Climate change, thermal comfort, and energy efficiency: Meeting the challenges of cities in the 21st century

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Direct observations made on and above Earth’s surface show the planet’s climate is significantly changing.

Human activities are the primary driver of those changes.

Scientific evidence for warming of the climate system is unequivocal.

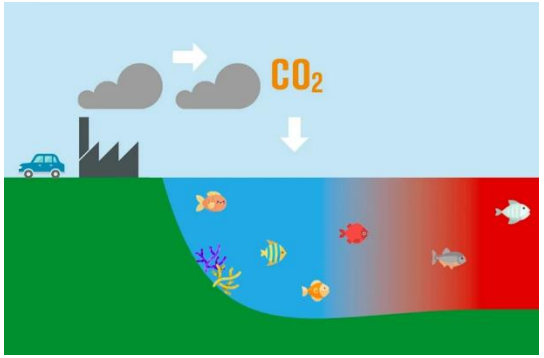
- Intergovernmental Panel on Climate Change

Rising temperatures

Decreased snow cover

Ocean warming

Extreme weather events



Ocean acidification

Rising sea levels

MATT SIMON SCIENCE JAN 7, 2021 7:00 AM

Climate Change Is Turning Cities Into Ovens

A new model estimates that by 2100, cities across the world could warm as much as 4.4 degrees Celsius. It's a deadly consequence of the heat-island effect.

Wired (2021)

Cities are heating up. Urban planners should prepare, UArizona researcher says

As heat waves blaze across the United States, a University of Arizona researcher says city planners should take the lead in managing and mitigating extreme heat.

By Kyle Mittan, University Communications

Mittan (2022)

Cities are heating up. How can we keep them cool?

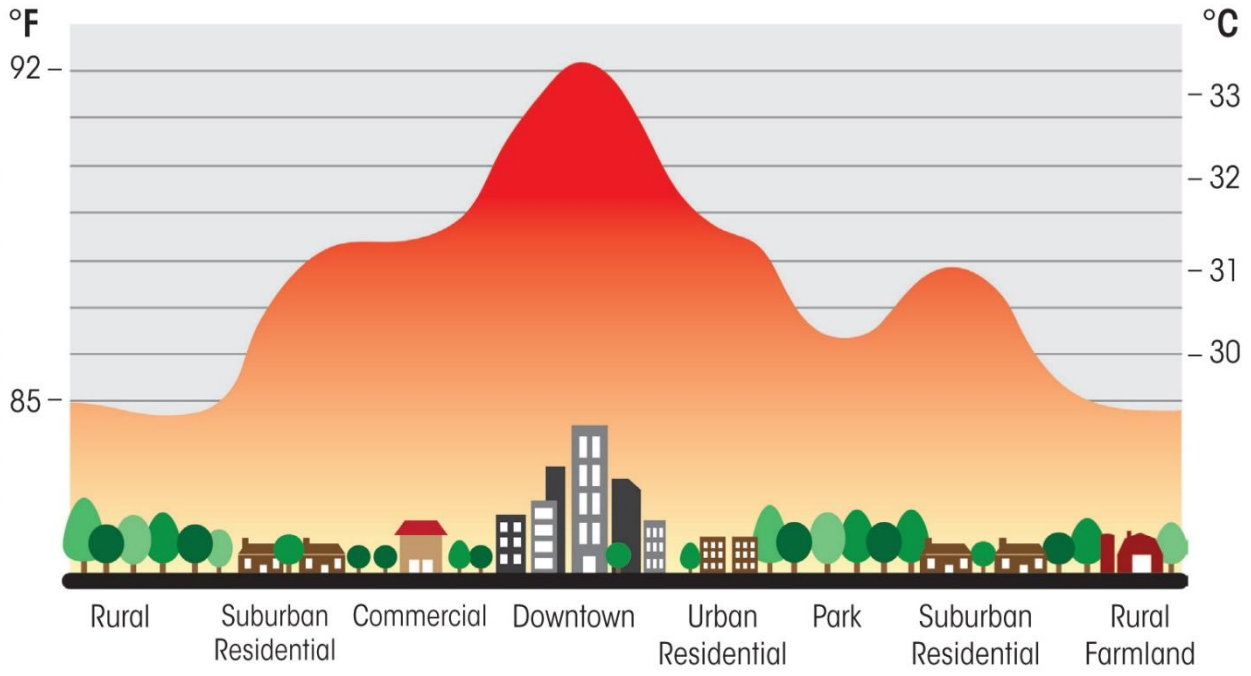
By 2050, Berlin could be as warm as Canberra in Australia. With cities around the world grappling over solutions to rising temperatures, Germany's sunniest city is wasting no time to act.

Schauenberg (2019)

Why Are

Cities Getting Hotter?

This rising heat index occurs as a result of **urban heat island (UHI),** a phenomenon in which a metropolitan area has a higher temperature than the surrounding less developed rural areas.



Babu (2017)

Urban Heat Island (UHI)

The **concrete buildings, pavements, and other surfaces** in cities absorb the midday heat, and release it slowly into the atmosphere.

In addition, **air conditioners, cars, and other machines**, pump hot air into the street making it near impossible for heat to escape. This effect increases the temperatures within cities, known as the urban heat island effect.

Urban Heat Island (UHI)

Between 2000 and 2016 the number of people exposed to heat waves rose by a whopping **125 million** people, claiming more than **166,000 lives** in the past three decades (WHO).

This number is only going to increase with time, as the proportion of **people living in urban** areas is expected to increase to **70% by 2050**.

What can we do?

- **Redesign the cities:**
  - Well spaced buildings
  - Grassy areas/ surfaces around the buildings

- **Roof Top Gardens**

- **Using reflecting surfaces on roofs**
  - Paints
  - Light Colours
  - Mirrors
  - Solar PV

