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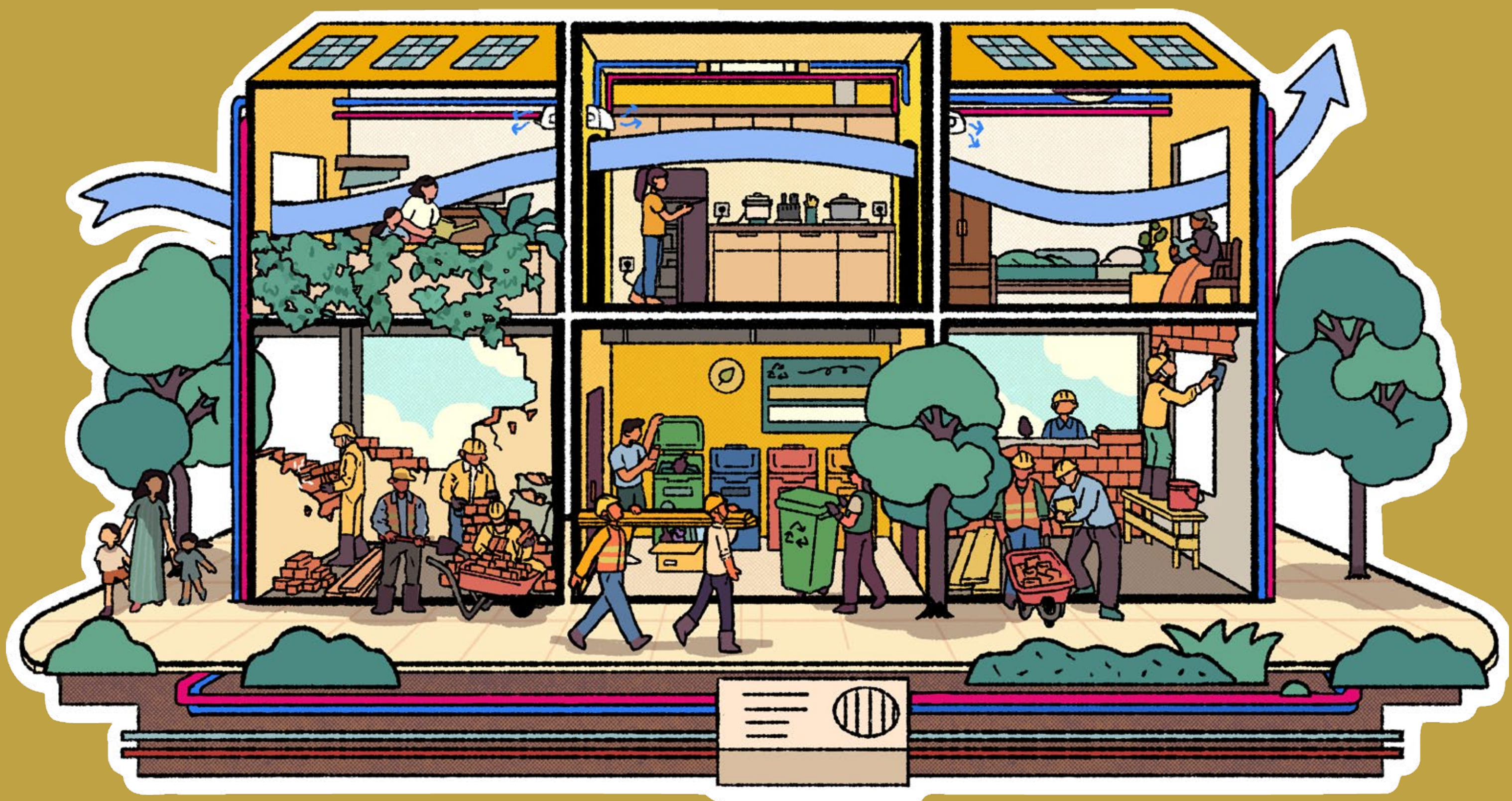

B4P TRANSFORMATION TOOLBOX

CLIMATE PROTECTION & ENERGY FLOWS GUIDELINE

02.4

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Sustainable Development of Urban Regions

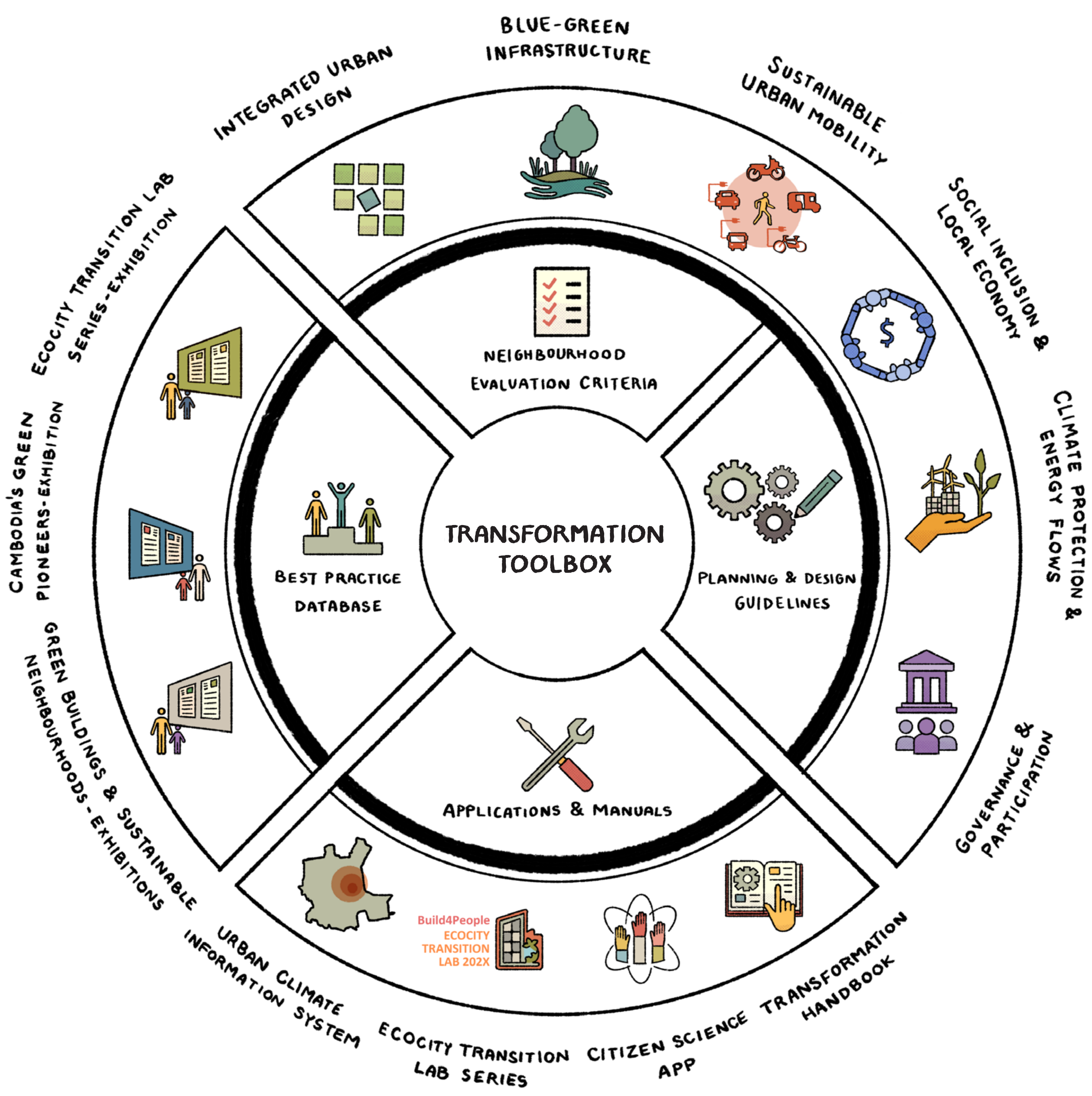

Figure 1. This guideline publication is part of the B4P Transformation Toolbox, a comprehensive learning platform developed by the Build4People project in cooperation with Phnom Penh City Hall to foster sustainable neighbourhood development in urban Cambodia.

