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Appropriate Complexity: Designing specialist cardiac care in Rwanda

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Abstract

Specialist cardiac care makes unusual demands on buildings. It requires a small number of tightly controlled environments in which intervention can be performed safely, and a much larger territory of ordinary spaces in which patients are screened, prepared, educated, rehabilitated and followed up for years afterwards. In low- and middle-income countries, hospital design has often responded by importing high-income specifications at a level of technical and constructional dependency that local building, procurement and maintenance capacity cannot always sustain.

The result can be a facility that opens at one standard but gradually settles towards the standard its context can actually hold - not through any single failure, but because of the accumulated drift of systems operating without the maintenance they require, adjacencies disrupted by later additions, and local capacity that the original design did not develop or enhance.

This paper reports the design of the Rwanda Egypt Heart Centre (REHC), now under construction in Kigali as the country's first dedicated cardiac teaching, treatment and research hospital and conceived as a national and regional centre of excellence in cardiac care.

Building on the model established at the Aswan Heart Centre, Egypt, the project subsequently extends beyond the specialist hospital through the Village Integrated Plug-In (VIPI), a community platform combining preventive healthcare and patient follow-up with shared social, educational and digital facilities, designed for future integration with Rwanda's national health data systems.

We analyse the design process itself as evidence, tracing how local and international clinicians, architects, policymakers and engineers arrived at key design decisions through project records, design iterations and co-design workshop deliberations.

From this analysis we introduce the concept of "Appropriate Complexity": a framework for designing a centre of excellence in which the highest specification is located precisely where clinical intervention demands it, while the wider infrastructure is designed to be operated, maintained and adapted within its context. Complexity is therefore located rather than reduced.

Neither project is yet operational. We therefore present Appropriate Complexity as a design-derived hypothesis rather than as evidence of clinical or operational outcomes, and specify the post-occupancy indicators, reference points and assessment schedule against which it can be tested.

1. Introduction

1.1 The cardiac care continuum

Cardiovascular disease caused an estimated 19.8 million deaths in 2022, around a third of all deaths worldwide, and more than three-quarters of these occur in low- and middle-income countries (LMICs)¹. In sub-Saharan Africa, rheumatic heart disease remains an important cause of cardiovascular morbidity and need for cardiac intervention, often affecting children and young adults². In Rwanda, patients requiring cardiac surgery have historically depended substantially on visiting specialist teams or treatment abroad, while long-term postoperative care must continue within the national health system³⁻⁵. For these patients, many of them young, surgery is rarely the end of treatment. Those who receive mechanical valves need lifelong anticoagulation with regular monitoring, and all need long-term follow-up, which in Rwanda has depended on district hospitals and a national registry^{3,4}.

For an architect, cardiac care presents an unusual temporal and spatial brief. Detection may occur in a rural community by trained community health workers⁶, while complex intervention requires some of the most technically demanding healthcare environments to design and build.

Yet surgery occupies only a few hours within a pathway that may extend over a lifetime: prevention, screening, referral, preparation, rehabilitation, monitoring and long-term follow-up all take place beyond the operating theatre, often beyond the hospital itself. The intervention is momentary and highly concentrated; the care surrounding it is continuous and widely distributed. No single facility can contain this entire pathway.

1.2 The Rwandan context

Rwanda makes this asymmetry particularly visible. Since the 1994 genocide against the Tutsi Rwanda has made substantial progress in rebuilding its health system, with investment in decentralised services, community health workers and community-based health insurance strengthening primary healthcare provision^{7,8}. Specialist cardiovascular capacity, however, has developed more slowly than the burden it must meet. In 2018, Rwanda had four cardiologists serving a population of approximately 11.4 million, while cardiac surgery remained substantially dependent on visiting specialist teams and treatment abroad⁵. The Centre was founded on a commitment to universal access: that the highest standard of specialist cardiac care should be available according to clinical need, irrespective of wealth, geography, gender, creed or social status.

This combination of an established community healthcare network and an unmet need for specialist cardiac care provides a particular context in which to examine how excellence in cardiac care might be distributed clinically, architecturally and socially.

1.3 Sustaining specialist capability

How specialist cardiac health infrastructure should be designed within such a system is not straightforward. Specialist cardiac hospitals require sophisticated clinical environments, engineering systems, equipment and highly trained staff. Yet specifications developed for settings with different construction, procurement and maintenance capacities can create dependencies that are difficult to sustain over time. Evidence from under-resourced healthcare settings has shown how limited maintenance capacity, unavailable spare parts, insufficient technical training and dependence on external support can compromise the continued operation of sophisticated medical equipment⁹. Many of the decisions that shape whether a hospital can sustainably deliver the care for which it was designed are therefore made early in the design process.

A compact relationship between operating theatre, catheter laboratory and intensive care can reduce critical transfer time. Materials that can be sourced, repaired and extended locally reduce dependence on fragile supply chains.

Daylight, shading and natural ventilation can maintain environmental quality across much of a hospital while reserving mechanical control for spaces where it is clinically indispensable. These are architectural decisions. They determine what an institution requires to operate and maintain its intended level of performance.

Where those requirements exceed what a setting can sustain, a building that opens at one standard may quietly settle towards the standard its context can actually hold. We describe this as capability drift: the incremental erosion of intended performance as systems become difficult to maintain, components cannot readily be replaced, or buildings are adapted in ways their original organisation did not anticipate. Because such drift is gradual, it may be difficult to attribute to any single failure or design decision. The mechanisms underlying this process - including maintenance capacity, access to spare parts and technical training - are well documented in relation to medical technology in under-resourced settings⁹; here, we extend the concern to the building and institution as a whole.

The response, however, is not to lower ambition. This is particularly important for a centre of excellence. "Appropriate" must not become a justification for under-investment: where patient safety and clinical performance require sophisticated technology, environmental control or specialist infrastructure, these should be provided. The question is instead where complexity is clinically and institutionally necessary, and where equivalent performance can be achieved with fewer dependencies.

1.4 Appropriate Complexity

This paper develops that proposition through the design of the Rwanda Egypt Heart Centre (REHC) (Figure 1) and the Village Integrated Plug-In (VIPI), a community health platform for prevention, health education and patient follow-up (Section 3.6).

The REHC builds on the successful model established at the Aswan Heart Centre, a centre of excellence where specialist treatment, education and research are integrated within a single institution committed to serving the region in which it is located¹⁰.