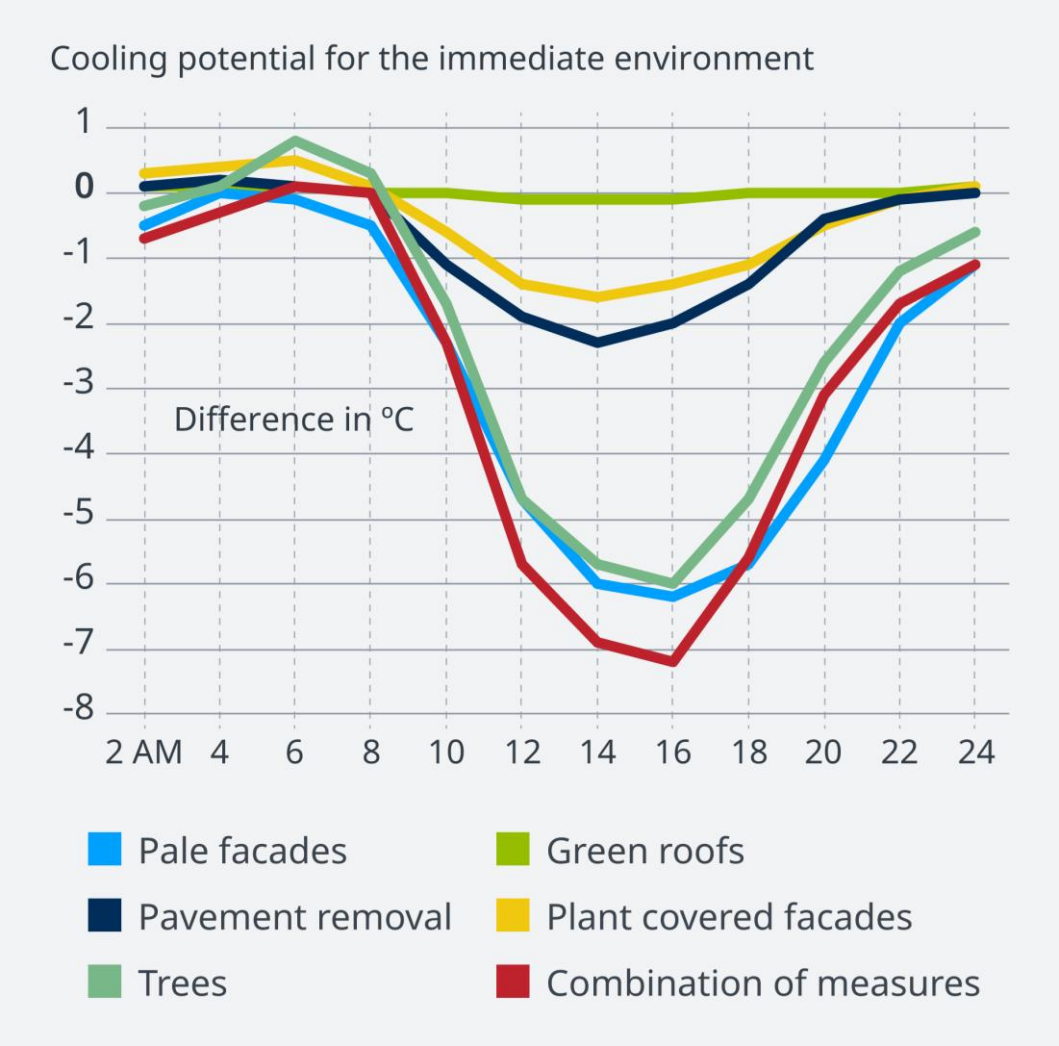
Resilient design: Master plan the NeoCity mixed-use innovation district in Central Florida prepared by Perkins and Will. [Photo: Perkins and Will]

Singapore has so far added plants to **100 hectares of building facades** in the city

A special white paint that reflects **80%** of sunlight (New York)

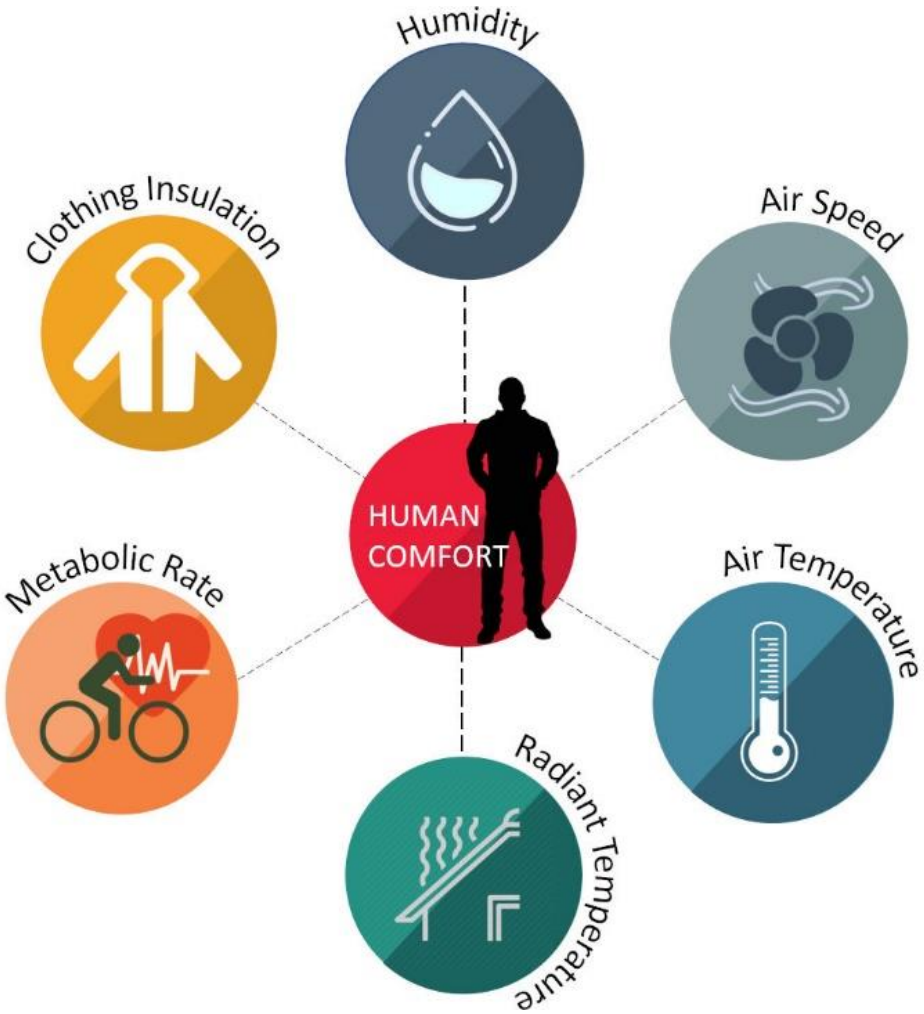
Bosco Verticale in Milan, Italy. [Design by Arup]

