DESIGNING

THE GREEN HOSPITAL

Sub-Saharan Africa:
designing tomorrow's healing today

Designing adaptive, low-carbon and regenerative healthcare infrastructure for a healthier, more resilient Africa.

For Africa. Context-specific solutions.

For people. Equitable access and dignity.

For the planet. Regenerative, not extractive.

For systems. Integrated, adaptive, resilient.

For the future. Designed for uncertainty.

> The challenge is not simply to build more. It is to build **differently—together.**

complexity,
uncertainty and
long futures

africa's healthcare infrastructure paradox

expanding access under conditions of ecological and infrastructural constraint

the pressure to build

demand is rising fast

2.1x — population growth
sub-Saharan Africa projected to double by 2050[1]

+950M — urbanisation
fastest urban transition globally[2]

+60% — healthcare demand
rapidly growing need for clinics, hospitals, maternal care, pharmaceuticals, cooling, digital systems[3]

-2.5M — infrastructure deficit
estimated shortfall of health infrastructure facilities in Africa[4]

major shortfalls in:

- healthcare facilities
- energy
- sanitation & water
- mobility
- housing

the paradox

simultaneously meeting development needs and planetary boundaries

conditions of uncertainty

compounding and interconnected

climate instability
more frequent heatwaves, floods, droughts and storms

energy insecurity
unreliable grids, load shedding and high energy costs

informality & rapid urbanisation
unplanned growth, inadequate services, strained systems

unequal access
significant urban–rural disparities in healthcare availability and quality

resource constraints
limited finance, materials, skilled labour and maintenance capacity

geopolitical volatility
supply chain disruption, cost escalation, policy uncertainty

1 UN DESA, World Population Prospects 2022
2 World Bank, Africa's Pulse, April 2023
3 WHO, Global Health Expenditure Database 2023
4 AfDB, Africa Infrastructure Development Index 2021

africa cannot simply:

- ✕ replicate high-carbon western development pathways
- ✕ nor delay infrastructure expansion and healthcare access

therefore:

transformation — not imitation — is required.

- build for equity and resilience
- design for low carbon futures
- use resources circularly
- innovate from african contexts

The challenge for Africa is not whether to build. The challenge is how to build differently.

Because not building perpetuates inequality and suffering — but building conventionally intensifies ecological instability.

hospitals operate within conditions of uncertainty

healthcare infrastructure must adapt to:

changing disease burdens
- emerging pathogens
- chronic disease rise
- antimicrobial resistance
- new public health threats

demographic shifts
- ageing populations
- urbanisation
- migration
- health inequities

technological disruption
- rapid innovation
- AI and automation
- new diagnostics
- telehealth expansion

multiple uncertain futures, one health system

climate instability
- extreme weather events
- heat stress
- flooding & storms
- air quality impacts

resource constraints
- energy insecurity
- water scarcity
- material shortages
- waste management pressures

evolving models of care
- shift to preventive care
- community-based care
- outpatient & day services
- personalised medicine

political & economic volatility
- policy change
- funding fluctuations
- global instability
- trade & supply chain disruption

each factor is uncertain.
together, they create deep complexity.
design must be adaptive, not predictive.

yet hospitals are often expected to remain operational for

40–80 years

designing for a long and uncertain future requires:

- flexibility & adaptability
- modular & upgradable systems
- resilience to shocks & stresses
- resource efficiency & circularity
- equity & social responsiveness

we cannot predict the future, but we can design to adapt, absorb and transform.

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evolution of hospital design

architectural ideas and values shaping healthcare infrastructure

period	architectural theory/movement	core ethos	hospital design expression
1900–1930	modern movement / bauhaus / international style le corbusier, walter gropius, mies van der rohe	form follows function: rationalism, efficiency, minimal ornament	hospitals as machines for healing: functional blocks, standardised wards, focus on hygiene and efficiency.
1930–1960	functionalism & early modernism industrial logic, taylorism, streamlined production	industrial logic, efficiency, standardisation, and rational planning	large institutional hospitals: emphasis on efficiency of circulation and centralised services.
1960–1980	postmodernism & humanism reaction against cold rationalism, pluralism, symbolism, contextualism	human scale, meaning, identity, and response to place and people.	rise of patient-centred hospitals: attention to comfort, privacy, family spaces, healing gardens.
1980–2000	evidence-based design / environmental psychology empirical research guiding design	design decisions informed by evidence and measurable outcomes.	hospitals designed with research-backed layouts: reduced infection rates, improved recovery via daylight, acoustics, stress reduction.
1990–2010	high-tech architecture / digital integration exposed systems, technological optimism	technology as enabler of performance, connectivity and innovation.	emergence of smart hospitals: advanced operating theatres, IT infrastructure, telemedicine, robotics.
2010–2025	neo-futurism / systems thinking / sustainable design flexibility, adaptability, ecological integration, community networks	resilience, adaptability, regeneration, and integration with natural and social systems.	innovative delivery models: modular hospitals, decentralised clinics, community-integrated care hubs, green design, resilience planning.

