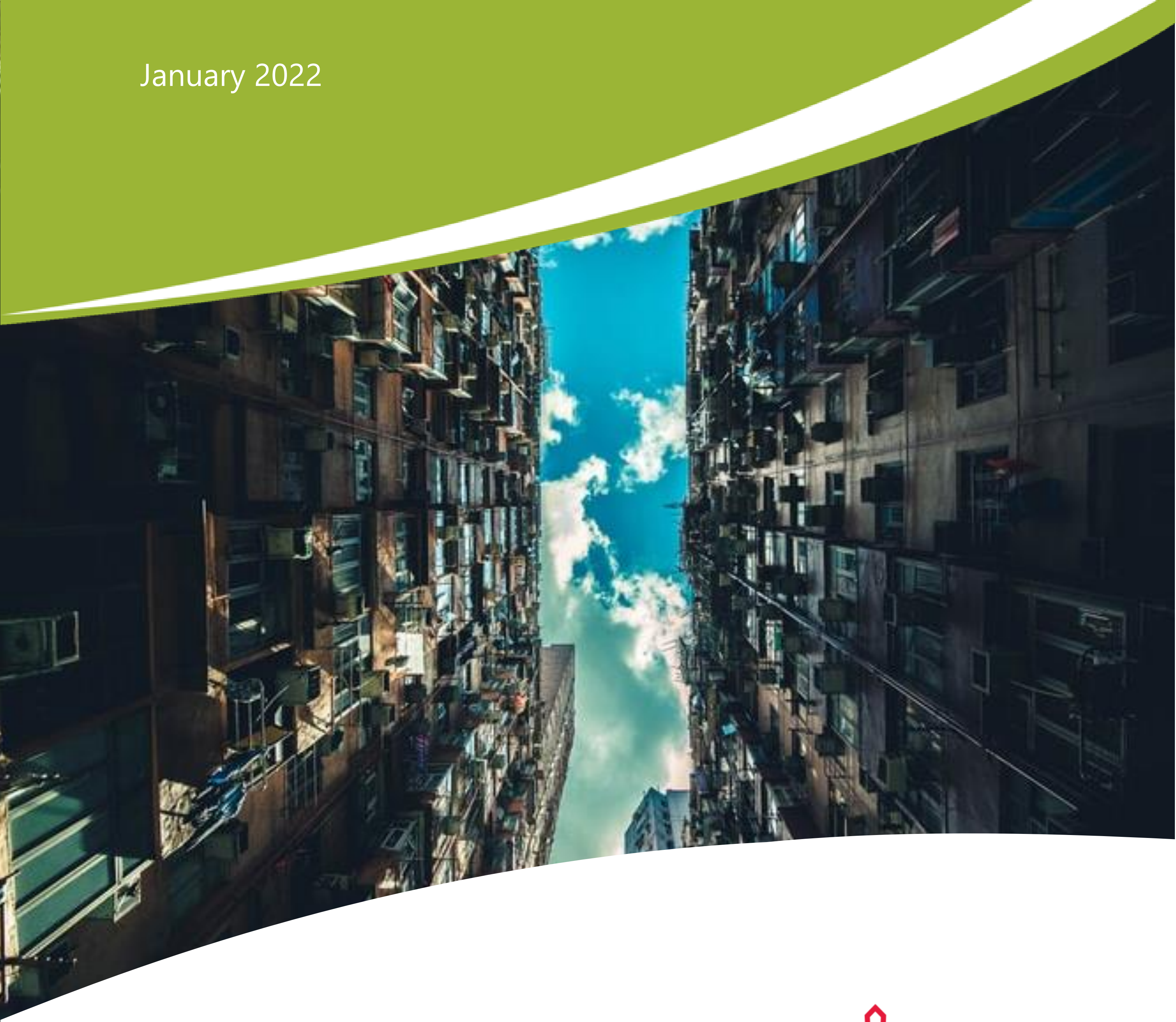
PRIORITISING CLIMATE ACTION ON BUILDINGS IN HOT CLIMATES

HOW MODELLING CAN IDENTIFY THE MOST EFFECTIVE MITIGATION MEASURES

January 2022



EEDUS
Energy Efficiency for Sustainable Urban Development

PEEB
PROGRAMME FOR ENERGY EFFICIENCY IN BUILDINGS

PRIORITISING CLIMATE ACTION ON BUILDINGS: RAPID ASSESSMENTS TO GUIDE DECISION-MAKERS

Climate action on buildings is urgent. Buildings and construction accounted for 37% of global energy-related carbon dioxide (CO_2) emissions in 2020[1]. Energy demand and emissions from buildings are expected to grow strongly, mainly in countries in hot climates, where population growth and increasing prosperity leads to higher energy needs, especially for space cooling.

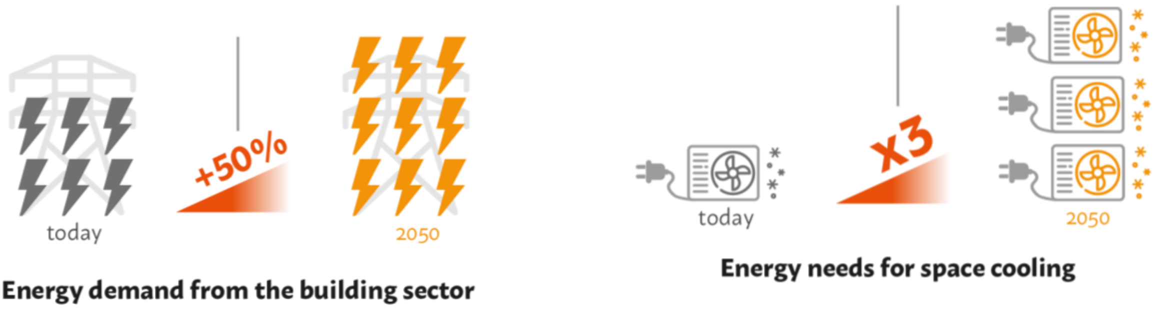


Figure 1: Projected growth of global energy demand and cooling needs by 2050 (Graph by PEEB based on: IEA World Energy Statistics and Balances. 2016)

Policy makers often lack information to **identify the largest energy saving and CO_2 reduction potential in the building sector to design effective policies**. How much CO_2 is caused by the building sector? Which building types are the biggest emitters? How do energy consumption and the effect of energy saving measures differ between climate zones? What is the impact of measures to improve the performance of buildings, new construction, or retrofits, and how much can be saved?

Modelling building energy demand, taking into account different building types and climate zones, as well as different kinds of energy efficiency measures - from retrofits to ambitious zero-carbon buildings - **shows where the greatest CO_2 reductions can be achieved** to target policy measures to where they are most effective.