It contains more than 900 trees on 8900 sq.m. of terraces



Department of Urban Development and Housing, Berlin

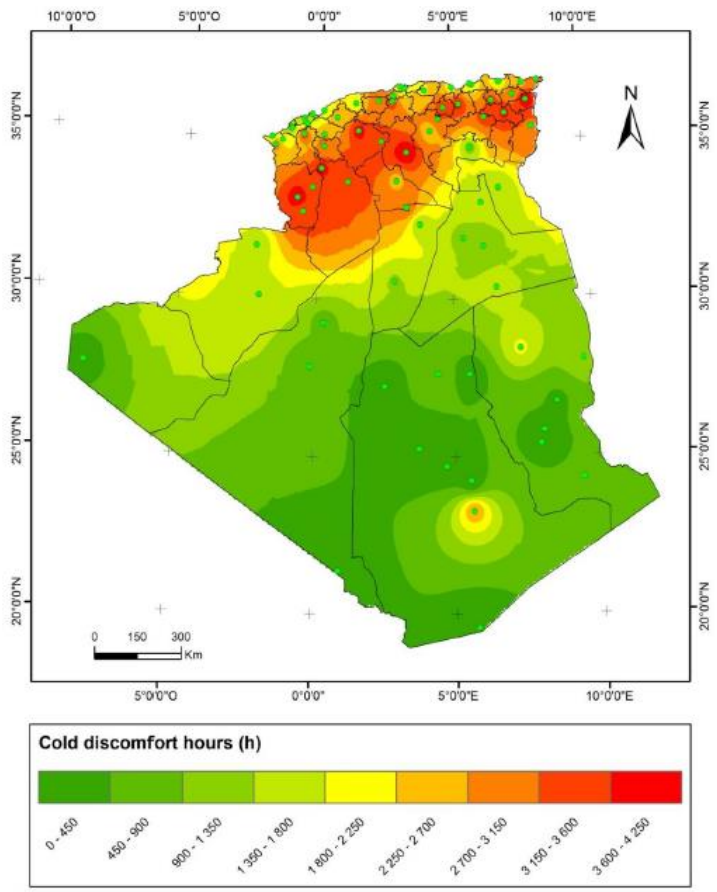
Thermal Comfort



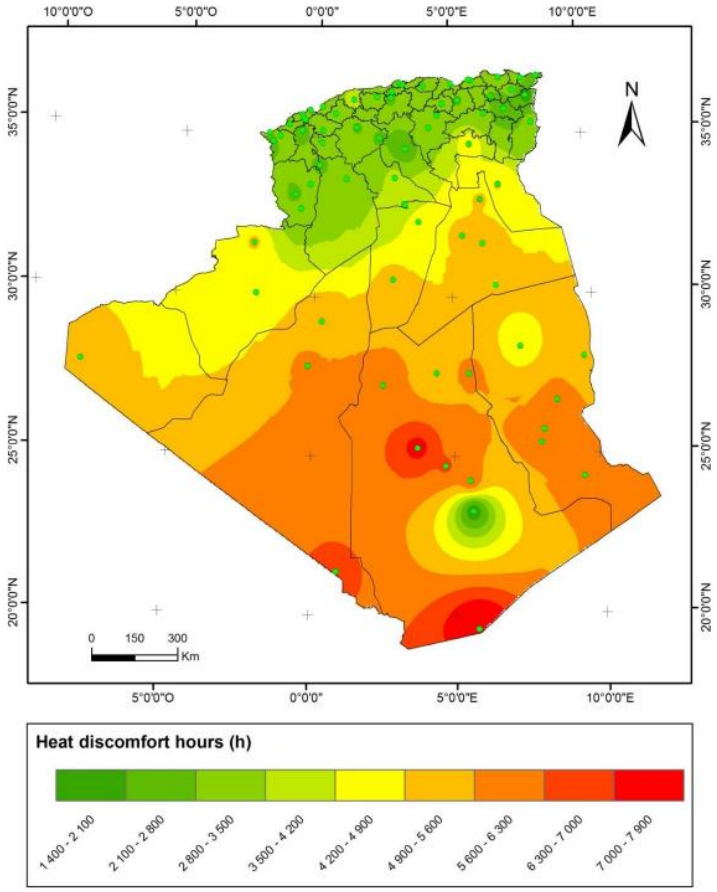
Factors that influence thermal comfort

Thermal Comfort

Spatial Distribution Maps for Energy Demand and Thermal Comfort Estimation in Algeria



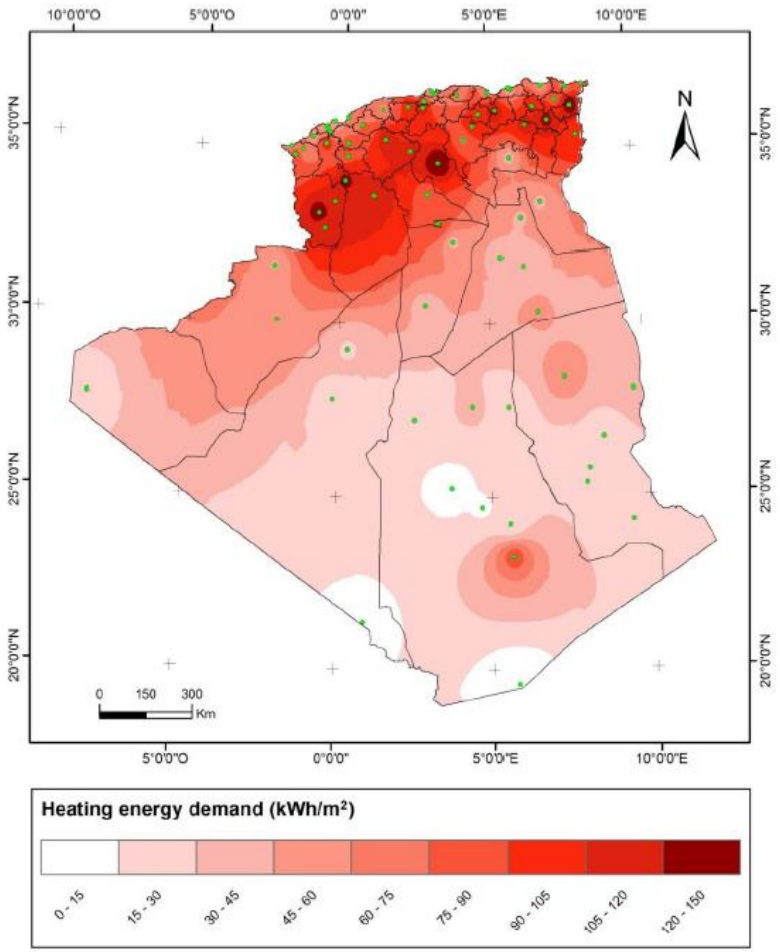
Cold Discomfort hours



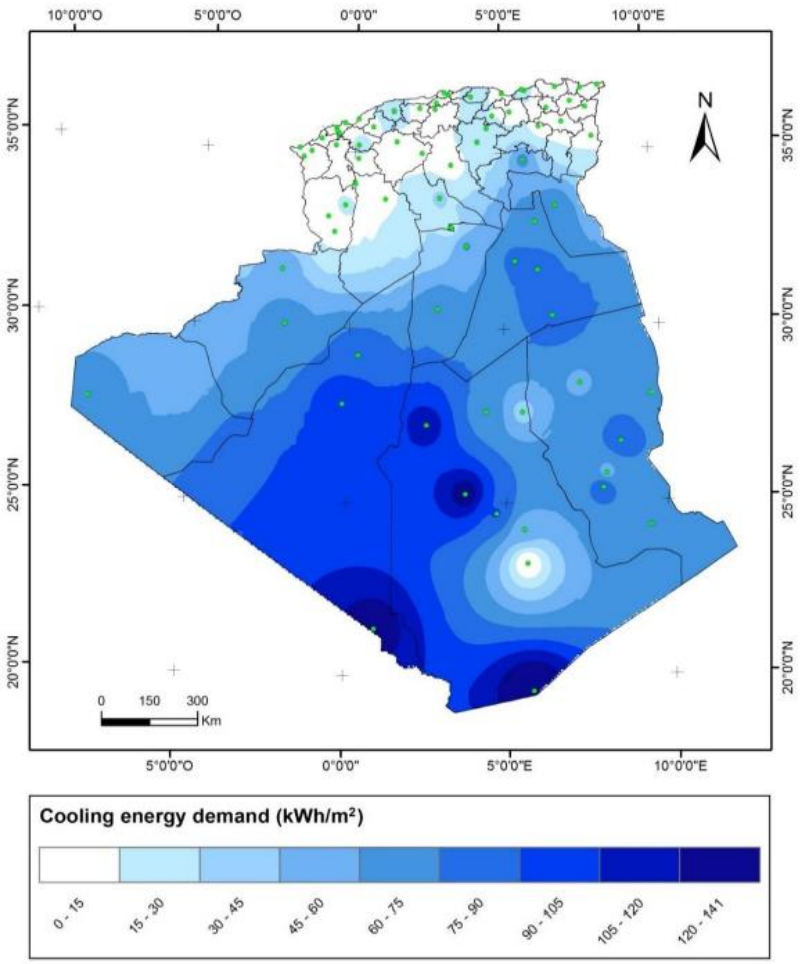
Hot Discomfort hours

Semahi et al. (2020)