Where Aswan developed through the adaptation and extension of an existing facility, Rwanda presented the opportunity to design such an institution from first principles - and to ask what

more architecture can and should contribute than the delivery of a specialist hospital. Within the Centre, this meant considering not only clinical performance, but how its design and construction could strengthen local skills, material and supply chains, technical knowledge, and the capacity to maintain and adapt the institution over time. The same question subsequently extended beyond the hospital through VIPI, connecting specialist care to the communities its patients come from. Together, the two projects expand the architectural question from the design of a building to the capabilities and infrastructure required to sustain specialist cardiac care.

We propose “Appropriate Complexity”: a framework for calibrating the architectural, technological and institutional dependencies of healthcare infrastructure to the capabilities each setting is required to support. It builds upon established thinking around appropriate technology and frugal innovation^{11,12}, adaptable hospital design¹³ and context-responsive healthcare architecture in Rwanda¹⁴. It asks not only what care should be provided and where, but what degree of complexity is necessary and sufficient to sustain each setting’s capability over time.

We present this as a hypothesis rather than a demonstrated result: that locating complexity in this way might reduce capability drift over the life of the Centre. Section 4 discusses how this hypothesis can be tested after occupancy, using the indicators in Table 1.

2. Evidence and method

2.1 The hospital design process

The hospital design developed through a structured sequence of co-design workshops, visits and technical reviews, producing a documentary record of revised drawings and updated briefs against which decisions can be traced. Initial workshops at the Aswan Heart Centre, Harefield Hospital and the Royal Brompton Hospital in London were observational: their purpose was to learn from established practice - and from clinicians, nurses, anaesthetists and intensive care specialists - what the spatial and operational logic of specialist cardiac care requires. An AHRC-funded co-creation workshop on the wards of two NHS hospitals, in which one of the authors took part, examined the pathways of pathogens and the implications for spatial organisation and infection prevention (Figure 2). This was complemented by visits to hospitals in Rwanda, including King Faisal Hospital, Kanombe Military Hospital and Butaro District Hospital, and meetings with their clinical staff and with patients’ families. These provided direct insight into patient needs, staffing structures, referral pathways and the operational realities of delivering care in Rwanda.

The spatial organisation of the REHC was subsequently developed through the wider interdisciplinary design process, with the relationships between intensive care, progressive care, catheter laboratories and operating theatres resolved in consultation with the clinicians responsible for defining their operation.

Technical feasibility was tested in parallel by specialist engineering consultancies. Max Fordham, UK, undertook environmental modelling to assess the thermal performance and viability of key architectural propositions prior to construction. Arup, Kenya, reviewed the environmental and sustainability strategy at site scale, testing and refining the design against the climatic, infrastructural and engineering conditions in which the building is expected to operate.

The primary evidence for this analysis was the sequence of revised drawings and updated briefs produced following workshops and technical reviews. Where the documentary record is

incomplete, the account draws on the authors' direct participation. This paper is therefore a reflective analysis by participants rather than an independent evaluation. Table 1 sets out three design iterations resulting from this logic.

Table 1. Design iterations resulting from the Appropriate Complexity logic. ICU = intensive care unit; MEP = mechanical, electrical and plumbing; CHUK = Centre Hospitalier Universitaire de Kigali (University Teaching Hospital of Kigali), of which Masaka Hospital is now part; UCL = University College London.

Design decision	Alternative rejected	Decision taken	Workshop or visit informing the decision (site, participants, year)	Appropriate Complexity logic
Acuity-adaptable inpatient beds	Standard ward rooms only, or more permanent ICU beds	16 ward beds with medical gases, upgraded MEP services and provision for airtight rooms, allowing higher-acuity care when needed	Co-design workshop, Kigali: medical team, medical equipment team, biomedical engineer, architects (2025)	Located in time: capability built in, used only when demand requires
Entrances and outpatient waiting	A single reception in the outpatient building, with indoor waiting only	Separate main and outpatient entrances; indoor outpatient waiting plus a generous outdoor waiting area with café and toilets for families	Observational visits to hospitals in Kigali and Rwandan district hospitals (crowded indoor waiting): clinicians and staff (2020 and 2022). Aswan Heart Centre (ad hoc outdoor areas): clinicians and staff (2019/20). UCL co-creation workshop on infection control: ward staff (2019)	Located by observed use: outdoor waiting planned from the outset, supporting comfort and infection control
Medical-waste incineration	A dedicated incinerator on site, as in the initial brief	Shared use of the incinerator at the neighbouring Masaka Hospital (CHUK), under an agreement to share	Masaka Health City planning workshop: Rwandan health specialists, local and international clinicians, engineers (2023)	Located at system scale: plant shared rather than duplicated, accepting a dependency on the neighbouring hospital

We write as participants: we designed the projects we analyse, and the Centre extends the model of the Aswan Heart Centre, which one of us founded and with which the Centre shares training programmes (see Competing interests). As both authors are based outside Rwanda, our account of the design process was checked by a Rwanda-based architect who is not among the authors. To limit the risk of reading our own record selectively, we confined the design iterations to decisions where the documentary record shows one option being replaced by another, and we report costs where they arise, such as the dependency created by sharing incineration. Our own proposals did not always prevail: to reduce construction time and cost and so speed up the delivery of care, hospital modules were initially planned around shipping containers, an approach that was abandoned because container construction proved to be vulnerable in Kigali's tropical climate.

2.2 The IDP Model Village research and the origins of VIPI

VIPI emerged in parallel with research by one of the authors into Rwanda's Integrated Development Programme (IDP) Model Villages. The IDP Model Village programme was established by the Government of Rwanda in 2010 as part of a wider strategy to improve housing and grouped settlement, initially including the relocation of vulnerable communities from scattered

and high-risk areas¹⁵. The programme subsequently developed at national scale, combining housing with essential infrastructure and, in different locations, educational, health, productive and welfare facilities¹⁵. This forms part of Rwanda's longer-term strategy to reorganise rural settlement, with a national target for 100% of rural households to be settled in integrated planned settlements by 2035, maintained through 2050¹⁶.