from buildings as machines to hospitals as adaptive, living systems

each era reflects the ideas, technologies and values of its time. our task is to design for the uncertainties and needs of tomorrow.

people · planet · performance · resilience

what is “green” anyway?

01 green building

doing less harm

buildings that reduce negative environmental impacts through efficient use of resources.

primary focus
reduce environmental footprint

key principles
- energy efficiency
- water conservation
- low emissions materials
- pollution reduction

system perspective
building scale

time horizon short to medium term

outcome orientation less bad

key scholars & sources
brundtland commission, 1987
gbcsa, 2021
green building council definition

implications for hospital design
high performance buildings that minimise energy, water and emissions.

> concepts overlap and are interdependent. the goal is not to choose one over another, but to integrate them for places that are healthy, resilient, just and regenerative.

02 sustainable design

doing things better

design that meets present needs without compromising the ability of future generations to meet theirs.

primary focus
balance environmental, social & economic goals

key principles
- life-cycle thinking
- triple bottom line
- integrated design
- resource efficiency

system perspective
building + site + community

time horizon medium to long term

outcome orientation better

key scholars & sources
wced, 1987
fiksel, j. (2006) 'sustainability and resilience'

implications for hospital design
integrated, life-cycle thinking across site, building, people and operations

> concepts overlap and are interdependent. the goal is not to choose one over another, but to integrate them for places that are healthy, resilient, just and regenerative.

03 resilient design

staying strong through change

designing to prepare for, absorb, recover from and adapt to shocks, stresses and uncertainties.

primary focus
adaptability & continuity of function

key principles
- redundancy
- robustness
- flexibility
- adaptability

system perspective
system & network scale

time horizon long term & uncertain futures

outcome orientation prepared

key scholars & sources
holling, c.s. (1973)
walker, b., holling, c.s., carpenter, s.r., kinzig, a. (2004)

implications for hospital design
hospitals that can withstand disruptions (climate, health, social) and continue to function.

> concepts overlap and are interdependent. the goal is not to choose one over another, but to integrate them for places that are healthy, resilient, just and regenerative.

04 circular economy

keeping resources in use

an economic system that eliminates waste and keeps products, materials and resources in use for as long as possible.

primary focus
resource loops & value retention

key principles
- design out waste
- keep in use
- regenerate natural systems

system perspective
material & economic systems

time horizon long term

outcome orientation efficient & restorative loops

key scholars & sources
ellen macarthur foundation (2013, 2015)
geissdoerfer, m. et al. (2017)
'circular economy – a new sustainability paradigm'

implications for hospital design
design for disassembly, modular systems, material passports, closed-loop operations.

> concepts overlap and are interdependent. the goal is not to choose one over another, but to integrate them for places that are healthy, resilient, just and regenerative.

05 regenerative design

restoring and renewing systems

design that actively restores ecological, social and economic systems and enhances life over time.

primary focus
restore, renew & improve systems

key principles
- net positive impact
- ecological restoration
- systems thinking
- place-based solutions

system perspective
ecological & social systems

time horizon long term to intergenerational

outcome orientation net positive

key scholars & sources
mang, p. & reed, b. (2012)
du plessis, c. (2022)
'design for regenerative cities and landscapes'

implications for hospital design
hospitals that actively restore ecosystems, support community health and improve over time.

> concepts overlap and are interdependent. the goal is not to choose one over another, but to integrate them for places that are healthy, resilient, just and regenerative.

06 just & inclusive sustainability

ensuring equity and wellbeing

approaches that ensure fair access, participation and benefits for all people, now and in the future.

primary focus
equity, access & social wellbeing

key principles
- social justice
- community participation
- health & wellbeing
- cultural relevance

system perspective
socio-ecological systems

time horizon long term to intergenerational

outcome orientation fair & thriving

key scholars & sources
raworth, k. (2017)
'doughnut economics'
un-habitat (2020)
'inclusive cities'

implications for hospital design
inclusive facilities that promote health equity, accessibility and community wellbeing.