Thermal Comfort



Heating energy demand



Cooling energy demand

Semahi et al. (2020)

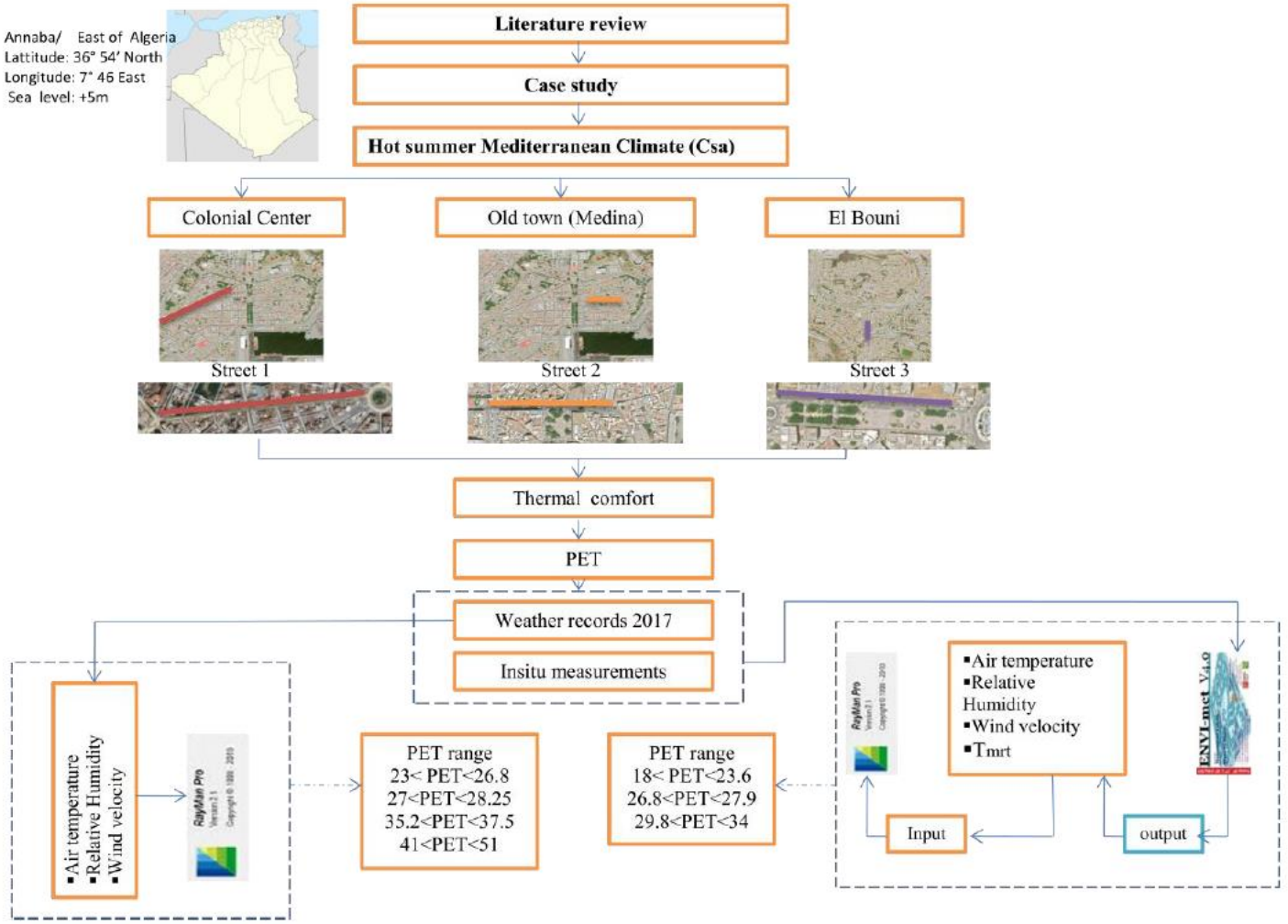
Thermal Comfort

Human Outdoor Thermal Comfort in a Palm Grove during the Date Palm Phenological Cycle

Matallah et al. (2022)

Thermal Comfort

How Tmrt affect the PET assessment in outdoor environments?



Labdaoui et al. (2022)

Thermal Comfort

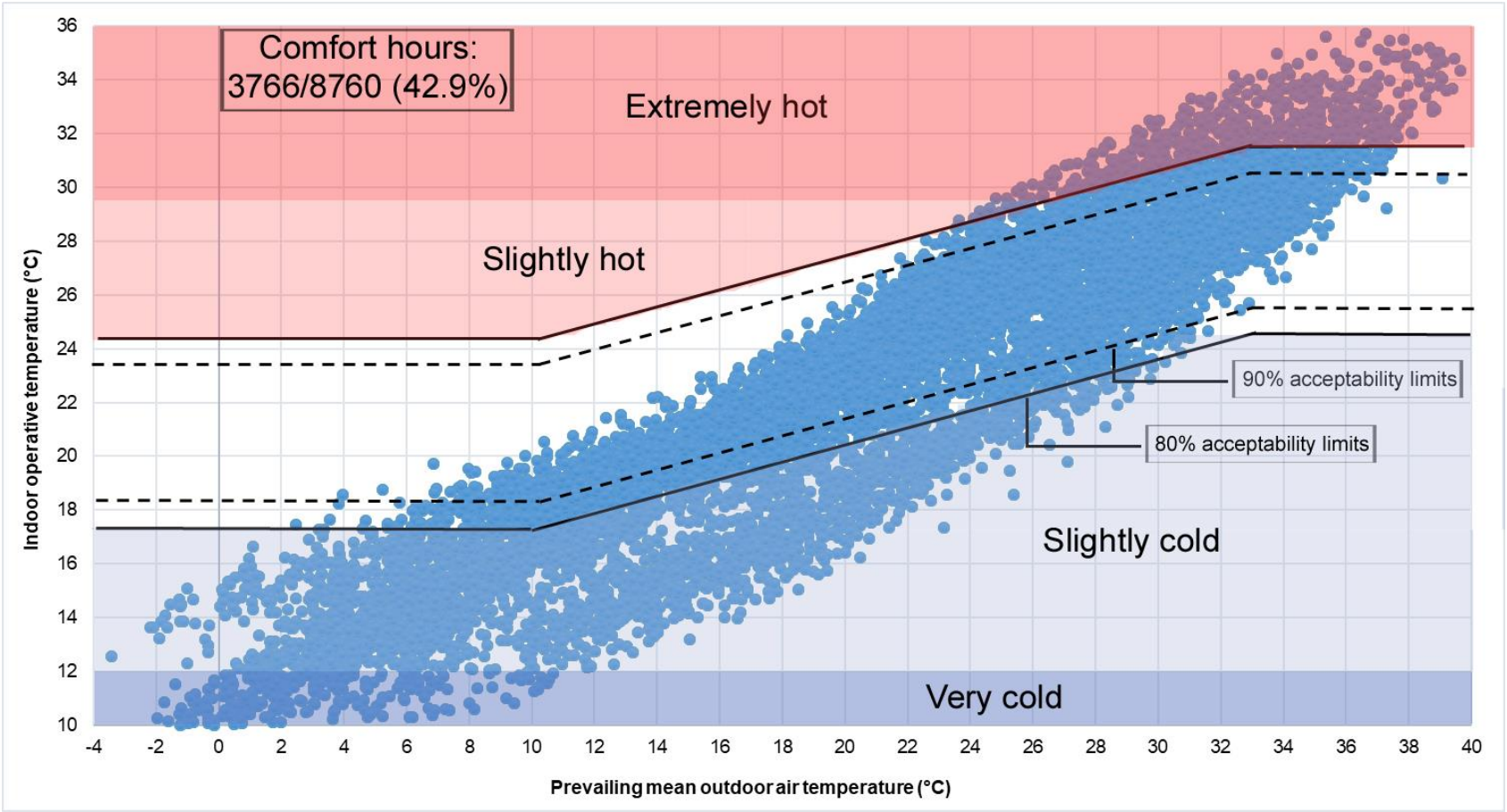
How Tmrt affect the PET assessment in outdoor environments?