Research by one of the authors examined the lived performance of this model through post-occupancy investigation of selected IDP villages (Figure 3)¹⁷. That research confirmed the programme's relative success in delivering affordable housing and essential infrastructure at scale but identified a recurring gap: the villages lacked shared community spaces, adequate provision for preventive healthcare and health education, and settings for sustained social interaction¹⁷.

These findings reframed the design problem beyond the hospital boundary. The patients served by the specialist centre come from communities whose built environment does not always support the prevention, health literacy and continuity of care required over a lifetime. The findings became one of the foundations for VIPI (Section 3.6). While its remit extends beyond cardiovascular disease to other non-communicable diseases, its development provided a means of examining how capabilities relevant to the cardiac pathway might extend into the communities where patients live.

3. Design: The Rwanda Egypt Heart Centre and VIPI

The Rwanda Egypt Heart Centre was designed around a central principle: different parts of a specialist hospital require different degrees of clinical, technological and environmental control. This shaped the organisation of the campus and, within it, the location of different capabilities - from the highly controlled intervention and critical-care environments of the clinical core to wards, outpatient, rehabilitation and public spaces with different technical and environmental requirements. It also informed the environmental and construction strategies and provision for future change.

The design can be read along the pathway of a patient with rheumatic heart disease, from detection in the community to lifelong follow-up (Figure 4). Technical complexity is concentrated where intervention demands it, while the stages before and after are supported close to where patients live. Two of the design iterations in Table 2 respond directly to this pathway, and follow-up of the Centre's surgical patients is one of the indicators by which the framework will be tested (Table 1).

3.1 A campus organised by different demands

The REHC accommodates two operating theatres, two catheter laboratories, intensive and progressive care, inpatient and outpatient facilities, imaging including MRI, CT and radiology, laboratories, research and teaching facilities, rehabilitation, a blood bank, a central sterile services department (CSSD), laundry, a staff canteen, staff facilities and a visitor coffee place, alongside the ancillary services required to support the hospital's operation. Rather than consolidating these functions within a single hospital block, they are distributed across three interconnected medical buildings arranged around landscaped courtyards (Figure 5). This allows functions with different

clinical, technical and environmental requirements to be grouped within distinct but closely connected buildings, while also permitting phased delivery should funding require it.

Landscape, views and circulation are integral to this organisation. Kigali's high-altitude tropical climate, with moderate year-round temperatures, together with the hospital's sloping site overlooking a valley (Figure 6), allows much of the building to maintain a close relationship with nature. Long views and planted courtyards are combined with circulation, waiting and recovery areas that extend into the landscape. Patient rooms face the valley and surrounding greenery, drawing on evidence that views of nature can support recovery and reduce patient stress.^{18, 19} Outdoor terraces directly in front of the wards allow patients to spend time outside during recovery, extending the wards outdoors. A covered route connects most departments on a single level while doubling as an outdoor cardiac rehabilitation track (Figure 7). Green courtyards provide seating for patients and families, staff respite and informal exchange, while a smaller kitchen garden supplies herbs and produce to the staff canteen. Whether these spaces are maintained, used and valued as intended is assessed after occupancy (Table 1, indicators 9 and 10).

The campus is organised through a gradient of privacy and clinical control, moving from the public entrance, outpatient and shared spaces towards progressively more private and controlled clinical areas.

Infection prevention is embedded within this hierarchy: staff, patient, visitor and service flows are separated where required, while key circulation routes are located outdoors or in naturally cross-ventilated covered spaces, reducing reliance on enclosed shared corridors. Separate main and outpatient entrances, and an outdoor waiting area with a café and toilets for accompanying families, extend this principle to arrival and waiting (Figure 8; Table 2). This careful interweaving of building and landscape supports infection control while integrating nature into the everyday experience of the hospital, and creates opportunities for interaction between patients, families and staff and for informal exchange across clinical, research and teaching teams.

The campus therefore establishes from the outset that different parts of a specialist hospital need not operate at the same level of environmental or technical complexity. A compact, highly serviced acute core sits within a wider hospital environment in which circulation, landscape, environmental control and construction can operate differently.

The Centre forms part of Masaka Health City, a cluster of health, research and training institutions being developed by the Government of Rwanda that includes IRCAD Africa and the University Teaching Hospital of Kigali (CHUK), which now incorporates the adjacent Masaka Hospital. A direct road connection between the Centre, CHUK and IRCAD Africa is planned, including for acute transfers. Medical-waste incineration is shared within Masaka Health City and not duplicated on site (Table 2).

3.2 The clinical core: concentrating complexity

The acute clinical core is organised horizontally, with two operating theatres, two catheter laboratories (one of them hybrid), intensive care and progressive care on a single floor in direct adjacency. For a cardiac patient in critical condition, every transfer between catheter laboratory, theatre and intensive care is a period of risk, and here each one is a short horizontal move. None of these transfers depends on a lift, and the hybrid catheter laboratory allows a catheter procedure to convert to surgery without moving the patient. Compactness is therefore a clinical decision.

Imaging and the CSSD sit directly below, connected by a bed lift and a separate clean-supply lift: the only vertical links in the acute pathway. This shortens the movement of patients, equipment and sterile supplies while keeping the separation of flows required for infection prevention.

This core carries the highest environmental and technological specification in the Centre. Theatres, catheter laboratories and intensive care need filtered mechanical ventilation, controlled pressure, temperature and humidity, uninterrupted power and specialist equipment. None of this can be simplified without putting patients at risk.

3.3 Environmental control and adaptability

Outside the acute core, the environmental strategy responds to the different clinical requirements of each building. Inpatient accommodation is arranged in single-loaded wards, with patient rooms facing the surrounding valley, providing daylight, views and a direct relationship with landscape. Dedicated family areas are incorporated within the wards, with additional waiting and gathering spaces near the main entrance, recognising the role of accompanying relatives, particularly for children and young adults travelling from outside Kigali.

The inpatient and outpatient buildings share a repeated double-skinned vaulted roof (Figure 9), establishing a common architectural identity and a cost-effective construction system that can be delivered using locally available skills and materials. Their environmental strategies, however, differ according to clinical need.

The inpatient wards are mechanically conditioned, and 16 ward beds are able to support higher-acuity care when needed (Table 2). The double-skinned roof reduces solar heat gain and cooling loads through its reflective outer skin and ventilated cavity, thereby reducing operational energy demand, carbon emissions and running costs. The double skin also provides acoustic buffering during heavy tropical rainfall, reducing rain noise within the occupied spaces below.

