energy and Buildings*, and *Building and Environment*.

In this period, WSA hosted international conferences such as Smart Energy Regions (2016), Generosity (2018), and Sustainable Built Environment (2020), strengthening research networks and dissemination. In addition to regular presentations of papers at conferences and symposia, our staff have delivered dozens of **invited talks** and **keynotes** in contexts ranging from major academic conferences to public events. While both have enabled wide dissemination of research and enhanced the School's prestige, the latter enabled reaching new audiences. Of particular academic prestige were Hardy's keynote at Allchin Symposium, Cambridge University, Jabi's keynote at the Eighth International Conference of the Arab Society for Computer Aided Architectural Design, SOAS, and Kaminer's talk at Rebuilding Architecture symposium, Yale. Within a wider public context, Davidová's talk at the UN World Creativity & Innovation Week, Davis's talks to The Labour Housing Group and to the London Tenants Federation, McVicar's talk at the Deutsches Architekturmuseum, Frankfurt, Sibley's talk and Prizeman's public debate participation at the Victoria and Albert Museum stand out.

Poortinga, who has delivered around twenty keynotes and invited talks since 2014, has contributed to public discussion and policy making by delivering written submissions and oral evidence at the Environmental Audit Committee, **House of Commons**, regarding his research into the plastic bag surcharge and disposable coffee cups (2013, 2017). Likewise, Knight has enhanced his work's impact on policy making by providing evidence to the **EU** in Brussels on energy demand data and modelling.

Reflecting the prowess of the School's research in fields that are of public interest, WSA academics have disseminated their research findings through **general media**. Thanks to extensive media attention, Poortinga could raise public awareness of the need to reduce plastic bag and coffee cup waste (more than **40 media appearances** on radio and TV interviews and numerous media mentions, including interviews by Sky News TV, by BBC Newsbeat and BBC Radio 5 Live, mentions by, among others, *The Times*, *The Guardian*, and the *BBC Magazine*).

Exhibitions are an important vehicle of dissemination of our by-design research. Wulff exhibited work at the Museum of Urban History of Barcelona and the 2016 Venice Biennale. A second high-profile Barcelona exhibition by Wulff (2016) was opened by the Mayor. Salter exhibited a specially commissioned work at the Arsenale in the 2018 Venice Biennale.

4.4. Societal, economic and cultural impact

WSA has developed long-term projects that contribute to communities' well-being and to sustainability. Through its collaborations with various partners and stakeholders, WSA research aims at transforming everyday life in four main **areas of impact**:

4.4.1 Sustainability and Energy

Our strong energy and sustainability research contributes to de-carbonising the building industry, reducing energy waste and improving policies in the field. Work by Jones, Patterson and colleagues, for example, has provided evidence that a systems-based approach to retrofitting and new-build can produce significant carbon reduction at lower cost. It has informed **Welsh Government policy** and is one of our Impact Case Studies (ICS). Another ICS maps energy costs, carbon emissions, fuel poverty and health in housing (Jones, Lannon, Patterson). Knight's research into the continuous automated monitoring of individual building services has been widely applied and is our third ICS (S1.5). Within the same field, the Welsh Government-funded study of retrofit case studies (Green, Lannon, Patterson) produced a rigorous comparative analysis of available options. **The research's recommendations have been accepted in principle by the Housing Minister**. They are now being used by Welsh Government to inform a decarbonisation strategy for the Welsh housing stock.

Poortinga contributed to the influential **Science Advice for Policy by European Academies** report 'Microplastics in Nature and Society', which informed the **European Commission's Group of Chief Scientific Advisors**. The latter commented that the work 'underpins many of the recommendations we make in our opinion [...]'. Poortinga's evidence to the House of Commons Environmental Audit Committee led the committee to recommend introducing a 'latte levy' on disposable coffee cups. A paper studying the impact of fuel poverty and cold homes on physical and mental wellbeing by Poortinga has been cited in four policy documents.

4.4.2 Industry Performance

A long-term project (Jones and colleagues), in collaboration with Hong Kong University, developed microclimate urban-scale modelling for measuring thermal comfort and building energy use. The models were the basis for software tools produced to inform the design process at an early stage when major decisions are made. These tools now **benefit the design industry**. They have been used primarily in South East Asia to introduce energy savings to the homes of 5,500 residents, to assess the environmental impact of seven urban renewal projects, and for a 164-hectare development project.