	Street 1							Street 2							Street 3						
	08/08/2017			26th and 28th of August 2017				08/08/2017			26th and 28th of August 2017				08/08/2017			26th and 28th of August 2017			
Time	T(a) (°C)	RH (%)	Wv (m/s)	T(a) (°C)	RH (%)	Wv (m/s)	T_{mrt} (°C)	T(a) (°C)	RH (%)	Wv (m/s)	T(a) (°C)	RH (%)	Wv (m/s)	T_{mrt} (°C)	T(a) (°C)	RH (%)	Wv (m/s)	T(a) (°C)	RH (%)	Wv (m/s)	T_{mrt} (°C)
8 am	28	62	5.4	25.2 - 25.3	below 94	0.2-0.4	13.3 - 13.5	28	62	5.4	24.9 - 25.1	96	0.3-0.4	13.6-13.8	28	62	5.4	26	48	0	12.8
10 am	36.7	29	11.2	30.5 - 30.6	68	0.5-0.9	17.7 - 17.9	36.7	29	11.2	30.5 - 30.6	below 73	0.9-1.2	18.3-18.5	36,7	29	11.2	33.4	32	0	19.9
12 pm	42	19	13	31.6 -32	57-59	0.9-1.9	18.7 -19	42	19	13	31.1 - 31.5	58-61	2-2.6	19.1-19.3	42	19	13	34.7	28.5	0.2	21.6
2 pm	38	23	22.3	33.9 - 34.2	71	0.8-1.5	21.2 - 21.5	38	23	22.3	33.2 - 33.5	70-74	1.6-1.9	21.7-22	38	23	22.3	31.6	50	2.4	20.5
4 pm	34.8	40	25.9	34.6 - 34.9	31-32	1-2.	23.9 - 24.3	34.8	40	25.9	34.3 - 34.5	below 33	2.4-2.9	24.5-24.8	34,8	40	25.9	33.2	25	2.6	23.8
6 pm	35	28	24.1	31-31.2	65	1-1.97	22.6 - 22.8	35	28	24.1	30.9 - 31.1	65-69	2.1-2.5	22.5-22.8	35	28	24.1	31.6	44	0.5	23.6
8 am	29	55	16.6	27.5 - 27.6	81-83	0.7-1.4	19	29	55	16.6	27.3 - 27.4	below 83	1-1.3	below 19.07	29	55	16.6	28.8	57	0.5	20.1

Labdaoui et al. (2022)

Thermal Comfort

Thermal comfort of houses in Quetta



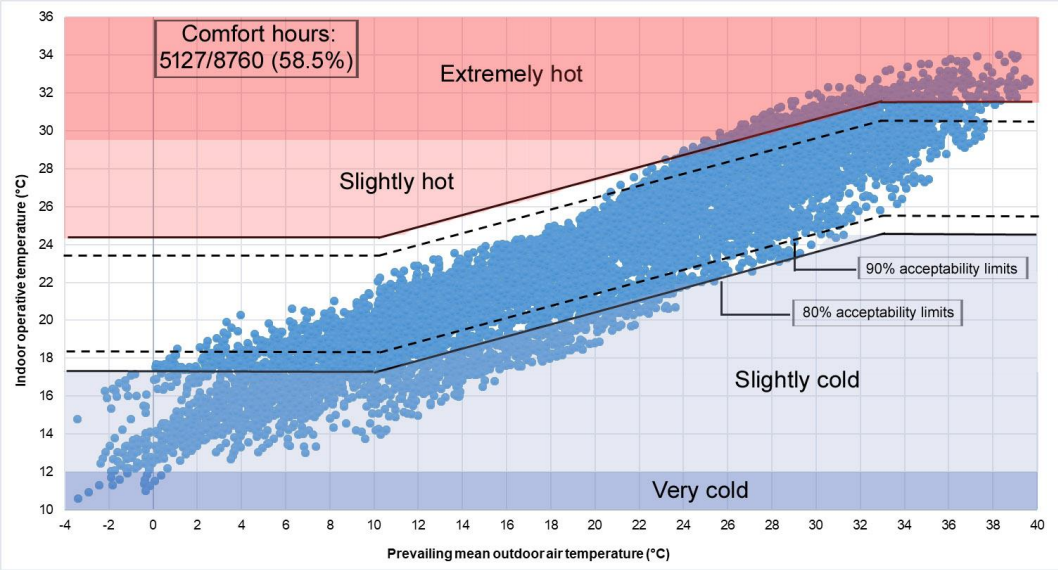
Comfort analysis of a house in Quetta

Based on ASHRAE 55 adaptive comfort model

Mahar et al. (2019)

Strategies	Name	Description	Comfort Hours (%)	Comfort Improvement (%)
Thermal mass	Case A	The thickness of the external walls was doubled from 0.34 m to 0.6 m. This raised the thermal resistance from 0.69 to 1.17 m^2 K/W.	43.9	Yes (1)
Low U-value windows	Case B	U-value of the external windows was reduced from 5.7 to 1.4 W/m^2 K i.e. to double glazing.	43.1	Yes (0.2)
Low U-value windows	Case C	U-value of external windows was reduced from 5.7 to 0.7 W/m^2 K i.e. to triple glazing.	44.3	Yes (1.4)
Low U-value roof	Case D	An insulated roof composed of asphalt and plasterboard. This raised the thermal resistance from 0.3 to 3.8 m^2 K/W.	53.6	Yes (10.7)
Low U-value walls	Case E	Three layered external walls: concrete walls (0.1 m), R-13 mineral fiber insulation (0.1 m), and concrete walls (0.15 m). This raised the thermal resistance from 0.6 to 3.2 m^2 K/W.	45.1	Yes (2.2)
Combination of strategies	Case F	Combination of Cases D and E.	56.1	Yes (13.2)
Combination of strategies	Case G	Combination of Cases C, D, and E.	57.5	Yes (14.6)
Combination of strategies and ventilation	Case H	Combination of Cases C, D, and E, and full day ventilation in summer.	58.5	Yes (15.6)