The outpatient building uses the same vaulted roof but operates through natural ventilation and passive cooling, without mechanical conditioning. Environmental modelling tested the performance of these sections and confirmed their capacity to support the respective environmental strategies (Figure 10). Whether this performance is sustained in use is assessed through indicators 4 and 5 (Table 1).

The same architectural system therefore supports different levels of environmental control: mechanically conditioned but passively assisted inpatient accommodation capable of future intensification, and naturally ventilated outpatient accommodation where clinical requirements permit.

At campus scale, north-south orientation, generous roof overhangs, self-shading massing and high thermal mass materials further moderate heat gain. Roof areas provide capacity for future photovoltaic installation, while the main circulation spine works with the natural fall of the site to contribute to stormwater management during the rainy season.

3.4 Construction

The construction strategy follows the same principle of calibration. During design development, much of the concrete was replaced with locally made brick, with reinforced concrete kept where the structure, including its seismic performance, requires it. The bricks are produced and fired in

kilns that burn residues from coffee processing rather than the fuelwood on which much informal brick production in Rwanda depends²⁰, and they meet the Rwandan standard for fired clay bricks. Emissions from fired clay brick vary widely with kiln efficiency and fuel, from 0.07 to 0.34 kg CO₂e per kg²¹; the substitution of brick for concrete also reduces the cement content of the building, a major source of construction emissions²². A project-specific embodied-carbon figure is not yet available. Blockwork and reinforcement are prepared in on-site maker yards (Figure 11), cutting transport and reliance on outside supply chains.

Local materials were not intended to imply reduced architectural ambition. Brick proportions, bonding and detailing were developed specifically for the Centre (Figure 12), combining Rwanda's material and building culture with a contemporary institutional identity. The construction process has also been used deliberately to strengthen local capability. To date, more than 700 workers have been engaged, approximately 10% of whom are women, with works undertaken predominantly by Rwandan subcontractors under Orascom Construction's management and supervision (Figure 13). This has enabled a two-way exchange of knowledge, combining local expertise with international standards of construction, quality control and project delivery. Local engineers have also been recruited and trained and now form part of the permanent site supervision team. The skills and technical knowledge developed through the project therefore extend beyond the delivery of the building itself, strengthening local economy and capacity for future maintenance.

3.5 Designing capability alongside capacity

A specialist cardiac centre cannot operate through physical infrastructure alone. Its capacity may be measured in operating theatres, catheter laboratories and beds, but its clinical capability depends on developing the people and technical knowledge required to operate and sustain them. Training was therefore conceived as an integral part of the Rwanda Egypt Heart Centre from the outset, with dedicated programmes for cardiac nurses, biomedical engineers, perfusionists and future clinicians designed to build specialist capability within Rwanda.

This commitment has spatial consequences. Teaching and research are integrated with clinical activity, supporting observation, discussion and knowledge exchange alongside patient care. Technical training is similarly embedded within the institution. A biomedical engineering workshop and maintenance facility were added to the brief following discussions with biomedical engineering expertise from Aswan, recognising that specialist equipment can only be sustained if the knowledge and facilities required to maintain it are developed on site and locally. The workshop's contribution is assessed through equipment downtime, maintenance support and staff retention (Table 1, indicators 1, 3 and 6).

3.6 VIPI: Distributing capability beyond the hospital

As the design developed, the limits of the hospital as the sole spatial unit of cardiac care became clear. Specialist intervention can be concentrated in Kigali, but prevention, screening, health education and long-term follow-up need to take place closer to where patients live.

The IDP Model Village research had shown where such care was missing: the villages lacked shared community space and adequate provision for preventive healthcare (Section 2.2). In response, we developed the Village Integrated Plug-In (VIPI), currently in the design phase. Its name draws on

vipi, a greeting in Swahili, one of Rwanda's official languages, meaning "how are you?": fitting for a place of regular check-ins.

VIPI is conceived not as a rural clinic, but as off-grid community infrastructure combining preventive healthcare and shared social facilities with reliable power, water and digital connectivity. It brings together a small outpatient facility with spaces for learning, meetings, digital access, a coffee place and informal gathering, placing healthcare within everyday community life, where a visit for screening or follow-up need not single anyone out as a patient. VIPI is designed as a flexible model that can be introduced into existing IDP Model Villages where needed or integrated into future settlements, responding to the community infrastructure gap identified through the research.

Architecturally, VIPI is organised around a modular 'smart roof' (Figure 14) that concentrates the infrastructure required for off-grid operation while giving the platform a distinct architectural identity. Solar generation and battery storage provide continuous power where grid supply may be unreliable (Figure 15), supporting diagnostic equipment, digital connectivity and the recording of patient data. The roof also integrates rainwater collection and filtration, shade and protection from heavy tropical rainfall. Constructed from locally available materials, it is designed for local fabrication and can be extended or replicated as needs develop (Figure 16).

Beneath the roof, simple brick volumes accommodate the outpatient unit and enclosed community facilities, while the spaces between them remain open and flexible for social, educational and civic use. Environmental control is predominantly passive.

The health programme is intended to support prevention and screening for cardiovascular and other non-communicable diseases, long-term follow-up, and referral where specialist investigation or treatment is required. Care is delivered primarily by community health workers and nurses, supported by the reliable power and connectivity that the smart roof provides. No screening technology has yet been selected. VIPI is therefore designed to accommodate whichever diagnostic tools prove appropriate, including AI-assisted tools once validated for the target conditions in Rwanda, without the platform depending on any of them. Advanced analysis is instead located at national level: data recorded at VIPI would flow, like that from Rwanda's community health workers and health facilities, to the Ministry of Health's National Health Intelligence Center, launched in 2025 to integrate and analyse real-time health data²³. The collection, storage and sharing of patient data will be governed by Rwanda's Law No. 058/2021 on the protection of personal data and privacy, which requires informed consent and restricts storage of personal data outside Rwanda without authorisation from the National Cyber Security Authority²⁴. At the same time, the shared social programme provides a setting for repeated contact, health education and community participation that digital technologies alone cannot always provide.

VIPI and the Rwanda Egypt Heart Centre therefore occupy different positions within the same care pathway. Cardiac intervention demands concentrated expertise, technology and environmental control; prevention and long-term follow-up require accessible community infrastructure combining social engagement with reliable off-grid power and connectivity.