02.4 CP&EF

CLIMATE PROTECTION & ENERGY FLOWS

CONTENT

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02.4 CP&EF

CLIMATE PROTECTION & ENERGY FLOWS

INTRODUCTION

As climate change intensifies, cities like Phnom Penh that are experiencing rapid urbanization must adopt sustainable building practices to reduce energy demand and greenhouse gas emissions. This urgency aligns with global commitments such as the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement, which call for decisive action to limit global temperature rise. In fact, the latest IPCC reports (International Panel on Cloimate Change) underscore the critical need to reduce emissions, as the unprecedented increase in greenhouse gases over the past 150 years has disrupted natural systems, threatening the stability of human livelihoods. In response, international regulations now mandate that new buildings achieve near-zero operational energy use by 2030- a target that requires transformative design, construction, and material choices.

For Cambodia, achieving sustainable buildings goes beyond energy efficiency; it demands a holistic strategy that integrates passive design, renewable energy, and careful material selection. While operational carbon (emissions from building use) must be minimized, embodied carbon (emissions from construction materials) also plays a decisive role. As buildings move toward net-zero energy operation, their ecological impact increasingly depends on resource-efficient materials and life cycle assessment (LCA) methodologies.

These guidelines provide actionable recommendations for practitioners and local authorities in Phnom Penh, supporting Cambodia's sustainable energy transition. By combining energy-efficient design, renewable energy integration and low-carbon materials, these measures contribute to a resilient, climate-neutral urban future. Through collaboration and policy alignment, Phnom Penh can advance its sustainability goals while fostering healthier, more adaptive living environments for its residents.

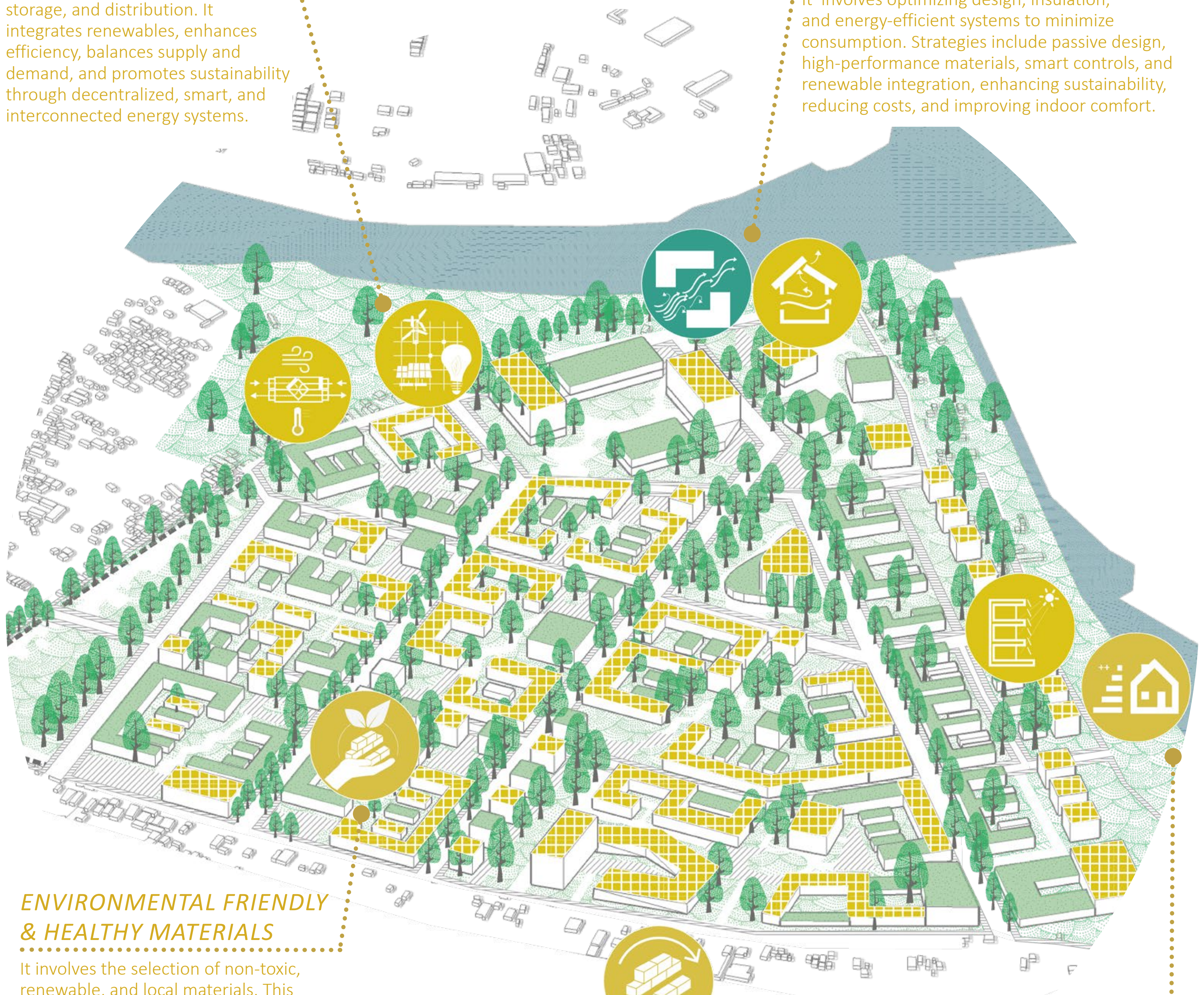

Figure 2. Proposal to integrate climate protection & energy flow solutions on neighbourhood level: Case study of the Chbar Ambov district, Phnom Penh, developed during the Build4People Ecocity Transition Lab 2023.

ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFITS

Implementing climate protection and energy flow strategies in Phnom Penh is essential for fostering sustainable urban growth and aligning with national policies. By integrating energy efficiency measures, green building standards, and renewable energy solutions, the city can support the Cambodian Construction Law's evolving compliance framework, contribute to the National Energy Efficiency Policy's reduction targets, and promote buildings and neighbourhood sustainability certifications. The full, or even the partial, implementation of the presented guideline would imply not just a congruent step align with resent policy efforts, but also would imply a serie of benefits for all stakeholders and the environment.

ECONOMIC BENEFITS FOR PRIVATE DEVELOPERS

- **Cost Savings & Efficiency:** Minimizes operational expenses over time, creating direct cost savings on utilities. Energy-efficient systems- such as optimized HVAC, lighting, and insulated construction - help developers reduce ongoing maintenance and energy bills, contributing to long-term profitability
- **Increased Property Value:** Sustainable buildings attract buyers and tenants, improving occupancy rates and rental yields. This adresses also future potential carbon taxing and related financial impact. Sustainability certifications enhance marketability in Phnom Penh's real estate market
- **Lower Lifecycle Costs:** Focus on durability, adaptability, and reuse, which reduces costs related to repair, maintenance and eventual demolition
- **Investor Appeal:** Investors increasingly seek projects that align with environmental, social, and governance (ESG) criteria. By adopting green building practices, developers may attract more interest from sustainable investors, improving access to capital.

ECONOMIC BENEFITS FOR PUBLIC AUTORITIES

- **Reduced Strain on Energy Infrastructure:** Demand on the city's energy grid decreases, delaying or reducing the need for costly upgrades and expansions.
- **Enhanced Revenue through Higher Property Taxes:** Increased property values boost tax income, supporting further urban development and public services.
- **Job Creation and Economic Growth in Green Sectors:** Sustainable construction drives demand for specialized materials, technologies, and labor, fostering economic growth.
- **Reduction in Waste Management and Landfill Costs:** Reduced construction and demolition waste decreases landfill and treatment expenses for public authorities.
- **Energy Independence and Security:** Supporting renewable energy generation at both building and neighbourhood levels increases local energy resilience. This can protect the city from energy price volatility and shortages, contributing to long-term energy security.