With the support of an EPSRC Impact Accelerator Award, Tweed and Zapata-Lancaster developed **energy monitoring kits** for Merthyr Tydfil Housing Association in 2016. The study persuaded the association to work more closely with its tenants and to provide bespoke advice on how to get the best from their homes. The outcomes were presented to the Welsh Government.

Publications aimed at practice are an important means of impacting industry. In this period, these included Gwilliam's *Living Architecture, Living Cities* (Routledge, 2020), focused on inclusive urban design for well-being, Latif's *Thermal Insulation Materials for Building Applications* (Institute of Civil Engineers, 2019), Lupton's additions and updated editions to her prize-winning RIBA book series on contracting, and Prizeman's edited anthology, addressing work in heritage environments, *Sustainable Building Construction* (RIBA, 2015).

4.4.3 Communities' Well-Being and Societal Justice

A major long-term WSA project in the field is the Community Gateway project in the Cardiff neighbourhood of Grangetown. The project engaged local residents and key stakeholders, **securing commitments by the city council, CU and Lottery funding** (S3.1). Orchestrating asset transfer from the council to the community, the project addresses multiple issues, including sustainability, well-being, participation and deprivation. Staff from 20 CU schools have so far been involved, contributing to engagement (e.g. wellbeing and careers events) and research (e.g. Somali migrants focus group leading to an ESRC grant, School of Geography and Planning). Wulff has led a long-term (2016-) project in Palermo, collaborating with the municipality and local residents, delivering a **key street market regeneration framework**. The 'Better/ More' government-commissioned study of alternative means of **developing affordable housing** (Green, Forster) has been widely disseminated to decision-makers in government and industry, and was called '[t]he most important report on housing to come out of Wales in a generation' by the Bron Afon Community Housing Director of Development (2017). The study was used for the launch the £90M Welsh Government Innovative Housing Programme.

4.4.4. Heritage

Prizeman's study of 424 UK Carnegie library buildings has networked **communities campaigning to save these historic buildings** from demolition (S3.1). Her work has been cited in the Department for Digital, Culture, Media and Sport's Farrell Review. Wulff's restoration of the Alhambra has won Europe's most prestigious heritage prize, the **European Commission Europa Nostra Heritage Award** 2019.

For the World Monuments Fund and the Government of Madhya Pradesh, Hardy's work has led to a **conservation strategy**, a **visitors' centre**, and **heritage walks** produced by the Indian National Trust. In collaboration with UNESCO, **conservation guidelines** for Tamil temple towns are being developed. In parallel, Prizeman, Sibley and Whitman have supported through their research **sustainable retrofitting of heritage buildings**, as in Sibley's work on improving the sustainability of Moroccan hammams.

4.5 Prizes & awards

The high esteem in which our research is held is demonstrated in this period by an array of important prizes our staff and their work have been awarded. These include:

- **Design** prizes: such as the German International Design Award 2017, RIBA Regional Award 2017, and RIBA National Award for Walmer Yard (Salter).

- **Engagement** prizes: Leading Wales Award and Sir Professor David Watson International Award for community–university partnerships, 2017 (Community Gateway, McVicar).
- **Heritage and conservation** prizes: the International Council of Museums in Egypt for Best Practice of Museum Research and Engagement for the Belle Epoque Cairo Museums Itinerary 2017 (Sibley).
- **Industry** prizes: from the UK Buildings and Energy Efficiency Awards and the Cynnal Cymru Awards 2015 for SOLCER (Jones and colleagues), the Chartered Institute of Housing award 2015 (Green), the CIBSE Carter Bronze Medal 2017 (Knight), the Constructing Excellence in Wales Innovation Award for 'Rightsizing', also Highly Commended at The National Constructing Excellence Awards 2020 (Forster).
- **Scholarly** prizes: 2018 Emerging Scholar Award by the Spaces & Flows Research Network (Peimani); PLEA 2018 Merit Award for best Technical Paper (Whitman); 2019 Young CAADRIA Award (Davidová).

4.6 WSA, future years

We are well-positioned to address key societal challenges in future years – climate emergency, the housing crisis, urban disfunction, and systemic inequalities, as S4.4 demonstrates. Over the last decade, our ties to Cardiff, Wales and the UK have strengthened, while our research has expanded to Europe and the world, driven by national and international collaborations (S1.4; S4.1). The School's research centres (S1.1), forthcoming Living Lab and External Advisory Board (S1.3) will be key vehicles in delivering research that is relevant to societal needs and impactful, whereas our growth and specific strengths, such as our expertise in energy and access to Welsh government, should provide the support needed to further our contributions to the discipline, to research, and to society – to scale our ambitions, and to extend our reach.