This paper presents a **rapid assessment tool for building emission** that allows to project building sector emissions, and the effect of different decarbonisation measures, in hot climates. It also presents the key findings of the modelling conducted with this tool. The tool has been developed by the global *Programme for Energy Efficiency in Buildings (PEEB)* and the *Project for Energy Efficiency for Sustainable Urban Development (EEDUS)* in Brazil. For details of the study and methodology, consult the technical background paper "***Building sector emissions in hot climate zones***"[2].

[1] Global Alliance for Buildings and Construction (GlobalABC). 2020 Global Status Report. https://globalabc.org/sites/default/files/inline-files/2020%20Buildings%20GSR_FULL%20REPORT.pdf

[2] Programme for Energy Efficiency in buildings (PEEB) (2021), Building sector emissions in hot climate zones, https://www.peeb.build/imglib/downloads/PEEB_Decarbonisation_Hot_Climates.pdf

Tool: Rapid assessment for building sector decarbonisation

To identify the largest CO_2 reduction potential in the building sector, this tool was developed to make a rapid assessment of energy demand and CO_2 emissions. The tool was developed based on in-depth **energy demand modeling with the *EnergyPlus*[3] thermal dynamic simulation application**[4]. The modelling results form the data basis for the **rapid building emission assessment tool** for the main building types in hot climate zones. The tool simulates:

- Energy demand and CO_2 emissions for different building types in five major hot climates
- Projections for energy demand and CO_2 emissions by building type per year and up to 30 years under a "business as usual" scenario
- Energy savings and CO_2 mitigation potential of Energy Efficiency (EE) retrofitting or new construction (basic or high ambition) for different building types and different climate zones

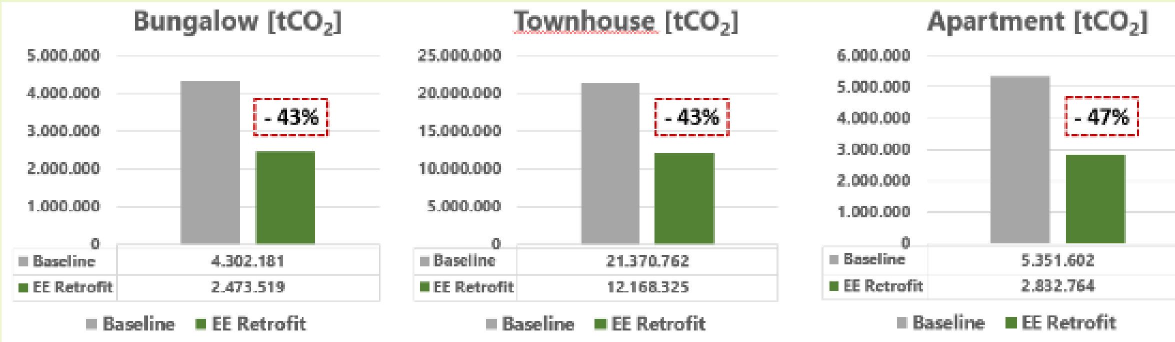


Figure 2: example of modelling results for a retrofit scenario

The **baseline scenario** assumes typical building structures, construction methods and building components, as well as standard building materials, technologies, equipment, and appliances which are most commonly found in these main climate zones. In comparison to the baseline scenario, the tool can generate three different energy efficiency improvement scenarios with the following features:

- The **EE retrofit scenario** (scenario 1) focuses on the renovation of existing buildings with a low energy performance. In this scenario, technically feasible and economically viable architectural passive building design measures are considered such as moderate improvements of the building shell, windows, external shading as well as moderate improvement to the building energy system such as improved split unit, provision of ceiling fan and night cooling (cf. table 2).
- The **basic EE new build scenario** (scenario 2) entails improved architectural passive building design measures and improved energy systems measures like split units, ceiling fan, night cooling. These standards a slightly higher than in the EE retrofit scenario (cf. table 2).

[3] *EnergyPlus* is a dynamic building energy simulation program (with hourly calculation) used by engineers, architects and researchers to model both energy consumption (for e.g. heating, cooling, ventilation, lighting and plug and process loads) and water consumption in buildings. https://re.jrc.ec.europa.eu/pvg_tools/en/#TMY and https://ec.europa.eu/jrc/en/PVGIS/tools/tmy

[4] Programme for Energy Efficiency in buildings (PEEB) (2021), Building sector emissions in hot climate zones, https://www.peeb.build/imglib/downloads/PEEB_Decarbonisation_Hot_Climates.pdf

- The **ambitious EE new build scenario** (scenario 3) applies almost the same architectural passive building design measures as scenario 2. It adds significant improvements for the energy systems such as central compression system and controlled ventilation with heat recovery and the integration of renewable energies. In this scenario, both solar thermal and photovoltaic (PV) systems are included (cf. table 2). This scenario is a **nearly zero carbon building**. Its implementation is considered challenging but feasible within the selected climate zones.

Data requirements

The tool contains preset data about the energy demand for a **baseline scenario** and **three energy efficiency improvement scenarios**, based on modeling results for the **five most common building types** (bungalow, town house, apartment building, hotel, office)[5]. Climate data for the **five most common hot climate zones** is included, and the tool takes into account the impact of rising average temperatures to 2050 due to global climate change.

A rapid assessment requires the following data input (see graph):

- Building type: share of building types in percent
- Area: existing building stock or annual new construction for up to 30 years.
- Climate zones: estimate of distribution of building types over climate zones
- CO_2 Emission factor: country-specific CO_2 emission factor.