ENVIRONMENTAL BENEFITS

- **Reduced Greenhouse Gas Emissions:** Contribute to lower carbon emissions by reducing fossil fuel dependency. On a neighbourhood scale these strategies can collectively decrease Phnom Penh's carbon footprint, help meeting national and international climate targets.
- **Conservation of Natural Resources:** Prioritize resource conservation, reducing the need for new raw materials and lowering environmental degradation associated with resource extraction and manufacturing processes.
- **Reduction in Urban Heat Island Effect:** Energy-efficient buildings and green infrastructure help to cool the surrounding environment and mitigate the urban heat island effect by avoiding hot air from air conditioning.

SOCIAL BENEFITS

- **Enhanced Public Health and Well-being:** Buildings with good ventilation, natural light, and non-toxic materials contribute to public health by lowering rates of respiratory illnesses.
- **Resilience to Climate Impacts:** When buildings and neighbourhoods are climate responsively designed, it reduces the vulnerability of residents to climate-related risks such as flooding or high temperatures. This enhances community resilience, especially for vulnerable populations, making Phnom Penh better prepared for climate change.
- **Improved Quality of Life:** Sustainable buildings prioritize occupant comfort through natural lighting, noise reduction and efficient temperature control.
- **Promotion of Social Equity:** When applied to affordable housing or incentivized for wider access, by creating inclusive housing policies, public authorities can ensure that more citizens benefit from high-quality, sustainable living environments, reducing disparities in living standards.

Source: Own compilation based on various sources.

GUIDELINE 02.4

SCIENTIFIC BACKGROUND AND KEY IDEAS

The ASEAN region presents a diverse regulatory landscape for sustainable construction, with countries implementing mandatory energy efficiency standards achieving notable progress toward global sustainability targets (ASEAN Centre for Energy [ACE], 2024).

Cambodia has begun laying important groundwork for net-zero carbon buildings, as outlined in the International Energy Agency's Roadmap for Energy-Efficient Buildings in ASEAN (IEA, 2023). However, full implementation requires complementary measures including training programs, practical implementation tools, and incentive mechanisms to bridge policy-practice gaps. Successful execution will depend on sustained collaboration between government agencies, developers, and construction professionals.

ENERGY EFFICIENCY FOUNDATIONS

In Phnom Penh's tropical climate, passive design strategies form the cornerstone of energy conservation. Proper building orientation, cross-ventilation, and solar shading can reduce cooling loads by 25-30%, as demonstrated across Southeast Asia (ACE, 2024). Enhanced building envelopes- incorporating thermal insulation, cool roofs, and high-performance glazing- provide additional energy savings of 15-20% in comparable climates (United Nations Environment Programme [UNEP], 2019). These measures align with Cambodia's growing emphasis on building energy performance standards.

RENEWABLE ENERGY INTEGRATION

At the neighborhood scale, distributed solar photovoltaic (PV) systems offer a practical pathway for decarbonization. Vietnam's success with community solar programs, achieving 10-15% penetration in urban areas (International Renewable Energy Agency [IRENA], 2021), provides a replicable model. System optimization through smart metering and energy-efficient appliances, as implemented in Indonesian pilot projects (Ministry of Energy and Mineral Resources, Indonesia, 2022), can amplify benefits by matching generation with consumption patterns.

SUSTAINABLE MATERIALS INNOVATION

The materials sector presents significant opportunities for emission reduction. Locally-sourced bamboo, stabilized earth blocks, and recycled construction waste can lower embodied carbon by 30-50% compared to conventional materials (World Green Building Council [WorldGBC], 2020).

LIFE CYCLE APPROACH:

Comprehensive sustainability requires life cycle assessment (LCA) methodologies to evaluate environmental impacts from construction through operation to end-of-life. Singapore's Green Mark certification system (Building and Construction Authority [BCA] Singapore, 2022) provides a valuable benchmark, emphasizing durability, adaptability and recyclability in building design. Applying these principles at neighborhood scale could yield additional synergies in material flows and energy systems.

IMPLEMENTATION FRAMEWORK

Three critical success factors emerge from regional experience:

1. Strengthened capacity building for regulators and practitioners
2. Targeted financial incentives for early adopters
3. Robust monitoring and verification systems

Cambodia's unique opportunity lies in adapting these proven strategies to local contexts while leapfrogging outdated technologies. By combining passive design, renewable energy, sustainable materials, and life cycle thinking within an enabling policy framework, Phnom Penh can establish a model for sustainable urban development in emerging tropical cities.

Table 1. Summary policy package towards net zero-carbon buildings in ASEAN. Source: redrawn by the authors based on IEA (2022).

		REGULATION
National Energy Efficiency Policy *Prakas No. 0159, issued in April 2023 by the Ministry of Mines and Energy* *Power Development Master Plan 2022-2040 (2022)* *National Cooling Action Plan SC.14*	*Building Energy Codes and Building Standards*	Set minimum energy efficiency, renewable integration, and carbon limits for all buildings, new and existing.
Subdecree No.254 on The Management and Improvement of Energy Efficiency of Electrical Appliances *Prakas on Energy Efficiency Labal for Designated Appliances*	*Product Standards*	Define mandatory Minimum Energy Performance Standards (MEPS) for appliances and building systems, regularly updated.
National Cooling Action Plan SC.14 *Draft NDC Roadmap for Low-Carbon, Climate-Resilient Buildings and Construction in Cambodia, Vision to 2050*	*Procurements regulation*	Require public projects to use low-carbon materials and efficient appliances, considering lifecycle emissions.
The Circular Economy (CE) Strategy and Action Plan (2023-2028)	*Regulation on materials*	Enforce protocols for deconstruction, waste collection, and material reuse/ recycling.
Prakas No. 0159, issued in April 2023 by the Ministry of Mines and Energy *National Cooling Action Plan SC.14*	*Framework regulations*	Support decentralized energy production, grid integration, and fossil fuel subsidy phase-out.
		INFORMATION
CAMEEL Green Building Tool (Cambodia Energy and Environmental Leadership)	*Certification*	Assess energy and carbon performance of buildings, promoting low-embodied carbon materials.
	Labelling	Provide energy and carbon performance ratings for buildings, harmonized with testing standards.
	Disclosure and benchmarking	Mandate energy and carbon performance reporting for new construction and major renovations.
	Training Programs	Educate on net-zero solutions, embodied carbon reduction, and energy-efficient home improvements.
	Education programs	Offer accreditation for professionals in low-carbon construction and energy management.
	Awareness Raising	Inform consumers on benefits of energy-efficient buildings, renovations, and incentives.
	Digital Tools and Data	Enable energy and carbon assessment through integrated design and management tools.
		INCENTIVES
	Financial Incentives	Provide grants, loans, and tax rebates based on energy and carbon performance.
	Non-financial Incentives	Expedite permits, reduce fees, and offer density bonuses for low-carbon buildings.
	Tariff Policies	Promote reflective energy pricing and preferential tariffs for distributed renewables.

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FROM LOW ENERGY DEMAND TO ENERGY STANDARDS & NET-ZERO

ANALYSING
ENERGY SAVING AND EFFICIENCY STRATEGIES

PASSIVE DESIGN STRATEGIES

The energy consumption of a building can be significantly reduced when it is well-designed. One of the most effective and sustainable strategies for lowering energy demand is passive or climate-responsive design. In Cambodia, where the climate is tropical, hot, and humid, building design should prioritize maximum protection from direct sunlight while ensuring optimal airflow within the structure. Cambodian vernacular and traditional architecture serve as valuable references, as they incorporate design elements that emphasize these principles, such as roof and window configurations.