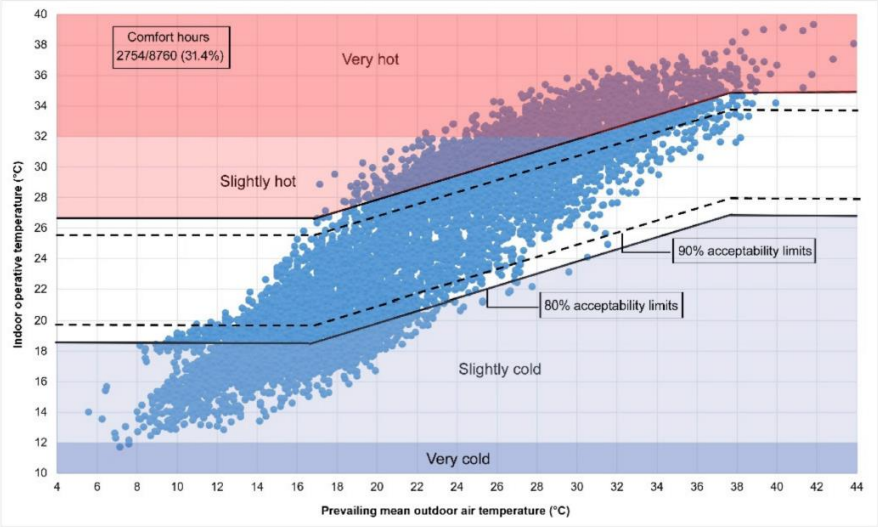
Parametric analysis



Mahar et al. (2019)

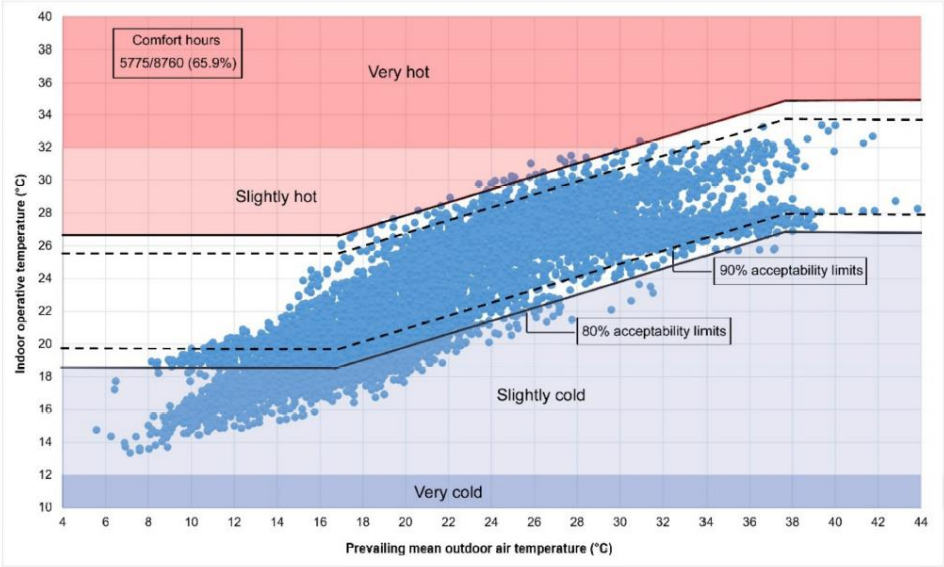
Thermal Comfort

Passive Retrofitting Scenarios in Hot, Dry Climates



Comfort analysis of a heritage residential building in Cairo

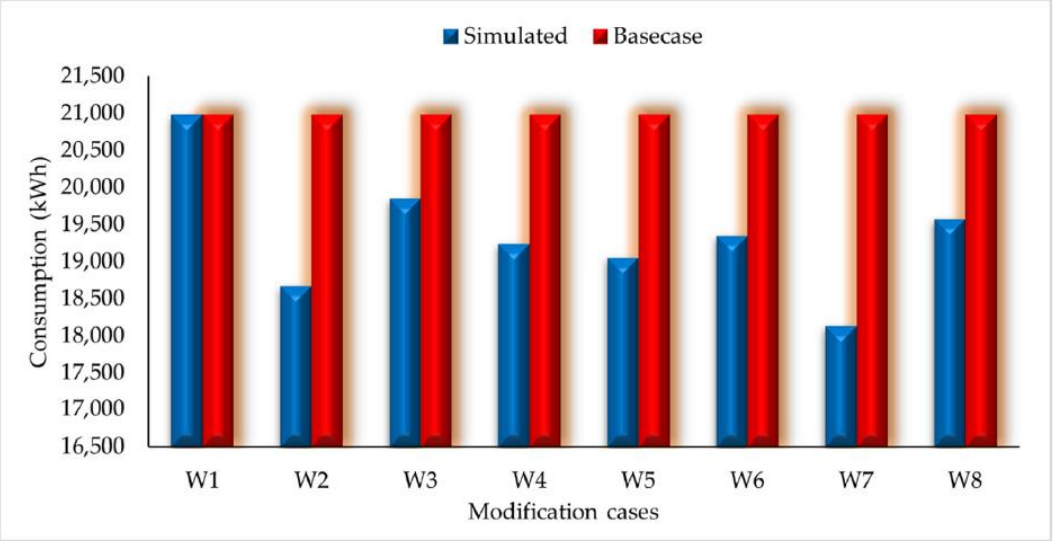
Based on ASHRAE 55 adaptive comfort model



Ibrahim et al. (2021)