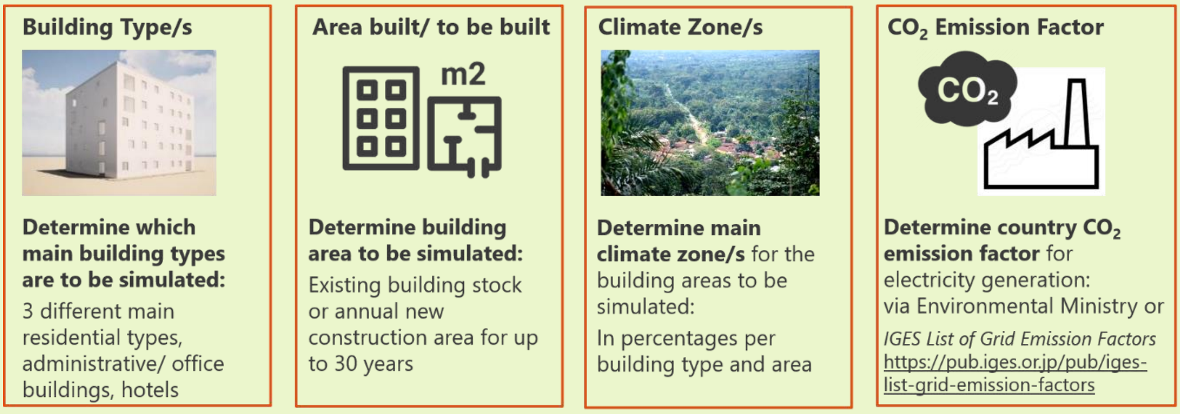


Figure 3: Data inputs required for rapid assessment tool

[5] Five types of buildings preset in the tool:
- **Bungalow**: Residential single-family house, 1 storey, housing units with 60 m^2 area
- **Town House**: Residential multi-family row house, 2 storeys, units with 80 m^2 area
- **Apartment building**: Residential multi-family apartment building, units between 40m^2 an 80m^2,
- **Hotel**: Multi-storey hotel building or student dormitory, average single rooms 22 m^2
- **Office**: Multi-storey office or administrative building, average floor area of 450 m^2.

KEY FINDINGS: PRIORITIES FOR BUILDING SECTOR DECARBONISATION

Modelling building sector energy use and CO_2 emissions with this tool allows to identify the most important and effective priority targets for climate action. The following section presents the results of the energy demand modelling that simulated the implementation of all three energy efficiency scenarios for five main buildings types, assuming an even distribution of buildings across the five climate zones[6].

Summary

- A **rapid building energy demand assessment** is a **cost-effective and fast way to identify the largest energy saving and CO_2 reduction potential** in the building sector to design effective policies.
- The CO_2 reduction potential in a country context depends on both, the **building typologies and how widespread** that building type is or will be.
- **Bungalows, hotels and townhouses** are often the most inefficient buildings with the largest energy savings potential per area.
- In absolute terms, the **residential building subsector** usually offers the highest energy savings potentials due to its largest share of buildings – with the bungalow type being the most inefficient, followed by the townhouse and apartment building as the most efficient residential type.
- Energy efficiency measures encompass improved building design, energy systems and renewable energy.
    - For building design, **improved windows** and **external solar shading** are often the most effective measures
    - For energy systems, **improved split units** (or their replacement by a central compression system) in connection with **night cooling** has the largest effect
    - For renewable energy, **domestic hot water by solar thermal** residential buildings and hotels has the biggest effect, as well as the use of **photovoltaics** in connection with **heat pumps**
- Climate zones matter a lot. **Hot arid and tropical wet climates** generally have the highest cooling demand, and buildings in these climate zones have the highest energy savings and CO2 reduction potential.
- Many of these measures, **from medium ambitious to zero-carbon buildings, are cost-effective**. Improved windows and heat pumps cause medium costs that are quickly amortised during operation, while measures like reflective coating, night cooling and solar thermal are cost neutral.