A building that is inherently designed to function passively enhances energy efficiency. Passive design strategies include:

- the orientation of the building
- spatial layout
- placement and design of openings
- roof and façade design
- shading techniques, and
- material selection.

Additionally, modern sustainable technologies, such as green roofs and green façades, can be integrated to further enhance energy efficiency and environmental performance.

To minimize heat gain, buildings in Cambodia should be southfacing, incorporate horizontal shading elements, utilize natural shading from trees, and employ materials with high thermal resistance.

Proper ventilation also plays a crucial role in reducing heat accumulation. To achieve this, openings should be strategically positioned in alignment with the prevailing wind direction and designed to maximize airflow through the use of louvers.

Additionally, passive cooling techniques such as stack ventilation, achieved through roof design, cross ventilation and the incorporation of wind wells within stairwells can further enhance natural ventilation and thermal comfort.

Figure 3. QR code to download the publicised Compendium for Passive Cooling Strategies in Cambodia prepared by the Ministry of Environment with technical and financial support of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), the United Nations Environment Programme (UNEP) Cool Coalition, and the ClimateWorks Foundation

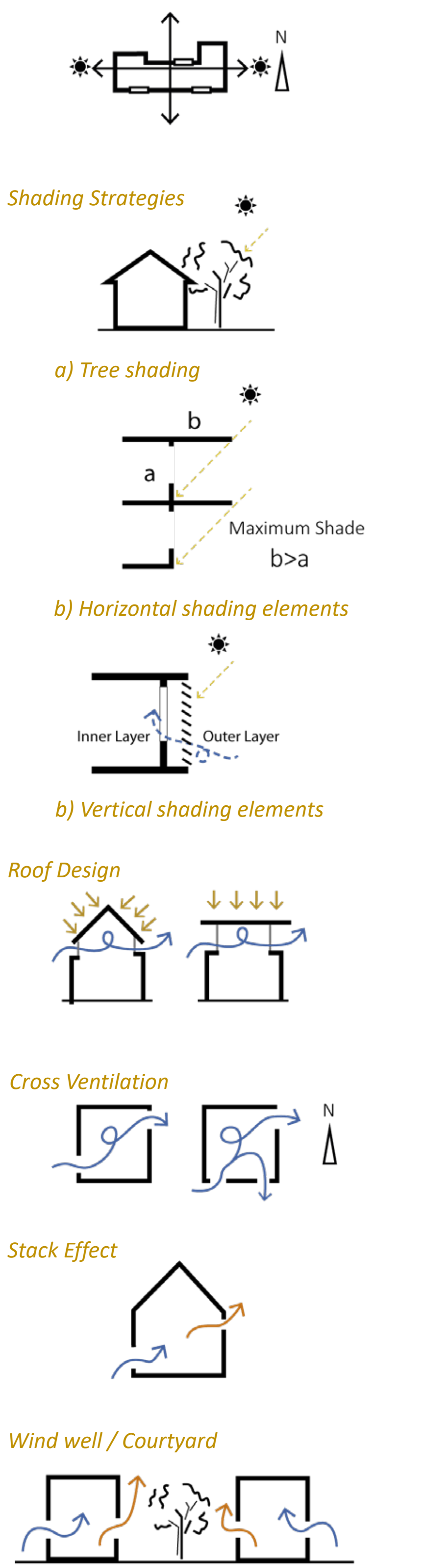

Figure 4. Climate responsive design for Cambodia. Source: Taing (2024).

ACTIVE DESIGN STRATEGIES

It focuses on optimizing building elements to minimize the need for active cooling systems. By applying active design principles, building cooling loads can effectively be reduced, thereby lowering energy consumption and operational costs associated with air conditioning, while also maintaining indoor thermal comfort. Some practical recommendations are:

- **Improving the Building Envelope**
  - » An efficient building envelope reduces the thermal load on cooling systems and reduces the need for air conditioning. It limits the amount of external heat that enters a building (see table 1, page 11).
- **Improving Glazing:**
  - » Critical in regulating indoor temperatures, and can significantly enhance a building's thermal performance (see table 1, page 11).
- **Integration of Efficient Appliances:**
  - » They help to lower both operational costs and greenhouse gas emissions (see table 2, page 14).

Through a combination of the above described passive and active strategies an optimal thermal comfort can be achieved. This hybrid approaches are particularly useful in tropical climates like in Cambodia, where passive strategies alone may not be sufficient during extreme weather conditions.

EVALUATION CRITERIA

ENERGY EFFICIENCY BUILDINGS

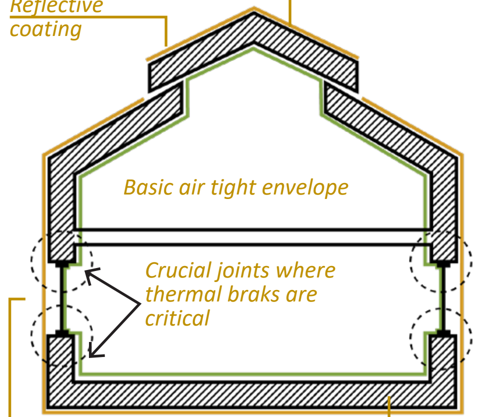

Figure 5. Summary of hybrid housing desing strategies.
Source: redrawn by the authors based on Passive House Institute (2007).

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PRACTICAL RECOMMENDATIONS FOR ACTIVE DESIGN

IMPROVING BUILDING ENVELOPE	*Use wall materials with high thermal mass + efficient cooling devices*	Materials like brick and stone absorb heat during the day and release it at night, reducing temperature swings. Combined with insulation, they slow heat transfer, keeping interiors comfortable.
	Basic air tightness	A moderately sealed building envelope limits hot, humid air infiltration, maintaining a stable indoor climate. Reducing thermal air bridges improves energy efficiency without causing ventilation issues in tropical conditions.
	Use reflective coating, especially on roofs	Bright or reflective roofs and walls deflect solar radiation, lowering indoor temperatures and reducing reliance on air conditioning. This passive cooling method is ideal for tropical climates like Phnom Penh.
	Integrate an insulation layer	Acts as a barrier against external heat, slowing penetration and reducing cooling demand. In Cambodia's hot climate, it works with thermal mass to keep interiors cooler.
IMPROVING GLAZING	*Using low-emissivity (low-E) glass or double-glazed windows*	It helps to maintain cooler indoor temperatures and reducing the load on air conditioning systems.
	Use wide, thermal breaks on windows	To achieve low solar heat gain fenestration use wide, thermal breaks to reduce conduction and light-colored frames to reduce solar absorption.
INTEGRATION OF EFFICIENT APPLIANCES	*Identify models that are energy efficient and environmentally friendly*	Cambodia recently introduced an energy label, but many sellers still use foreign rating systems. For instance, Thai-made ACs display the Energy Saving Label No. 5 to indicate electricity consumption.

Table 2. Recommendations to improve building envelope in tropical climates. Source: ACE (2024) and Wagner (2022).

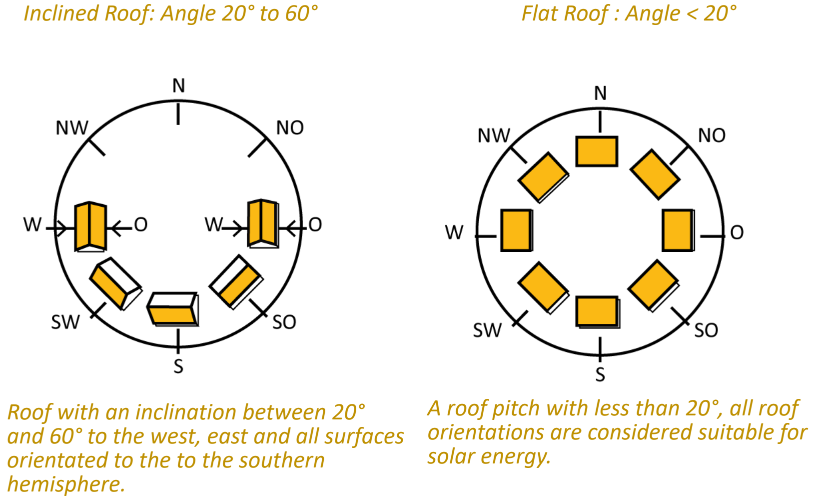

Figure 6. Solar suitability of pitched and flat roof surfaces for different roof inclinations. Source: Redrawn by the authors based on Stryi-Hipp et al., (2023).