4. Discussion and conclusions

A hospital is a building patients enter at their most vulnerable, often frightened, in pain, and far from home. The environment they find, whether it lifts or intimidates them, whether it feels made for people like them or indifferent to their situation, is not separate from their care. It is part of it. This is the founding conviction of the Rwanda Egypt Heart Centre: that the highest standard of cardiac care should be available to all, that excellence and access are not in tension, and that architecture can give physical form to that commitment, from the precise organisation of the acute clinical core to the courtyards, landscape, and quality of light experienced by each patient.

This conviction is also a design constraint. A hospital genuinely accessible to the poorest, to a child from a rural district whose family cannot afford transport to Kigali more than once, or to a community whose only contact with specialist care is a village health worker with a screening device, cannot be designed only as a specialist institution. Its reach must extend in an appropriate way to where those patients are. A building that aspires to serve its patients with dignity must be buildable to that standard not just at opening but continuously over decades, in a setting where imported systems degrade and local capacity either grows or does not, depending in part on the original design.

Beauty in this context is not a luxury. The coffee-fired brick, vaulted roofs, valley views, and courtyards with the rehabilitation track moving patients through planted landscape are not embellishments to a clinical programme. They are the form dignity takes when built. Appropriate Complexity argues that local constructability need not reduce architectural ambition. The two are not in opposition. Where a building must last and be maintained by its users, the ambition is to create beauty through materials and methods that belong to the place.

The Rwanda Egypt Heart Centre and VIPI were designed in response to a specific problem: how to build a centre of excellence in a setting where the dependencies a high-income specification creates may be difficult to sustain, without lowering the clinical standard that justifies building it or placing that standard beyond the reach of the patients who need it most. Together, the two projects suggest an answer we have called “Appropriate Complexity”: concentrate complexity where it produces necessary clinical capability and avoid it where it creates dependency without equivalent benefit.

Three implications follow from this that extend beyond the specific projects.

The first concerns what designing for sustainability means in this context. The relevant question is not the standard at which a facility opens but the conditions required for it to remain at that standard. A technically advanced solution is not resilient if its continued operation depends on components, expertise or supply chains that are difficult to access locally. Equally, a simpler solution is not inherently appropriate: its value depends entirely on whether it achieves the performance the setting requires. Capability drift is the failure mode the framework is intended to prevent. We propose that it is prevented not by lowering specification but by locating it accurately and building the capacity to hold it.

The second concerns the distinction between capacity and capability. Healthcare infrastructure is commonly described through measurable capacity: beds, theatres, equipment, consultation rooms. These are necessary measures, but they describe what a facility contains more readily than what an institution can reliably do. Clinical capability also depends on trained staff, technical

knowledge, maintenance, supply chains and the capacity to adapt as demand changes. The decision to incorporate a biomedical engineering workshop as a named room, to train the next generation of cardiac clinical staff within the institution, and to build using trades that remain locally available are not peripheral but integral to the architectural proposition. A building designed on the assumption that these capabilities will exist must contain the spaces that produce them.

The third concerns scale. The cardiac pathway does not correspond to the boundary of a hospital. Prevention, detection, referral, intervention, rehabilitation and long-term follow-up require different forms of infrastructure and occur across different geographical and temporal scales. VIPI is not a smaller version of the hospital. It occupies a different position in the same pathway - one where clinical dependencies are low but social and continuity requirements are high, and where reliable off-grid power and connectivity, and links to national health data systems, extend clinical reach without reproducing the hospital's infrastructural model; the analytical complexity sits at national level, not in the village. The relationship between the two projects suggests that the architectural unit of consideration for specialist cardiac care is not the hospital but the system.

These propositions can be tested only after occupancy. Table 2 sets out ten indicators for doing so, including the four most directly linked to drift: downtime of critical equipment, local sourcing of spare parts, retention of locally trained staff, and environmental performance against design intent. The hypothesis is supported if performance holds as activity grows and warranties expire, and challenged if it deteriorates.

Published reference points exist for equipment, with an average of 38.3% out of service across hospitals in sixteen low- and middle-income countries²⁵, and for thermal comfort in naturally ventilated spaces²⁶; for the other indicators, the Centre's own baseline provides the comparison. Assessment extends to ten years because purchased equipment in comparable settings is more likely to be out of service five to six years after arrival²⁷. Three measures require post-occupancy research for which funding has not yet been secured, and are presented as a proposed protocol. Several indicators, including retention, also depend on factors beyond the building; they test whether the Centre sustains its intended capability, not whether architecture alone determines it.

Ultimately, Appropriate Complexity proposes that excellence lies not in maximising complexity, but in locating it where it matters, building the capability to sustain it, and extending its reach from the specialist hospital to the communities it serves.

Table 2. Proposed post-occupancy indicators for testing Appropriate Complexity. Data are recorded from opening; assessment points are years after opening, aligned with the end of warranties and initial service contracts. B = baseline at handover, where a design-intent value exists. Indicator 6 starts from the nurses and perfusionists already trained at opening; indicator 7 is first assessed at year 3, as the Centre opens with the help of visiting teams. Routine = collected by hospital management as good practice; Set-up = routine data configured at commissioning (e.g. spare-part suppliers, training cohorts, data loggers); Research = dedicated post-occupancy evaluation. *Subject to research funding, not yet secured. Small numbers are reported as counts and aggregated to protect anonymity. VIPI will be evaluated separately. ICU = intensive care unit; UPS = uninterruptible power supply; INR = international normalised ratio.