> concepts overlap and are interdependent. the goal is not to choose one over another, but to integrate them for places that are healthy, resilient, just and regenerative.

adapted from: du plessis, c. (2022). "the city sustainable, resilient, regenerative – a rose by any other name?". in 'design for regenerative cities and landscapes: rebalancing human impact and natural environment' (pp. 23–48). cham: springer.

net zero buildings

balancing operational and embodied carbon

a net zero building aims to **reduce, eliminate or offset** greenhouse gas emissions across its life cycle.

not all net zero buildings are regenerative, resilient or socially just.

net zero = balance

total emissions (operational + embodied) = total removals & offsets ⇌ net zero outcome

operational carbon

emissions during building use

- cooling systems
- ventilation systems
- lighting
- medical equipment
- electricity demand
- backup generators

operational emissions can decline through:

- efficiency
- electrification
- renewable energy
- smart systems

embodied carbon

emissions locked into materials and construction

- extraction & mining
- material manufacturing
- transport
- construction & installation
- maintenance & replacement
- end-of-life demolition & disposal

embodied carbon is emitted before the building even opens.

net zero strategies

reduce demand · electrify systems · renewable energy · low-carbon materials · adaptive reuse · circular procurement · carbon sequestration · offsets (last resort)

measure → report → reduce → remove → restore → repeat

net zero is necessary— but may not be sufficient

a hospital can theoretically achieve net zero carbon while still:

- consuming excessive water
- damaging biodiversity
- reinforcing inequality
- generating waste
- excluding communities
- lacking resilience

net zero carbon is one part of the wider sustainability agenda, not the whole.

the future challenge is not only net zero buildings— but **regenerative, resilient and socially just** health infrastructure.

key references

IPCC (2022) · WorldGBC (2023) · LETI (2020–2023)
Architecture 2030 (2021) · MECLA / Hudson Worsley (2022)
UK Net Zero Carbon Buildings Standard (RIBA, 2021)

difficult conversations

tensions, contradictions and unintended consequences in 'green' building transitions

1 greenwashing + checklist culture

when sustainability becomes a tick-box exercise, transformation is lost.

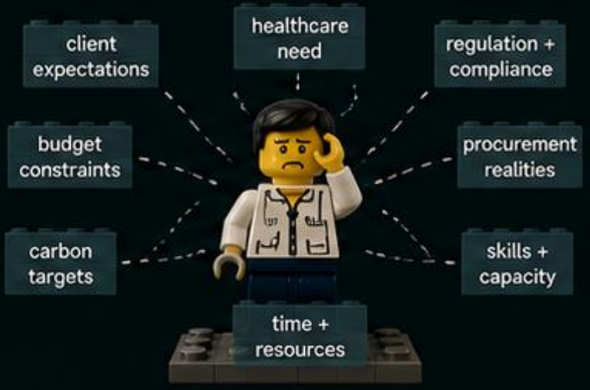
- certification ≠ transformation
- metrics can obscure systemic impacts
- sustainability reduced to compliance
- 'green' as branding exercise

are we redesigning systems—
or decorating business-as-usual?

sustainability transitions are complex, contested and imperfect.

2 professional anxiety + moral burden

many professionals experience invisible pressures as they try to do the right thing.



- guilt regarding environmental harm
- uncertainty about best practice
- fear of making incorrect decisions
- paralysis from complexity

sustainability is increasingly
psychological as well as technical.

3 the cost paradox

short-term affordability pressures often conflict with long-term value.

- low-carbon transitions may initially cost more
- African healthcare systems face severe fiscal pressure
- high-performance systems need skills and maintenance capacity
- financing models often reward lowest upfront cost

the cheapest building today may become
the most expensive future liability.

beyond simplistic narratives

technology	×	nature
growth	×	sustainability
optimism	×	pessimism

↓

adaptive transformation

4 techno-optimism + resource finity

technology is vital, but it is not a panacea.
every solution has a material and energy footprint.

- material finity
- ecological overshoot
- geopolitical instability
- unequal resource access
- waste + pollution

every technological system depends on physical extraction
and planetary limits.

these tensions are real.
ignoring them leads to
naïve solutions and
unintended harm.

the challenge is not to design perfect buildings.
it is to make better decisions under conditions of uncertainty, constraint and competing priorities.

critical reflection,
contextual intelligence
and ethical leadership
are our greatest tools.