INTEGRATING
RENEWABLE ENERGY AND EFFICIENCY STRATEGIES ON A NEIGHBOURHOOD LEVEL

With an average of eight hours of sunlight per day year-round, Cambodia has immense potential for solar energy. Solar power is far cheaper than coal-generated electricity, making it a cost-effective and sustainable alternative. As a result, solar energy presents a financially viable and environmentally responsible alternative to traditional fossil fuels.

NEIGHBOURHOOD SOLARIZATION:

To fully harness the immense potential of solar energy, it is crucial to maximize photovoltaic (PV) coverage across suitable roof surfaces.

- **Developping a solar cadaster:**
  - » Identifying and mapping rooftops best suited for PV installations to support data-driven decisions and optimize solar deployment.
- **Solarization criteria as planning tool:**
  - » Evaluation of neighbourhood layouts that can maximize solar energy generation. Factors such as building orientation, roof inclination, shading, and surface area play a crucial role (see Figure 6 and Figure 7).

DISTRICT COOLING SYSTEMS: CENTRAL CHILLERS

Cambodia's tropical climate, with high temperatures and humidity year-round, creates a strong demand for cooling, making district cooling systems a viable and smart option.

- **Assess Cooling Demand:**
  - » Suitable for high-density loads in mixed-use buildings, malls, and large residential complexes.
- **Integrate Early in Design:**
  - » Incorporate centralized cooling infrastructure in the planning phase to optimize layout, piping, and energy efficiency.
- **Adopt Cost-Effective Business Models:**
  - » Consider Build-Operate-Transfer (BOT) or third-party energy service companies (ESCOs) to reduce upfront investment costs.
- **Ensure Long-Term Reliability:**
  - » Smart monitoring systems improve performance, predictive maintenance, and energy efficiency.
- **Optimize Energy Storage:**
  - » Central chillers can produce chilled water during off-peak hours.

EVALUATION CRITERIA
ENERGY EFFICIENCY NEIGHBOURHOODS

Which roof surface is considered suitable for solar energy?
Depending on orientation and inclination

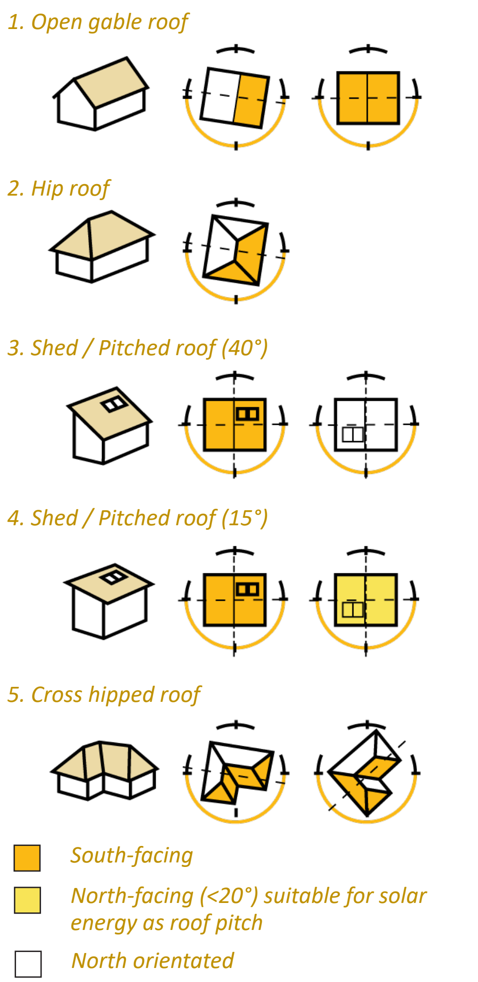

Figure 7. Solar suitability of inclinated roof surfaces. Source: redrawn by the author based on Stryi-Hipp et al., (2023).

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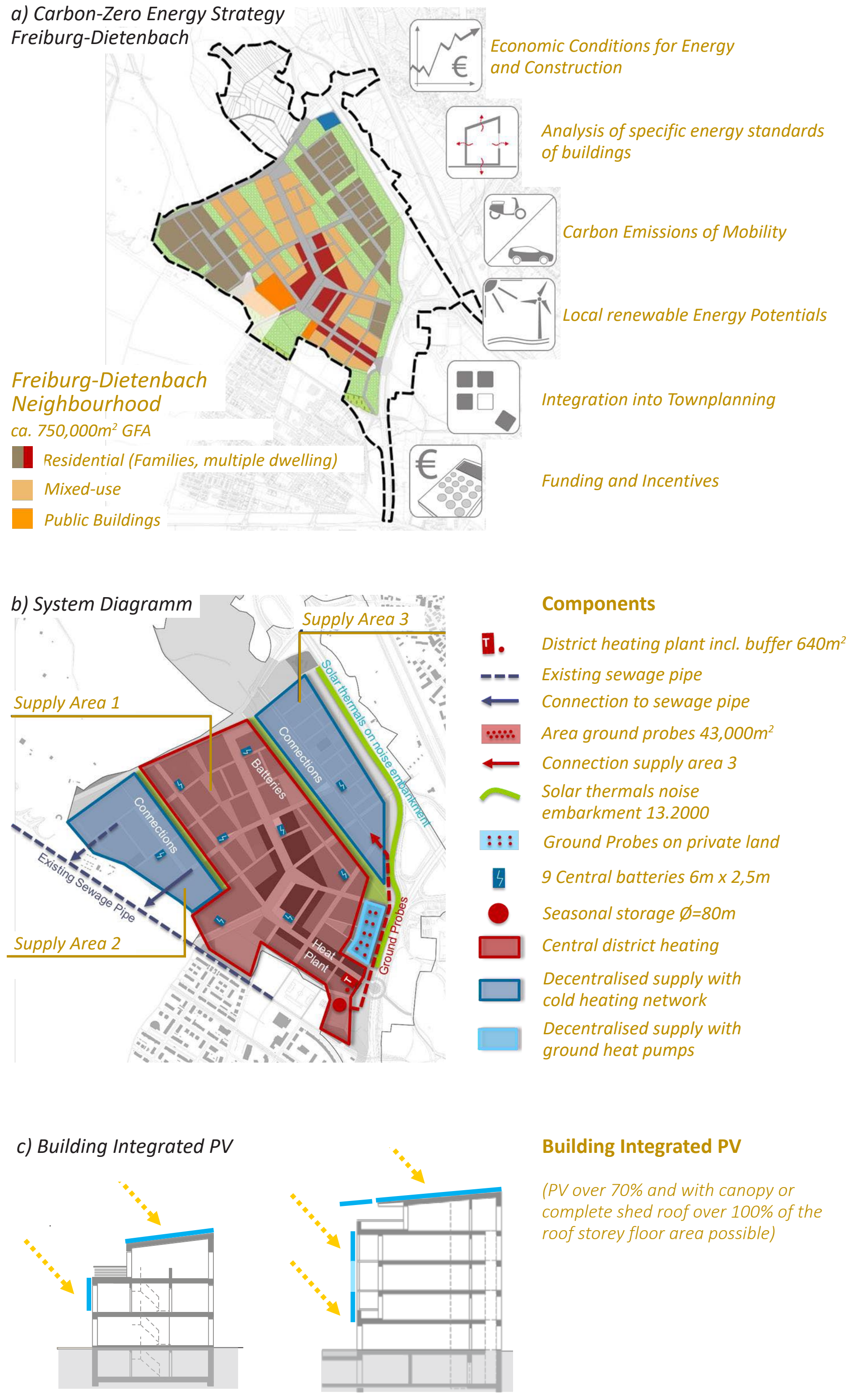

Figure 8. Freiburg-Dieterbach carbon-zero energy strategy development.
a) Carbon-zero strategy components, b) Conceptual diagramm of the energy system,
c) Conceptual diagramms of the scenario tested: building integrated roof.
Source: Stadt Freiburg - EGS-plan, Eble Messerschmidt Partner, IER University of Stuttgart.