Indicator	Measure	Drift signal	Data source	Assessed (years)
<i>A. Complexity concentrated in the clinical core remains functional</i>				

Indicator	Measure	Drift signal	Data source	Assessed (years)
1. Critical equipment downtime (catheter laboratories, CT, MRI, heart-lung machines, ICU ventilators)	Uptime under service contracts; annual inventory audit	Falling uptime or more equipment out of service, especially after warranties end	Routine	B, 1, 3, 5, 10
2. Critical building systems in the core	Annual ventilation validation (theatres, catheter laboratories, ICU); grid outages; backup power response; generator and UPS tests	Failed validations; backup power failures or missed tests	Routine	B, 1, 3, 5, 10
<i>B. Dependencies outside the core stay within local capacity</i>				
3. Spare parts and maintenance support	Supplier location and lead time for critical spares (core and building services separately); % of work orders done in-house or locally	Growing reliance on overseas suppliers or contractors; longer lead times	Set-up	3, 5, 10
4. Environmental performance outside the core	Temperature, humidity and CO ₂ over a year against the design model; rain noise in wards	Comfort or air quality out of range; disturbing rain noise	Set-up	B, 1, 3, 5
5. Retrofitted cooling and alterations	Air-conditioning added to naturally ventilated areas; alterations against the as-built plan	Ad hoc cooling; alterations breaking core adjacencies or cross-ventilation	Routine	3, 5, 10
<i>C. Capability grows with capacity</i>				
6. Retention of locally trained staff	Trainees in post (biomedical engineers, perfusionists, cardiac nurses), as counts; exit conversations	Trained staff leaving; posts back-filled by visiting staff	Set-up	B, 1, 3, 5, 10
7. Local clinical leadership	Procedures with a Rwanda-based primary operator, catheter and surgical separately	No increase once trainees qualify; return to visiting teams	Routine	3, 5, 10
<i>D. The Centre sustains its role in the cardiac pathway</i>				
8. Follow-up of surgical patients	% followed up at 12 months; anticoagulation control where INR data exist	Loss to follow-up; poor anticoagulation control	Research*	3, 5
<i>E. The environment supports recovery and wellbeing</i>				
9. Landscape and outdoor spaces	Annual photographic condition survey; observed use in wet and dry seasons; rehabilitation-track use	Planting lost or paved over; spaces closed, repurposed or unused	Routine (condition); Research* (use)	3, 5, 10
10. Experience of the environment	Short interviews with patients and families in Kinyarwanda; staff survey	Declining experience of the environment	Research*	1, 3

Competing interests

Julia Backhaus led the design of the Rwanda Egypt Heart Centre and VIPI as practice-based research at The Bartlett School of Architecture, UCL. Fluxarchitects, of which she is founding director, acts as statutory duties holder only. Magdi Yacoub contributed to the clinical brief for both projects and founded the Aswan Heart Centre, with which the Centre shares training programmes. Both authors are co-founders and trustees of the Rwanda Heart Care and Research Foundation. Julia Backhaus also took part in the UCL research cited in Section 2.1 and is an author of reference 17. The Centre is funded by the Governments of Rwanda and Egypt and by private donations. No funding was received for this paper.

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Figures & legends



Figure 1. The Rwanda Egypt Heart Centre, Kigali. Computer-generated rendering, 2020. © Julia Backhaus.



Figure 2. Co-design workshop on a hospital ward. Paths of Resistant Pathogens in Hospitals research project, 2019. © Julia Backhaus.



Figure 3. Co-creation workshop in an IDP Model Village, Rwanda, 2022. © Julia Backhaus.

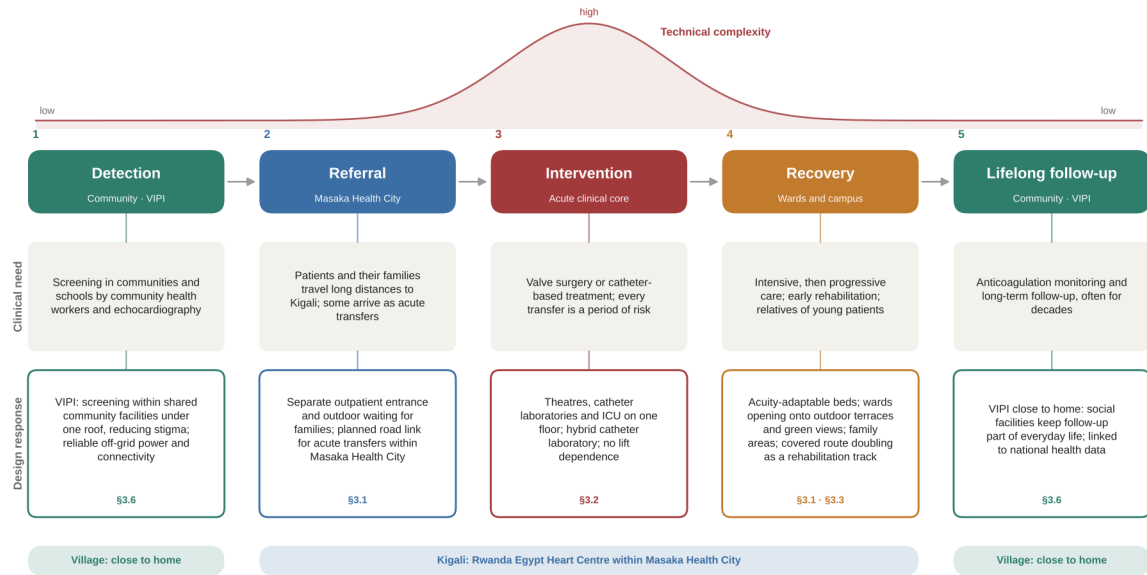


Figure 4. The rheumatic heart disease pathway traced through the design. Technical complexity is concentrated in the acute clinical core, where intervention demands it; the stages before and after are supported close to where patients live. Diagram © Julia Backhaus.