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carbon | materials | metabolism

> *“it may seem a strange principle to enunciate as the very first requirement in a hospital that it should do the sick no harm.”*
>
> — florence nightingale, 1859

harm

- noise
- glare
- disorientation
- poor air quality
- isolation
- infection risk
- sleep disruption
- thermal discomfort
- institutional stress

healing

- daylight
- quiet
- dignity
- social connection
- bioghilia
- restorative views
- clean air
- autonomy
- comfort

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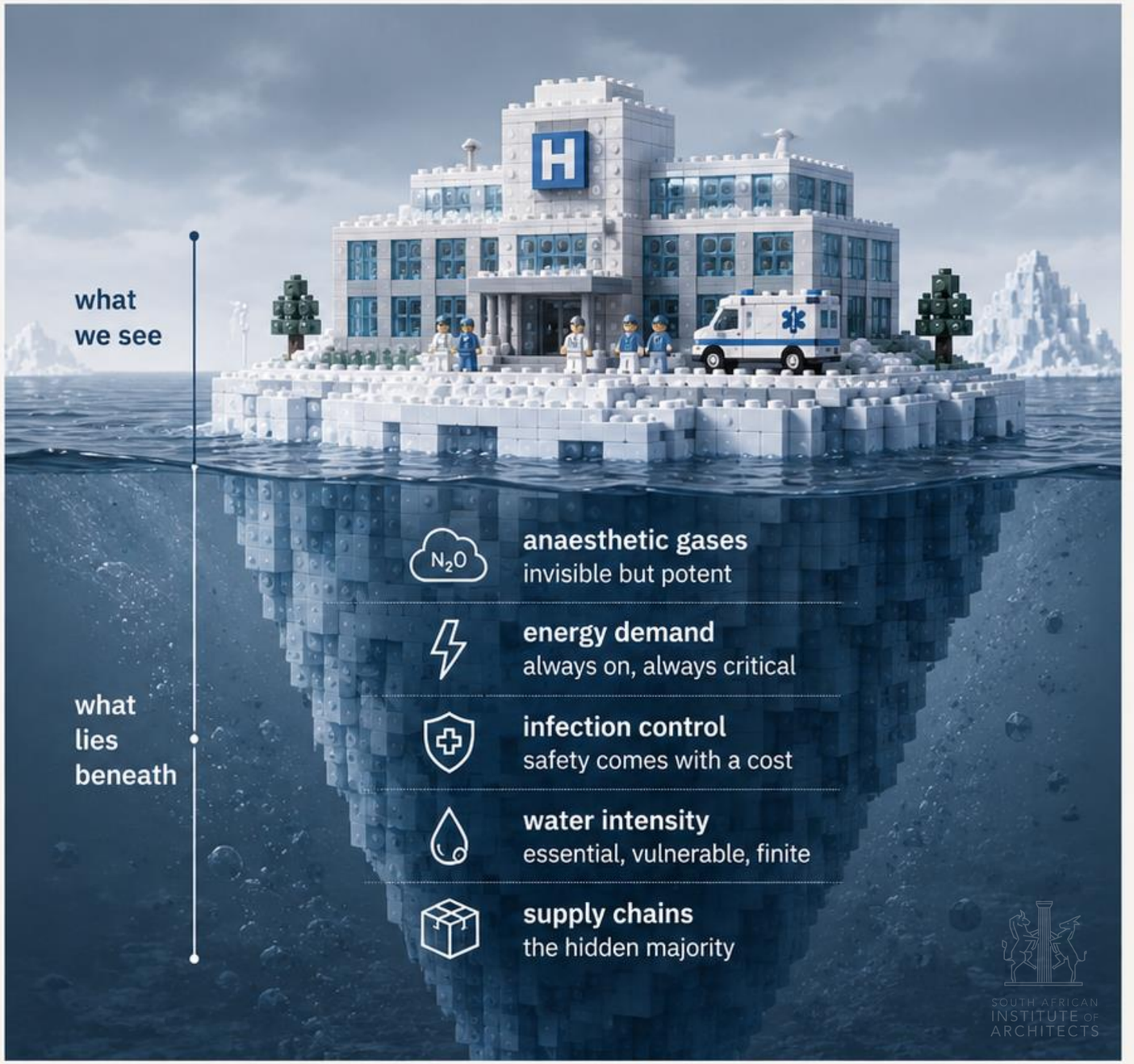
healthcare's hidden emissions

the ecological paradox of care

anaesthetic gases	invisible but powerful greenhouse gases e.g. desflurane, nitrous oxide have thousands of times the warming potential of CO_2
24-hour energy demand	cooling, ventilation, imaging and sterilisation make hospitals among the most energy-intensive buildings
infection control	sterility saves lives, but drives high use of single-use materials and energy-intensive processes
water intensity	essential for sanitation, sterilisation, laundry and dialysis — under increasing pressure in a changing climate
supply chains	medicines, equipment, logistics and food generate the majority of healthcare's emissions (scope 3) beyond the building

healing has a footprint. awareness is the first step to change.



healthcare extends far beyond its walls. our impact does too.

material metabolism

the hidden carbon inside buildings

buildings are temporary material assemblages. understanding their life cycle is key to decarbonising the built environment.