FREIBURG-DIETENBACH NEIGHBOURHOOD

CARBON-ZERO ENERGY STRATEGY ON A NEIGHBOURHOOD LEVEL

Net-zero neighbourhoods should be Cambodia's mid-term objective. This means that urban areas must produce as much energy as they consume through a combination of:

1. Optimized energy efficiency in urban structures
2. Minimized energy consumption in buildings
3. Maximized renewable energy use and efficient energy supply.

These aspects apply to a proposal for a new district area "Freiburg Dietenbach" of around 108.4 ha in Germany. Besides the demand for a proposal that included a healthy mix of uses and appealing public spaces, it needs to be aligned with the city-wide objective of climate protection. The project aims to create a climate-friendly urban area by integrating:

- Energy-efficient building standards
- Local, emission-free renewable energy sources
- A sustainable energy supply concept

It includes an integrated approach that considers energy supply, building energy standards and building structures as well as other urban planning qualities. Eble Messerschmidt Partner, EGS-plan, and IER University of Stuttgart propose the consideration of 2 strategies:

- Maximizing Solar Gains
  - » South-facing buildings with wide sun exposure and low depth.
  - » Mono-pitch roofs for large-scale photovoltaic (PV) systems.
- Minimizing Energy Losses
  - » East/west-facing buildings with compact designs.
  - » Deep structures and flat roofs with elevated PV systems.

It includes proposed and evaluated energy supply strategies, integrated with differenciated urban densities and landuses: biomass heat plant, wastewater heat recovery, ground probes, solar thermals in combination with district heating and energy storage.

The results informed the neighbourhood planning process and influence the design on a building level. As shown in Figure 7, to achieved a carbon-zero district, mono-pitch roofs facing south optimsed the PV area and thus the potential electricity generation. Some conclusios derived of the analysis are:

- Available PV Area: 100% of roofs and 30% of main facades to be used for PV systems
- Suitable roof area maximization:
  - » Through overhangs and elevated PV systems.
  - » Minimized shading from buildings, elevator shafts and other structures.
  - » Integrated PV in unshaded façades with large, contiguous surfaces.

MULTI-ACTOR ALIGMENT TOWARDS SUSTAINABLE ENERGY IMPLEMENTATION

Germany's transition to renewable energy has been driven by strong collaboration between government institutions, financial entities, and industry stakeholders. This multi-actor approach has ensured the successful implementation of sustainable energy strategies.

MINISTRY OF ENVIRONMENT, CLIMATE AND ENERGY ECONOMY – BADEN-WÜRTTEMBERG

Since 2022, solar installations are mandatory for:

- New buildings, renovations and parking lots with over 35 vehicles
- Residential buildings, where at least 60% of suitable roof areas must be covered with PV panels.

The combination of green roofs and PV systems are encouraged as both strategies are key to mitigate climate change in urban areas.

KFW DEVELOPMENT BANK – ENERGY EFFICIENCY STANDARDS

Financial incentives are offered, including low-interest loans, encourage developers to adopt energy-efficient designs.
KfW 40 and KfW 55 building standards promote low-energy construction:

- KfW 40: New buildings consume only 40% of a conventional building's energy.
- KfW 55: Renovated buildings consume 55% of a standard building's energy.

These standards have significantly reduced Germany's overall building energy demand and offer a model for other countries like Cambodia.

GERMAN SUSTAINABILITY BUILDING COUNCIL (DGNB) – CLIMATE-NEUTRAL ROADMAP

The Sustainable Building Criteria in its latest version V2023 require:

- Planners and developers to outline climate neutrality strategies for buildings by 2050.
- A focus on life-cycle carbon assessments and sustainable materials.

This is just and example of how through coordinated efforts, Germany has taken significat stepts towards the integration renewable energy and efficiency measures, providing a blueprint for global sustainability initiatives.

FROM REDUCTION OF CARBON-INTENSIVE MATERIAS TO LIFE-CYCLE ORIENTED REASONING

EVALUATION CRITERIA

LIFE CYCLE ORIENTED DESIGN

INTEGRATE

LOW CARBON MATERIALS

Using low-carbon materials offers a significant opportunity to reduce building emissions throughout their lifecycle.

GREEN CONCRETE
It is produced when the fine or coarse aggregate in conventional concrete is replaced with alternatives, resulting in a robust structure with lower energy requirement, GHG emission or waste generation in production. The aggregates should be materials with high silicate ash content like:

- Coal fly ash
- Rice husk ash
- Volcanic ash
- Ground granulated blast-furnace slag

Other alternatives are "waste materials". Using recycled aggregates could imply important emission savings if the aggregates source site is close to the building site. Some examples could be:

- Demolition sites
- Stone crushing waste

RENEWABLE MATERIALS

Renewable materials like wood and bamboo are locally sourced and widely used in Asia for walls, flooring and furniture. Unlike synthetic materials, they are non-toxic and do not emit harmful chemicals. At the end of their lifespan, they can be reused or safely returned to the environment as biodegradable materials that enrich the soil.

- **Timber:** Sustainably harvested timber is a low-carbon building material suitable for structure and cladding. Locally sourced wood reduces import costs and enables easy construction. Timber buildings, being lighter than concrete structures, require simpler foundations and tools.
- **Bamboo:** Known for its high tensile and compressive strength, bamboo is durable, fire-resistant and withstands strong winds and moderate earthquakes. It offers a cost-effective construction solution, with a 35 sq.m. home costing around USD 5.000 (INBAR, 2016). Early research suggests bamboo as a viable replacement for steel reinforcements in concrete.

EARTH-BASED CONSTRUCTION

Earth-based materials regulate extreme temperatures, enhancing occupant comfort without air conditioning. Common techniques include mud, adobe, or earthen blocks. In areas with low natural clay content, additives improve workability and durability.

- **Interlocking Hollow Compressed Stabilized Earth Brick:** A successful method where lime replaces cement as a stabilizer, providing comparable strength to concrete blocks. Stabilized earth blocks also perform well in humid environments and are ideal for low-carbon, on-site production, minimizing transport costs.

REUSED/RECYCLED MATERIALS

Utilizing reclaimed materials reduces waste and minimizes raw material demand.

- **Wood & Metal:** Wooden elements like doors and window frames can be reused. Metal components can be repurposed, reworked, or smelted for new applications.
- **Concrete & Stone Waste:** Crushed concrete serves as coarse aggregate in fresh concrete or asphalt. Broken bricks, concrete blocks, and ceramic tiles are viable for backfilling and compacting. Industrial waste like fly ash can partially replace sand, stone, and cement in concrete mixes.
- **Structural Elements:** When reusing materials for beams or columns, professional assessment is essential to ensure structural integrity.

Figure 9. Building in Phnom Penh with an organic bamboo facade as a local and renewable material to build
Source: Antoine Raab

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EVALUATION CRITERIA

LIFE CYCLE ORIENTED DESIGN

APPLY

LIFE CYCLE REASONING IN BUILDING AND NEIGHBOURHOOD DESIGN

Life cycle assessment (LCA) of a building calculates how it will affect the environment across its entire lifetime, from the raw material extraction and construction processes to operational use, and finally demolition and recycling or disposal. LCA helps building owners, designers, developers and investors and government officials to make informed decisions in building design, operations and construction and setting standards, and to drive innovation to improve construction product quality and process efficiency.