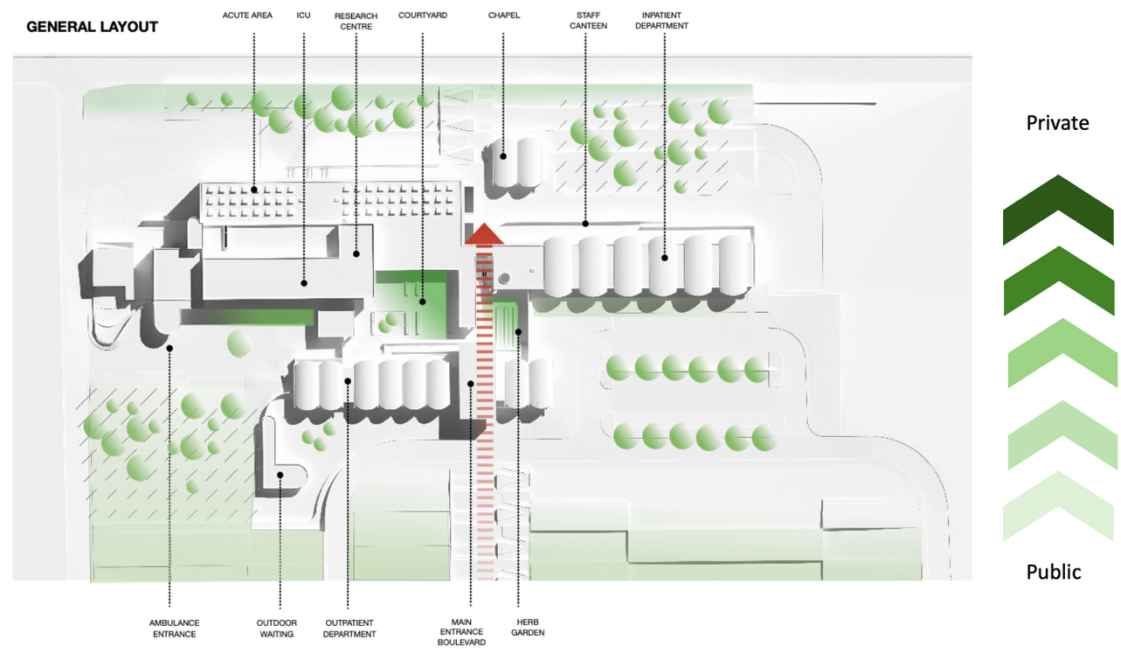


Figure 5. Campus layout of the Rwanda Egypt Heart Centre: three medical buildings arranged around landscaped courtyards. Drawing, 2020. © Julia Backhaus.



Figure 6. Drone image of the construction site above the valley, July 2026. © Julia Backhaus.



Figure 7. Courtyard and covered external circulation, which doubles as a cardiac rehabilitation track.
Computer-generated rendering, 2020. © Julia Backhaus.



Figure 8. Outpatient waiting area. Computer-generated rendering, 2025. © Julia Backhaus.



Figure 9. Double-skin vaulted roof structure over the inpatient ward. Photograph, 2026. © Julia Backhaus.

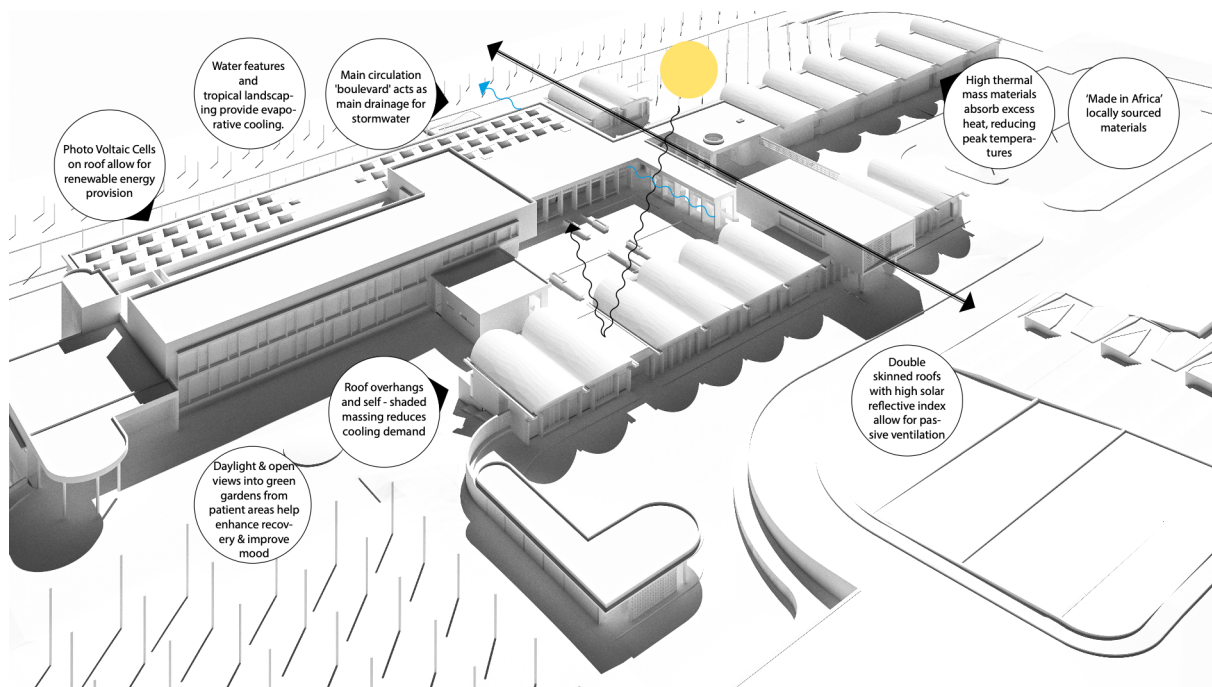


Figure 10. Environmental strategies for the inpatient and outpatient buildings. Rendered drawing, 2020. © Julia Backhaus.



Figure 11. On-site maker yard for blockwork (2025). © Julia Backhaus.



Figure 12. Brick façade detail under construction (2026). © Julia Backhaus.



Figure 13. Drone image of the Centre under construction July 2026. © Julia Backhaus.