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operational carbon

the "low hanging fruit"

28%

of global building-related emissions [3][4]

most emissions occur during building use and can be reduced through:


renewable energy integration


efficient HVAC systems


efficient lighting & equipment


smart controls & optimisation


energy storage & demand management

grids can decarbonise.
systems can become more efficient.

embodied carbon

the difficult challenge

11%

of global emissions before occupation begins [3][4]

embodied carbon is emitted across the entire life cycle of materials and construction.

- harder to avoid
- supply-chain intensive
- difficult to measure
- locked in for decades

embodied carbon intensity of common building materials [5][6]

concrete (1 m³)	steel (1 tonne)	glass (1 m³)	bricks (1 000 units)	aluminium (1 tonne)
				
200 – 350 kg CO_2-e	**1 600 – 2 500** kg CO_2-e	**120 – 250** kg CO_2-e	**80 – 150** kg CO_2-e	**8 000 – 12 000** kg CO_2-e
• cement production is carbon intensive • ~8% of global CO_2 emissions [5] • use SCMs, low-carbon cement & structural optimisation	• energy intensive production • high strength & recyclability • use recycled steel & electric arc furnaces	• high temperature manufacture • operational trade-offs: daylight vs heat gain • optimise glazing ratios & performance	• kiln-fired – energy demand • durable & low maintenance • locally sourced bricks reduce transport impact	• extremely high embodied energy • lightweight & corrosion resistant • recycling is critical to reduce impact

embodied carbon intensity (kg CO_2-e per functional unit) — lower impact — higher impact

values are indicative ranges from global databases [5][6]

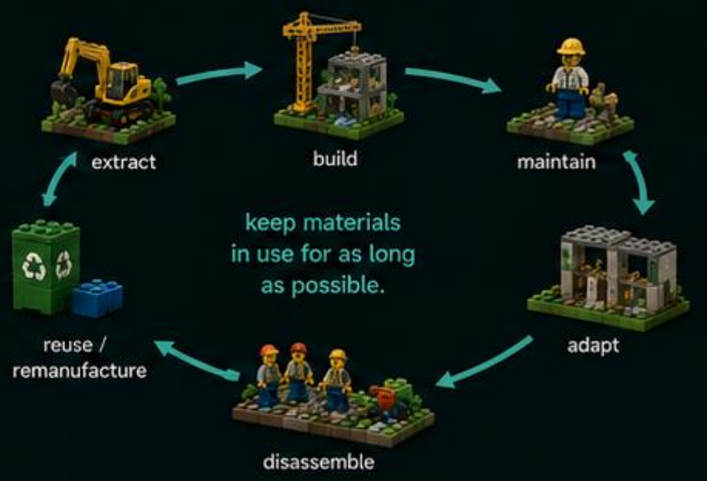
material metabolism

linear vs circular [7]

linear model (current practice)

resources are extracted, used once and lost.

circular model (future practice)



demolition becomes urban mining.
materials remain valuable.

if **not building** is not an option,
and **current practice** is not sustainable,
transformation is required. [8]

- we must design for radically lower carbon.
- we must build circular material systems.
- we must create healthy, just and resilient places.

healthcare waste and environmental impacts

beyond the building

the healthcare sector's environmental impact from radioactive, toxic and chemical substances is a significant, growing concern.

hazardous healthcare waste (HCW) comprises roughly **15%** of total healthcare waste.[1]

24% of global deaths are linked to modifiable environmental factors, including chemical and waste pollution.[2]

the healthcare sector is responsible for roughly **4.4%** of global net greenhouse gas emissions.[3]

What we generate: waste streams of concern

sharps & infectious waste

- needles, syringes, scalpels
- contaminated materials
- blood and body fluids

single-use & disposable items

- gloves, masks, gowns
- tubing, IV sets, catheters
- packaging and plastics

pharmaceutical & chemical waste

- expired medicines, antibiotics
- solvents, disinfectants
- laboratory reagents, heavy metals

radioactive waste

- radiopharmaceuticals (e.g. I-131, Tc-99m)
- contaminated materials
- sealed sources

collection & segregation

- safe separation at point of generation prevents contamination and reduces risk.