Design of buildings and neighbourhoods means considering the environmental, economic, and social impacts of each phase - design, construction, use, and end-of-life.

MINIMISE RESOURCE CONSUMPTION

Cambodia is in the early stages of transitioning into low carbon, sustainable buildings. Currently, there is no mandatory national building energy efficiency code or green building certification system. While efforts are underway to raise awareness and enhance capacity for sustainable building design and construction practices.

REDUCE CARBON EMISSIONS

Reducing significant stress on natural resources and the environment

1. **Design Phase:**
   - Climate sensitive architecture
   - Material selection: locally sourced, renewable or recycled materials
   - Energy efficiency and integration of renewable.

The use of low carbon and renewable materials, locally sourced and produced, for building construction (see Topic 2.1) while leveraging passive design will reduce emissions throughout the whole life of the building from construction, operations to demolition and disposal. Passive building design focuses on harnessing natural resources such as sunlight and wind- incorporating micro-climatic conditions to create a comfortable indoor temperature and minimize energy consumption. It uses building orientation, materials and layout to control solar gain, natural ventilation and thermal mass, reducing the need for mechanical heating and cooling. There are passive cooling techniques such as insulation, reflective surfaces, shading, natural ventilation, shading, solar heat gain coefficient and window-to-wall ratio that can significantly lower the cooling load of a building and reduce annual electricity consumption by an average of 35% . High performance building envelopes with insulated roofs, walls and window glazing offer the greatest benefits in terms of maintaining comfortable indoor temperatures and reducing cooling loads.

Strategic building orientation and window placement (e.g., in a tropical climate, buildings should avoid having large window openings on the east and west sides) is important for indoor air quality, natural lighting and natural ventilation to reduce dependence on mechanical cooling.

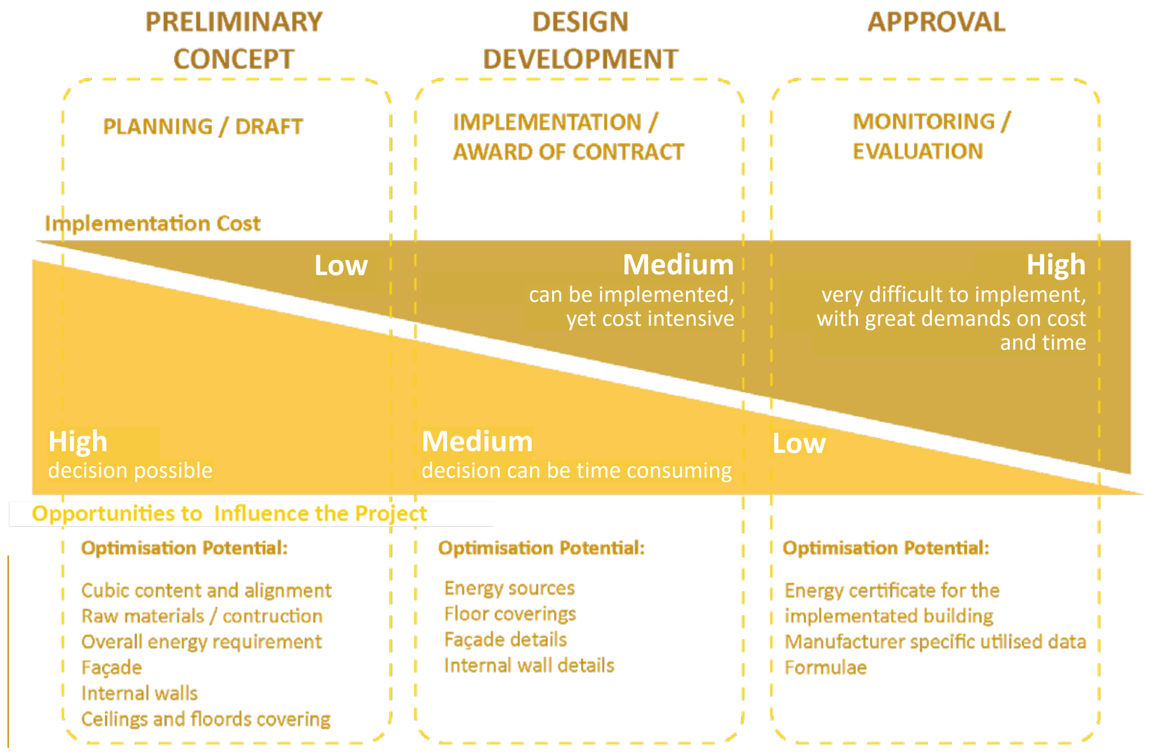

Figure 10. Optimisationpotential, opportunities for influence and expenditure incurred by changes in the planning and manufacturing process. Source: DGNB (2018)

2. **Construction Phase:**
   - Efficient resource management: Modular construction
   - Waste minimisation: Recycling construction waste

Southeast Asia is experiencing a surge in modular construction, transforming the way buildings are designed and developed. The Asia-Pacific modular construction market was valued at USD 38.72 billion in 2023 and is expected to reach USD 58.07 billion by 2029, growing at a CAGR of 6.83%. This growth reflects the increasing demand for efficient and scalable construction methods. Modular construction, also known as prefabricated construction, involves manufacturing building components in a location separate from their final construction site and then transporting and installing them at the final location. These components or modules are designed and manufactured under controlled conditions, ensuring high quality and precision in construction.

Key benefits of modular construction are optimized construction times and 30-50% faster than conventional construction; cost savings by 20-30% making it an attractive option for developers, and sustainability and waste reduction as modular construction generates less waste, consumes fewer resources, and lower carbon emissions compared to traditional methods.