Energy

Impact of passive energy efficiency measures on cooling energy demand



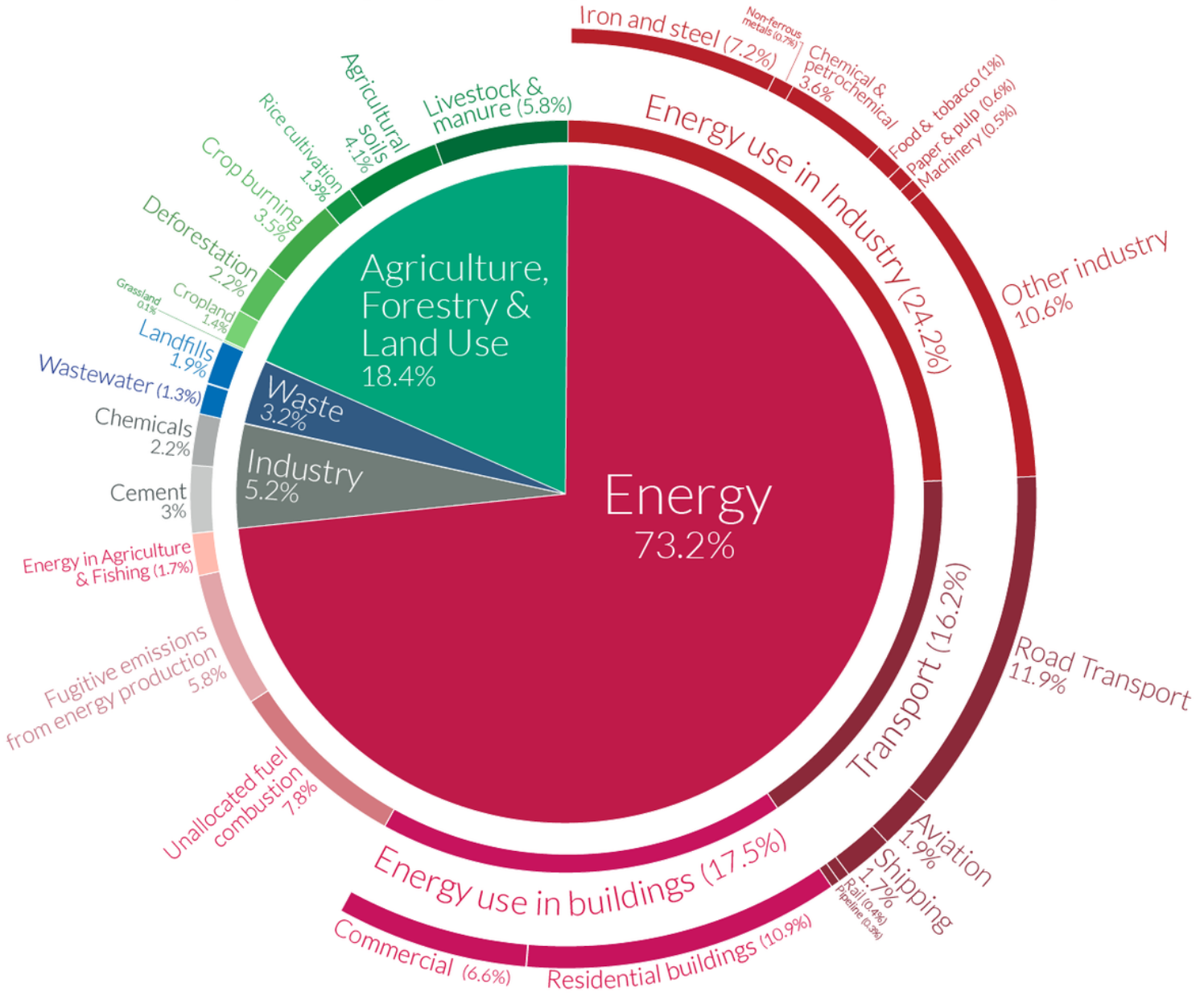
Cases	Insulation	Cost of Insulation in USD	Energy Demand (kWh)	Reduction in Energy Demand (%)
Base case	No	-	20,975.48	0
W1	No	-	20,975.48	0
W2	Loose-fill cellulose insulation	34.54 per kg	18,667.75	11.1
W3	0.05 m EPS (standard)	11–16 per m^2	19,842.35	5.4
W4	Glass mineral wool	1–3 per m^2	19,234.08	8.3
W5	Rock mineral wool	0.98–1.84 per m^2	19,045.3	9.2
W6	EPS (light weight)	11–13 per m^2	19,338.95	7.8
W7	0.1 m EPS (standard)	11–16 per m^2	18,130.79	13.56
W8	0.075 m EPS (standard)	11–16 per m^2	19,569.68	6.7

Source: Bughio et al., 2021

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data

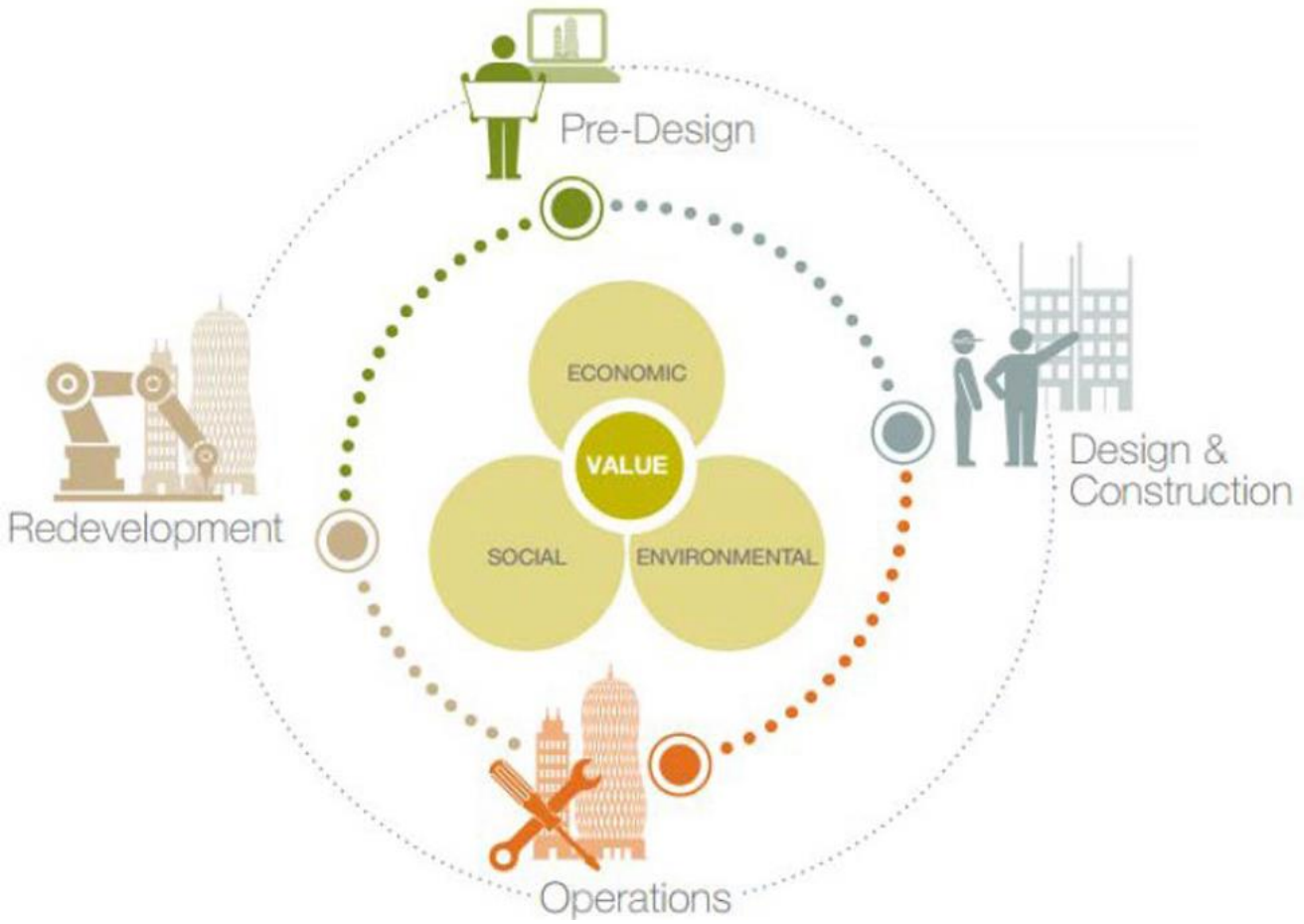


UN SDGs

UN SDGs, 2015

Challenges

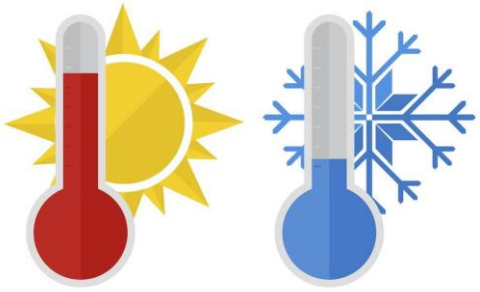
Real challenge (architects): existing buildings