[6]This section summarizes the results of modelling done for PEEB and EEDUS: Doris Österreicher and Axel Seerig (2020), Building Climate Studies, Report on Scenario Simulations.
For more details consult: PEEB (2021), Building sector emissions in hot climate zones, https://www.peeb.build/imglib/downloads/PEEB_Decarbonisation_Hot_Climates.pdf

1. SAVINGS POTENTIAL: WHICH BUILDINGS ARE THE MOST INEFFICIENT?

The tool identifies the savings potential of 5 different types of buildings (Figure 3). For ease of using the tool, the design of the building type has been standardized.

Figure 4: Main building types

Bungalows and hotels, followed by the **townhouse,** are often the most inefficient buildings, and have the highest energy and emission per area. Bungalows and townhouses have a high surface-to-volume ratio which results in higher energy losses through the building envelope that increases energy needs for space cooling. In addition, they are generally not climate-friendly due to their high land consumption per user and the expansive decentralized utility supply infrastructures required. Hotels have a high energy demand for cooling and hot water.

In comparison, the energy-saving and mitigation potentials of **apartments and offices** are lower, as they require less energy for space cooling due to their higher compactness. Though offices have high internal loads (equipment and lighting), domestic hot water plays only a minor role.

Building type	Energy and CO_2 use and savings potentials
Bungalow	**High due to high surface-to-volume ratio**
Hotel	**High due to high cooling and hot water demand**
Townhouse	**Medium**
Apartment building	Low
Office	Low

Table 1: Energy-saving potential of building types

2. WHAT ARE THE MOST EFFECTIVE BUILDING MEASURES?

The measures that were implemented to minimise greenhouse gas emissions can be catagorized into: **building design**, **energy systems** and **renewable energy**. A combination of measures from these three categories was used for each scenario (see table 2), ranging from the most basic to the most complex and ambitious scenario.

These measures should not be seen as stand-alone measures but build on each other (cf. figure 5). Better building designs and passive measures are the basis, as they can reduce or even avoid the energy demand for space cooling. This includes improved design of the building shell, windows, external shading and reflective coating on roofs and facades. Better building designs are highly cost-efficient. For more details, check the publication "Better design for cool buildings"[7].

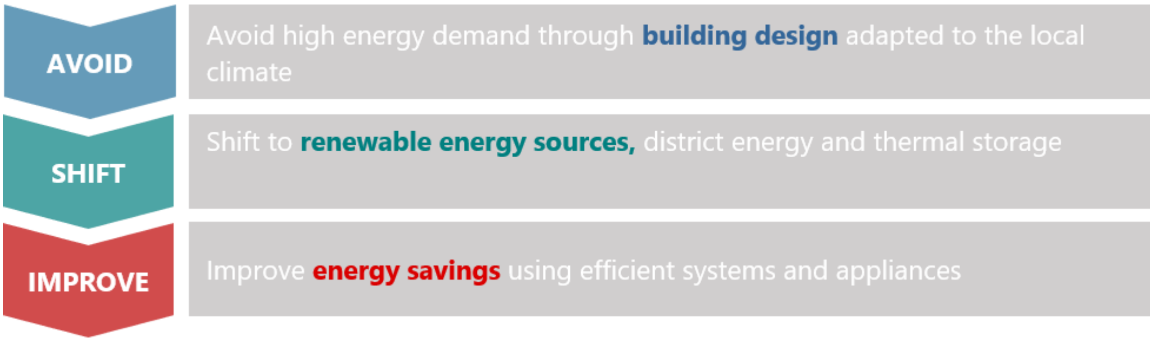


Figure 5: Integrated building design should encompass improved building design, better energy sources and efficient appliances. Source: PEEB (2020), Better design for cool buildings

In the following, for each set of measures, the most effective measures in terms of energy and CO2 savings were identified.

Building design measures

Amongst the building design measures, the greatest impact can be achieved through **improved windows**, with high-performance glazing showing good effects as a first step. The use of **external solar shading** is of similar importance in all regions. Both measures reduce cooling loads without any operating energy.