GUIDELINE 02.4

Life Cycle Assessment (LCA) in Planning Process

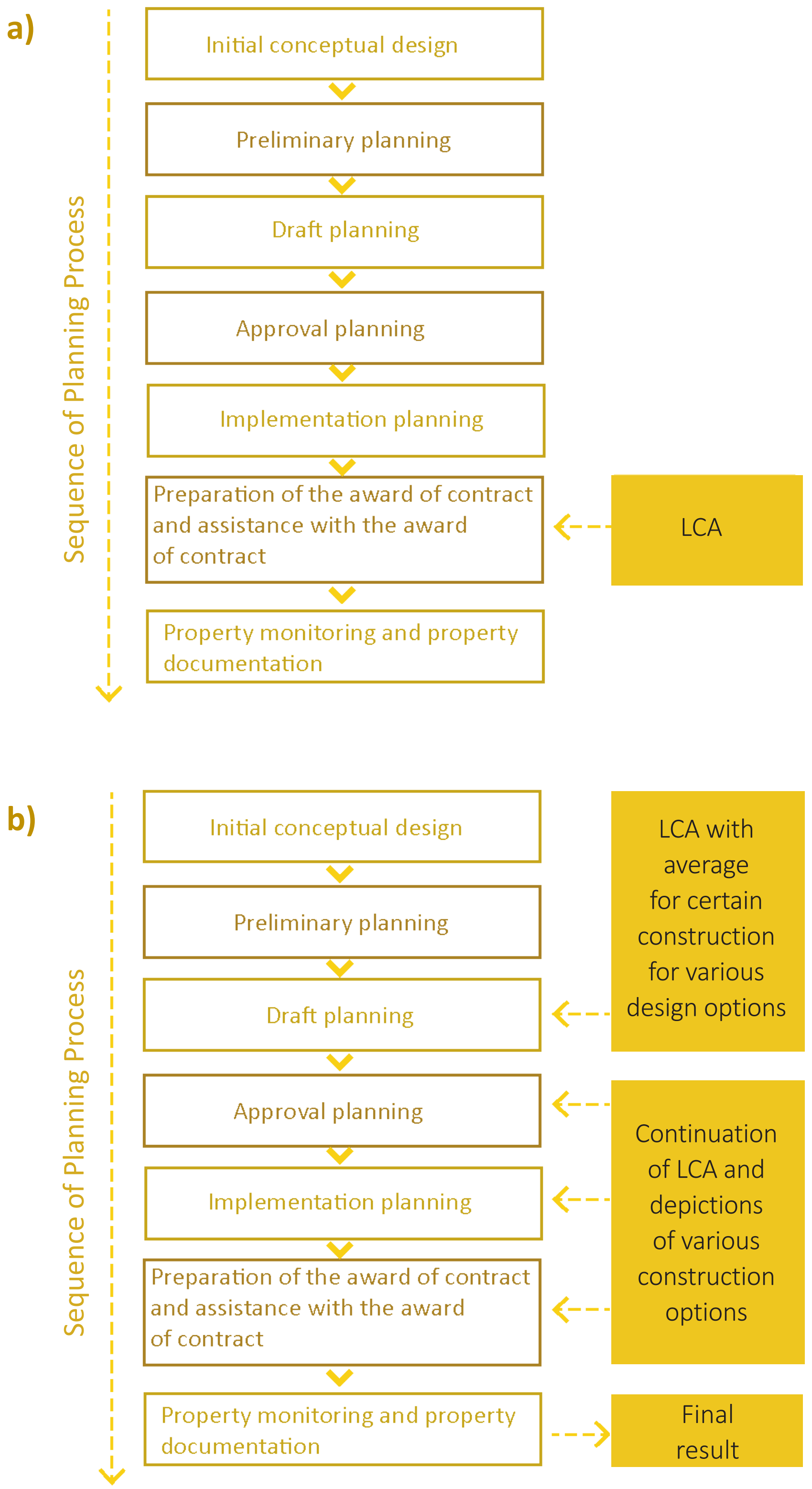

Figure 11.
a) Conventional application: Single implementation of the life cycle assessment at the end of the construction process as a prerequisite for certification.
b) Optimised application: Repeated implementation of the life cycle assessment at various points throughout the planning process.
Source: Fraunhofer Institute for Building Physics (IBP)

3. Use Phase:

- Energy Efficiency and Renewable Energy
- Maintenance and durability
- Versatility in Design

A building management system (BMS) is a useful tool for optimizing operational energy. BMS algorithms can simultaneously consider the external factors (climate), and internal factors (operations, occupancy, micro-climate, indoor air quality, thermal and visual comfort), and optimize energy and water consumption. Now, with artificial intelligence and machine learning algorithms, BMS can automatically reset itself to the best combination. BMS is useful as historical data and trends can easily be accessed for troubleshooting.

By integrating renewable energy sources like solar power, buildings can generate their own electricity or heat, thereby reducing reliance on the grid. This not only helps lower energy costs for building owners and occupants but also promotes energy independence and resilience in the case of power outages or disruptions. These include photovoltaic system and solar thermal system. A 100-liter capacity solar water heater can replace an electric water heater for residential use and save 1,500 units of electricity and can prevent the emissions of 1.5 tons of carbon dioxide per year.

4. End-of-Life Phase:

- Design for deconstruction
- Recycling and Urban Mining

Buildings are demolished at the end of their useful life. Careful dismantling of building components during demolitions such as doors, windows, structural elements, roofing components for potential reuse in another construction project or recycling them into a new product (see Topic 2.1) reduces carbon emissions associated with materials production as well as the material costs for builders. This also minimizes the amount of construction materials that may end up in landfills.

THE BUILDING EMISSION ASSESSMENT TOOL (BEAT)

The Asia Low Carbon Buildings Transition (ALCBT) Project develops the building emission assessment tool (BEAT) which provide a comprehensive framework for whole-building carbon assessment. The tool evaluates buildings as integrated systems taking into account embodied carbon and operational carbon. BEAT employs methodological robust and practical applicability for the building sector in Asia based on EN 15978 and adapted ISO 14067, incorporating regional material flow analysis, integrating building energy performance calculations, utilizing statistically significant regional building samples, and more importantly, establishing country-specific benchmarks by building typology.

BEAT uses data from various Environmental Product Declarations to provide a comprehensive analysis. Basic data input include year the building was completed as construction practices, material availability, and building codes change over time, all of which influences the type and quality of building components used and therefore is needed for proper LCA modelling; and climate zone which is a crucial detail that categorizes the building based on its climate. On embodied energy and carbon calculations, BEAT configure each structural and non-structural components that make up the building including roof, foundations, walls, columns, beams and window from the quantity and type of materials used for these building elements. The building life is set at 50 years by default but can be changed/manually inputted. The output includes primary energy demand (PENRT) and global warming potential (GWP) data. The operational energy demand which are the net amount of electricity consumed annually in kilowatt-hours per year, amount of natural gas consumed annually in cubic meters per year, and other types of energy consumption. These data are used to assess the operational impacts in conjunction with the embodied impacts, for a whole life cycle assessment of the building.

The development and application of BEAT is supported by the deep dive assessment of around 250 buildings in Phnom Penh in collaboration with the Ministry of Land Management, Urban Planning and Construction. BEAT was launched on 24 June 2025. Its features are carefully crafted to address the complex needs of various stakeholders in the construction industry, from architects and engineers to policymakers and financial institutions.

III WAY FORWARD

TO BE FURTHER DISCUSSED WITH LOCAL STAKEHOLDERS DURING B4P IMPLEMENTATION PHASE 2025-2027

PRACTICAL RECOMMENDATIONS FOR POLICYMAKERS AND PRACTITIONERS

REGULATORY FRAMEWORK

- Adopt Green Building Codes: Develop and enforce building codes that integrate energy efficiency and energy supply, water conservation and sustainable materials.
- Incentives for Green Practices: Provide tax breaks, subsidies or low-interest loans for buildings meeting sustainability certifications
- Mandatory Building Audits: Require large commercial buildings and developments to conduct energy efficiency audits.
- Establish Benchmarks: Develop metrics to track energy, water and material efficiency in buildings.

ENERGY EFFICIENCY & SUPPLY

- Encourage Renewable Energy Integration: Promote solar panels, rooftop photovoltaic systems and passive cooling designs for new and existing buildings.
- Energy-Efficient Equipment: Set minimum energy performance standards (MEPS) for HVAC systems, lighting, and appliances.
- Passive Design Strategies: Promote the use of shading, natural ventilation and high-performance building envelopes to reduce reliance on air conditioning.

SUSTAINABLE MATERIALS

- Promote Local and Eco-Friendly Materials: Use bamboo, recycled bricks, and locally sourced materials to reduce carbon footprints and construction costs.
- Reduce Concrete Usage: Encourage alternatives like rammed earth, stabilized soil blocks and light weight materials.
- Construction Waste Management: Mandate recycling and reuse of construction and demolition waste.

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AUTHORS

Taing Kimnenh, LUCID, Faculty of Applied Science, University of Liege and Research and Innovation Center, Institut of Technology of Cambodia
Julie Robles, Regional Manager, ALCBT, Global Green Growth Institute
Nuria Roig, Eble Messerschmidt Partner

REVIEWERS

Michael Waibel, Department of Geography, University of Hildesheim
Rolf Messerschmidt, Eble Messerschmidt Partner

CONCEPT & GRAPHIC DESIGN

EBLE MESSERSCHMIDT PARTNER
Architekten und Stadtplaner PartGmbB

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT
Life Cycle Assessment for Transitioning to a Low-Carbon Economy

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CONTACT

Dr. Taing Kimnenh
E-Mail: kimnenh.taing@doct.uliege.be

Ms. Julie Robles
E-Mail: julie.robles@gggi.org
Web: https://alcbt.gggi.org/

HTTPS://BUILD4PEOPLE.ORG/

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