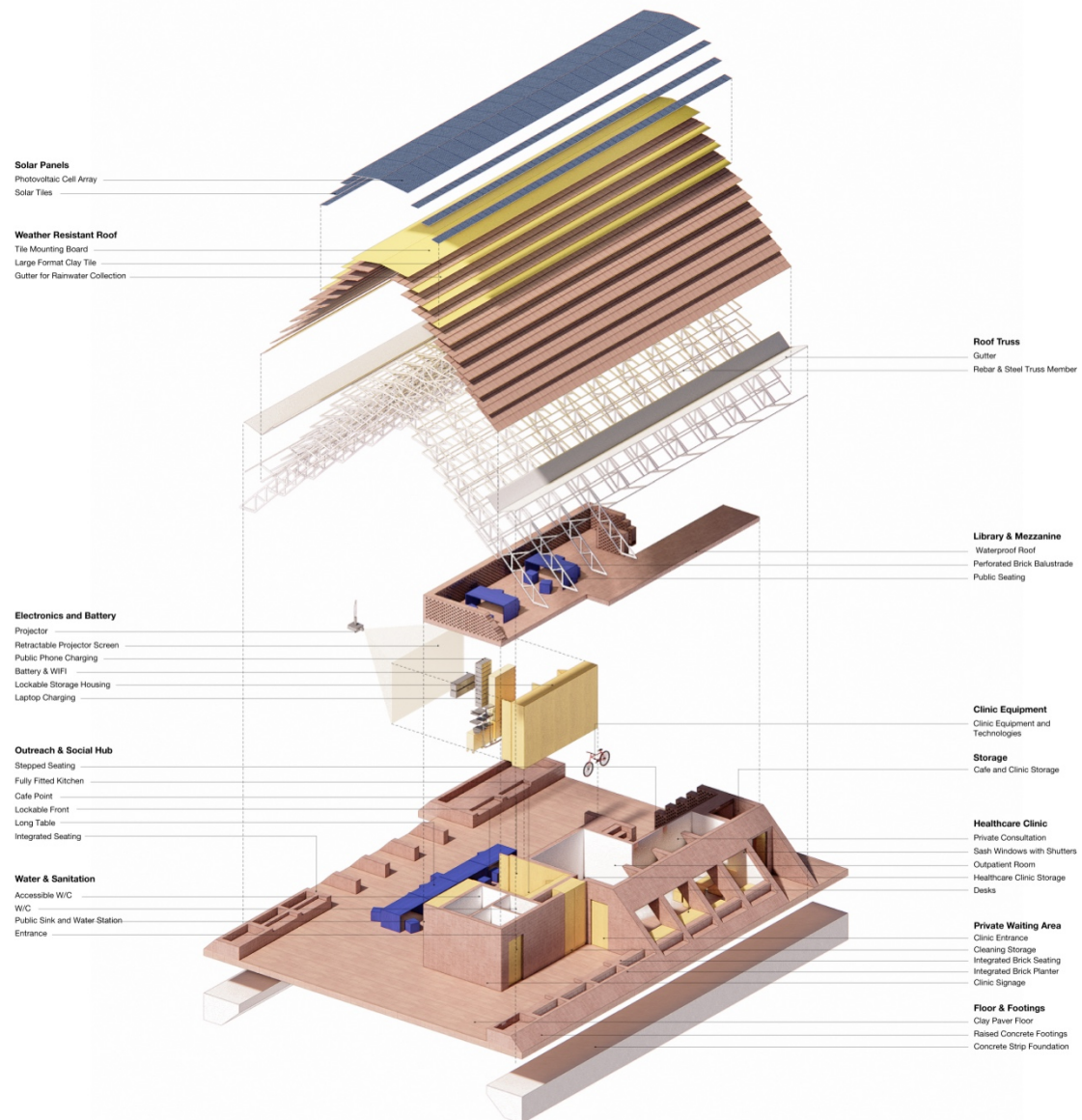


Figure 14. VIPI: axonometric diagram of the smart roof and brick volumes, 2025. © Julia Backhaus and UCL VIPI team.



Figure 15. VIPI at night, powered off-grid by its smart roof. Computer-generated rendering, 2025. © Julia Backhaus and UCL VIPI team.

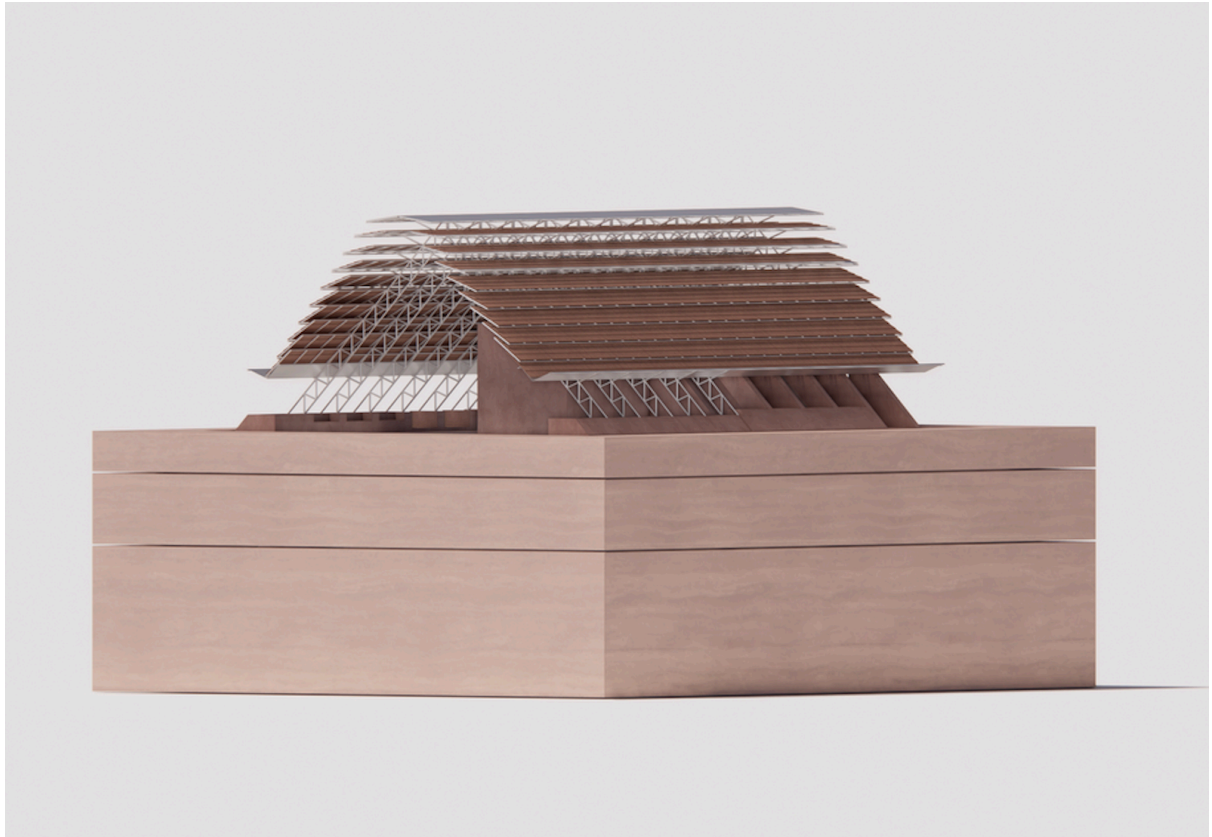


Figure 16. VIPI: physical model, 2026. © Julia Backhaus and UCL VIPI team.