In regions with high sun elevation angles (in all climate zones except the mediterranean climate), a fixed external sunshade or manually controlled shading is sufficient. In regions with a mediterranean climate with lower sun elevation angles, a flexible external sunshade is required. For good performance of this type of shading, automated control is recommended.

Building energy system

When comparing the different options for building energy systems, the greatest effect can be achieved through **improved split units** (or their replacement by a central compression system) in connection with **night cooling** that reduces the cooling load in the building. The use of ceiling fans has an additional small impact on thermal comfort.

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[7] Programme for Energy Efficiency in buildings (PEEB) (2020), Better design for cool buildings. https://www.peeb.build/imglib/downloads/PEEB_Cool%20Buildings_Working%20Paper_August%202020.pdf

Most effective renewables

The renewable energy system measures integrate sustainable energy sources into the building to meet all or part of its electricity and heating energy demand. These measures include water heating through solar thermal, photovoltaic, solar heating and cooling, and the use of heat pumps. The use of **domestic hot water by solar thermal** has the greatest effect, especially in buildings where domestic hot water plays an important role, such as residential buildings and hotels. Another important measure is the use of **photovoltaics** for the improved scenarios in connection with **heat pumps**.

	Building measures	Baseline	Retrofit (S1)	Basic new build (S2)	Ambitious new build-near zero carbon (S3)
Building design	Building Shell	Standard	Improved	High performance	High performance
	Windows	Standard	Improved	High performance	High performance
	External Shading	No	Fixed / Flexible - manual	Flexible - manual	Flexible - automatic
	Reflective coatings	No	Light coloured	Light coloured	Light coloured
Energy systems	Split unit	Decentralized	Improved decentralized	Improved decentralized	Central compression system
	Ceiling fan		Yes	Yes	
	Night cooling		Natural	Natural / mechanical	Controlled ventilation with heat recovery
Renewables	Domestic hot water by solar thermal		Yes	Yes	Yes
	Photovoltaics				Yes
	Solar heating				Yes
	Solar cooling				Yes
	Heat pump (heating & cooling)				Yes

Table 2: Energy efficiency measures incorporated in the baseline and three scenarios.

Cost efficiency: Of the above-mentioned measures, improved windows and heat pumps cause medium costs, which, however, are quickly amortised during the building's operation. External shading improved decentralised split units and photovoltaics represent low additional investment costs, while reflective coating, night cooling and solar thermal are considered cost neutral. However, costs can vary greatly due to local condition and economy.

3. CLIMATE ZONES MATTER (A LOT)

Figure 6: Main hot climate zones worldwide and representative cities (Elaboration by PEEB)

It is important to compare different climate zones to understand the impact of climate policies. Hot arid and tropical wet climates generally have the highest cooling demand that results in higher energy demand and resulting CO_2 emissions. Buildings in these climate zones therefore have the *highest energy savings and CO2 reduction potentials*[8] compared to other climate zones.

Climate zone	Energy demand	CO_2 reduction potential
Hot arid climate (semi-arid)	**Very high cooling demand**	**Very high**
Tropical wet climate (rainforest)	**Very high cooling demand**	**Very high**
Tropical wet and dry climate (savannah)	Medium cooling demand	Medium
Humid subtropical climate	Low cooling demand	Low
Mediterranean climate (hot summer)	Low cooling demand	Low

Table 3: CO_2 reduction potential of hot climate zones

4. ADAPTATION: RISING TEMPERATURES INCREASE NEED FOR COOLING

Due to **global warming** with increasing average temperatures, the cooling demand for all building types in all hot climates will generally increase. The building energy modeling shows that therefore the **highest increase** in energy demand and CO_2 emissions will occur in the **hottest climates** if no energy efficiency measures are implemented.

In contrast, in **subtropical and mediterranean climates**, the decrease in **heating demand** due to global warming will be **negligible**.

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[8] Programme for Energy Efficiency in buildings (PEEB), Energy Efficient Building Design, https://www.peeb.build/imglib/downloads/PEEB_Overview%20Building%20Designs%20and%20Climate%20Zones-Master-25.03.2020.pdf

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