on-site storage & transport

- secure containers and trained handling minimise exposure and leakage.

treatment & final disposal

incineration, autoclaving, chemical treatment or secure landfill – each with impacts.

emissions & releases

air emissions, ash residues, leachate and effluent can pollute beyond the site.

impacts of disposal practices

incineration hazards

burning waste containing chlorine or heavy metals produces highly toxic compounds such as dioxins and furans.

incineration emissions

incomplete combustion releases hazardous black carbon and greenhouse gases.

landfill contamination

leachate from landfilling untreated waste can contaminate groundwater and produce methane – a potent greenhouse gas.

key environmental consequences

water contamination

radioactive, toxic and pharmaceutical waste enters water bodies, threatening aquatic life and human health.

air quality degradation

emissions from incinerators (dioxins, furans, heavy metals) threaten both ecosystems and neighbouring communities.

climate change contribution

the healthcare sector contributes roughly 4.4% of global net greenhouse gas emissions, partly due to energy-intensive waste management.

ecosystem disruption

persistent chemicals and drugs lead to long-term damage, such as endocrine disruption in wildlife and reduced biodiversity.

references

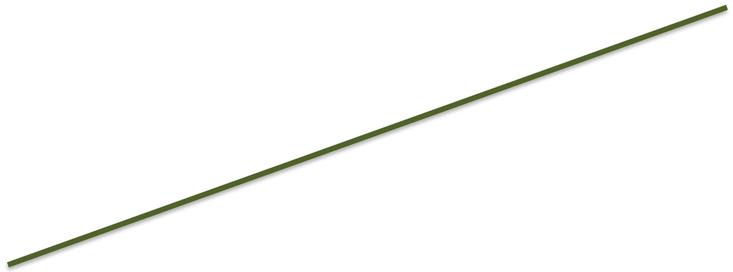
1 World Health Organization (WHO). Health-care waste. 2023. www.who.int/news-room/fact-sheets/detail/health-care-waste

2 World Health Organization (WHO). Environmental health. www.who.int/health-topics/environmental-health

3 Health Care Without Harm. Health care's climate footprint. Report. 2019 (with updates). noharm-global.org/global-news/healthcare-climate-footprint-report

statistics are approximate and global in scope.


HOSPITAL



pathways
to
progress

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the hospital as a living system

integrated ecosystems, interconnected flows, shared value

a hospital does not operate in isolation. it is part of a living network of ecological, social and technological systems. when these systems are designed to work together, we create healthier people, stronger communities and a thriving planet.

how flows connect

- water flows
- energy flows
- material flows
- people & mobility flows
- data & information flows
- value & social flows

systems thinking. connections create value.

better by design

integrating these systems helps hospitals operate more responsibly and create shared value for people and planet.

tools, frameworks and emerging capacities

building the knowledge ecosystems required for low-carbon and regenerative healthcare infrastructure

No single tool solves the challenge.
Transformation emerges through connected knowledge, local context, collaboration and adaptive learning.

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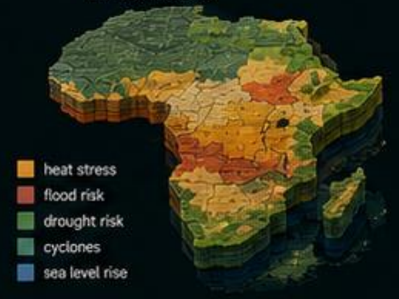
1 climate + risk intelligence

understand future risk to design resilient healthcare infrastructure.



GREENBOOK
CSIR climate-risk platform for settlement and infrastructure planning. [7]

IPCC reports
climate science, scenarios and guidance.

World Health Organization
climate and health resources for adaptation and resilience.

African Climate & Development Initiative
regional data and policy insights for Africa.

better decisions.
better systems.
better health.

2 operational carbon + energy tools

reduce energy demand and enable clean, reliable and efficient operations.

SANS 10400-XA [9]
energy performance in buildings

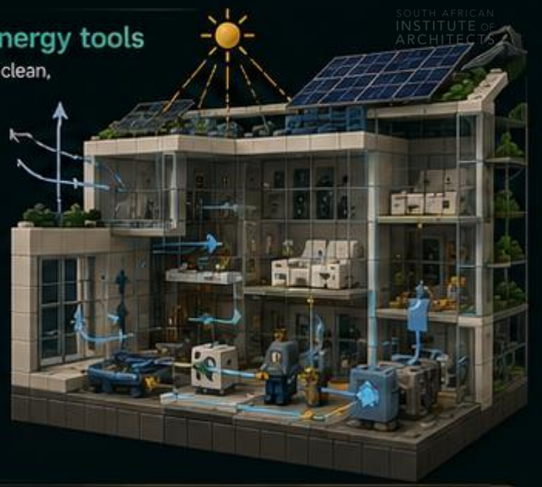
energy performance certificates

EnergyPlus
dynamic energy modelling

DesignBuilder
whole-building simulation

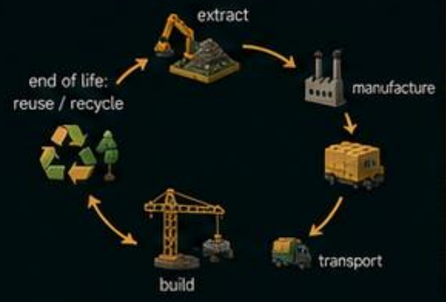
IES
integrated environmental solutions

PHPP
passive house planning package



3 embodied carbon + lifecycle assessment

understand and reduce the carbon locked in materials and construction.



EC3
embodied carbon in construction

One Click LCA
lifecycle assessment platform

eTool
early-stage LCA for buildings

Tally
revit plugin for embodied carbon

LCAQuick
simplified LCA for all

ecoASA [8]
Africa's eco-labelling system for sustainable building products.

4 regenerative + systems thinking

shift from doing less harm to creating conditions for ecological and social regeneration.

- **circular economy** — design out waste, keep materials in use
- **regenerative design** — restore ecosystems, build living infrastructure
- **resilience thinking** — prepare for shocks and uncertainty
- **living systems approaches** — learn from nature, design with complexity
- **urban metabolism** — see cities as dynamic flows of resources

key thinkers and contributors

- Chrisna du Plessis — systems + sustainability
- Bill Reed — regenerative design
- Donella Meadows — systems thinking
- Many African scholars, practitioners and communities generating context-specific knowledge

5 african institutions + collaboration networks

no institution can solve this transition alone. we need connected, multi-scalar action.

CSIR research, tools and innovation

Green Building Council South Africa
standards, guidance, advocacy

C40 Cities global network for urban climate action

universities research, education, innovation

policy, planning and regulatory agencies

professional institutes
SAIA, ECSA, AAHK, AIAAS and others

research collaboratives — pan-African knowledge exchange

the most important resource: interdisciplinary collaboration

complex challenges require diverse expertise and shared purpose.

together we design for people, planet and prosperity.

— useful first steps

the transition toward regenerative healthcare infrastructure is not driven by a single technology or certification.
it emerges through expanding networks of knowledge, collaboration and adaptive learning.

DESIGN FOR WELLNESS & VITALITY

design shapes daily health

The places we design outside the clinic determine the health inside and beyond it.

- car-dependent environments
- unhealthy food access
- convenience over wellbeing
- depleted public realm
- pollution + stress

→ Healthy futures start long before we ever reach the hospital.

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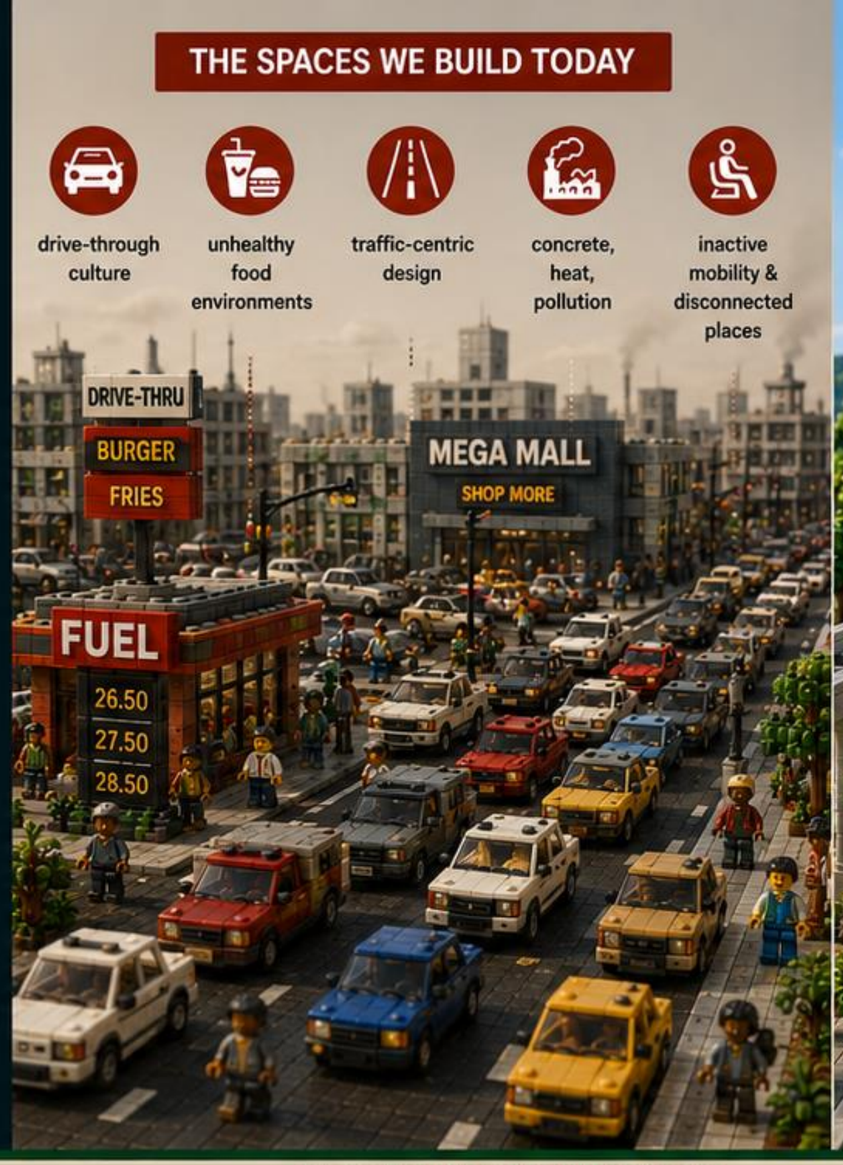
THE SPACES WE BUILD TODAY

drive-through culture · unhealthy food environments · traffic-centric design · concrete, heat, pollution · inactive mobility & disconnected places



A HEALTHY AFRICA IS POSSIBLE

Let's design it—together.

active mobility friendly · local food, healthy choices · green spaces, clean air · cool, green, climate responsive · people-first places

WE CAN DESIGN DIFFERENTLY

move more · eat well · live with nature · connect communities · use clean energy · design circular · build equity · choose public transport · cycle safe · play and unwind

Healthy Africa begins with the places we build every day.

sources, credits and authorship

designing the green hospital

sub-saharan africa: designing tomorrow's healing today

authored by

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chief executive officer
south african institute of architects (saia)

alumni
council for scientific and industrial research (csir)

2026

intellectual influences

this presentation draws on scholarship and professional discourse relating to:

regenerative design | systems thinking | evidence-based healthcare design | circular economy | resilience theory | adaptive infrastructure | ecological urbanism | urban metabolism

key intellectual influences include

- chrisna du plessis — sustainability scholar
- donella meadows — systems thinker
- bill reed — regenerative design theorist
- jason f. mclennan — living building challenge founder
- healthcare systems and evidence-based design scholarship

selected references

this presentation synthesises insights from a diverse body of international and african scholarship, standards, reports and datasets, including:

- ipcc assessment reports
- world green building council (worldgbc)
- cib task group 124 – global practices of net zero carbon building design and construction (2025)
- csir greenbook
- ecoasa – agrément south africa
- sans 10400-xa – energy usage in buildings
- nbi / b usa / bcg – decarbonising south africa's buildings and construction sector (2022)
- lützkendorf & balouktsi – embodied carbon research (2020)
- healthcare sustainability and systems literature
- publicly available urban, climate and infrastructure datasets

note: data ranges reflect different methodological boundaries and operational/embodied assumptions.

data and visualisation notes

statistics and diagrams are interpretive syntheses assembled from multiple published sources. carbon accounting figures vary depending on methodological boundaries and operational/ embodied assumptions.

ai-assisted workflows

selected visualisations, speculative illustrations and diagrammatic compositions were developed using ai-assisted image generation and iterative editorial refinement.

ai tools were used as collaborative visualisation instruments only.

all final curatorial, conceptual and editorial decisions remain the responsibility of the author.

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> the future of healthcare is not merely a building – it is a world we build together.

people centred | planet positive | systems thinking | collaborative action | healing futures