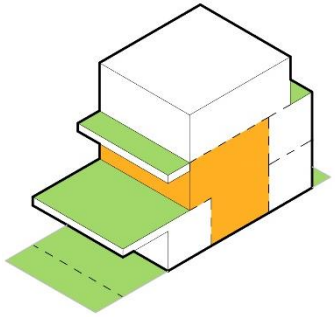


Multi-scale challenges

Challenges

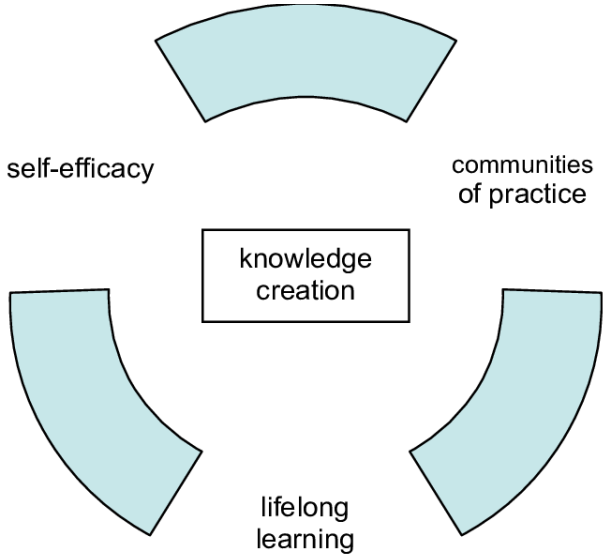
Real challenges (Pakistan)

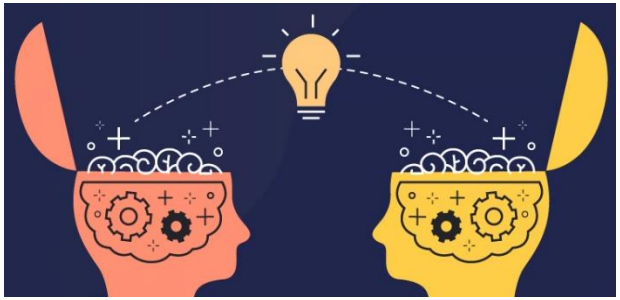


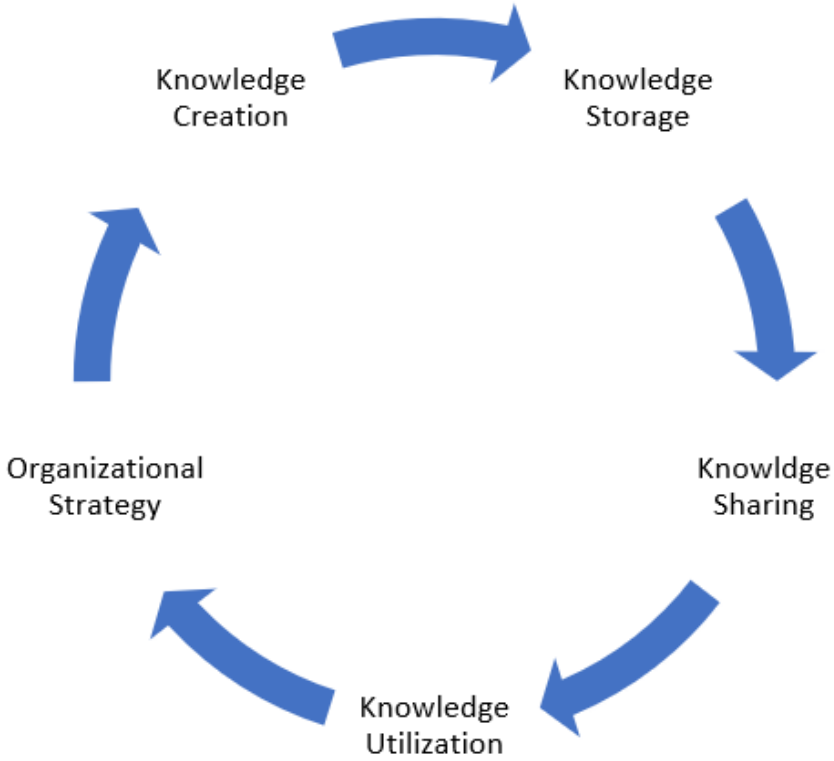


Challenges

Real challenges: My opinion







Energy

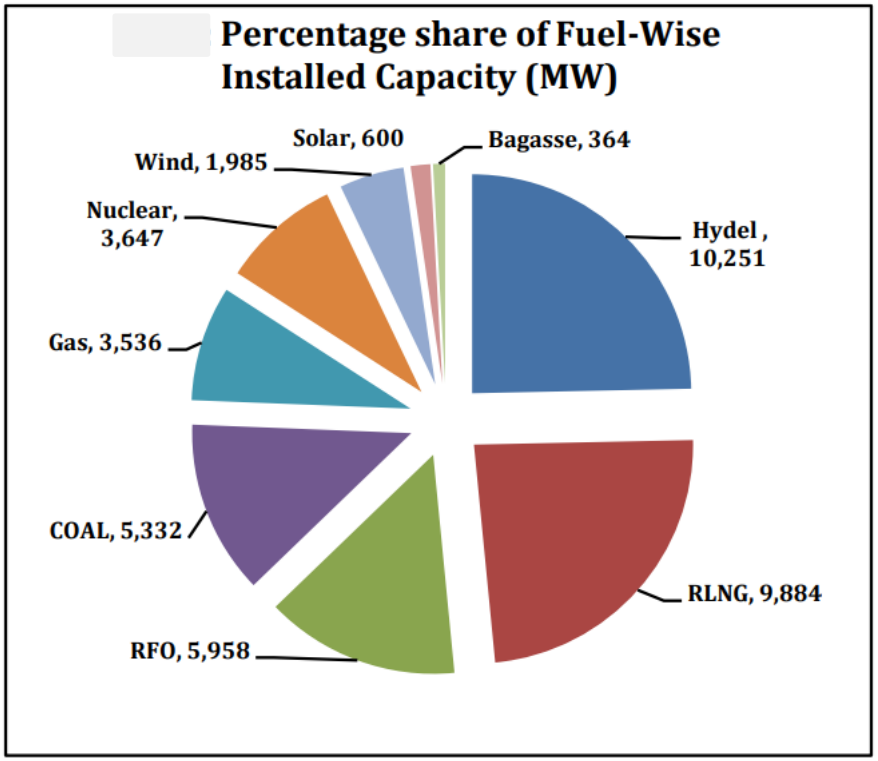
Building and construction sectors are responsible for almost

- 15% of direct CO2 emissions
- one-third of total global final energy consumption

The major areas of energy consumption in buildings are:

- HVAC (almost 35% of total building energy);
- Lighting (11%);
- Major appliances (water heating, refrigerators and freezers, dryers)-18%;
- remaining 36% in miscellaneous areas including electronics.

Energy

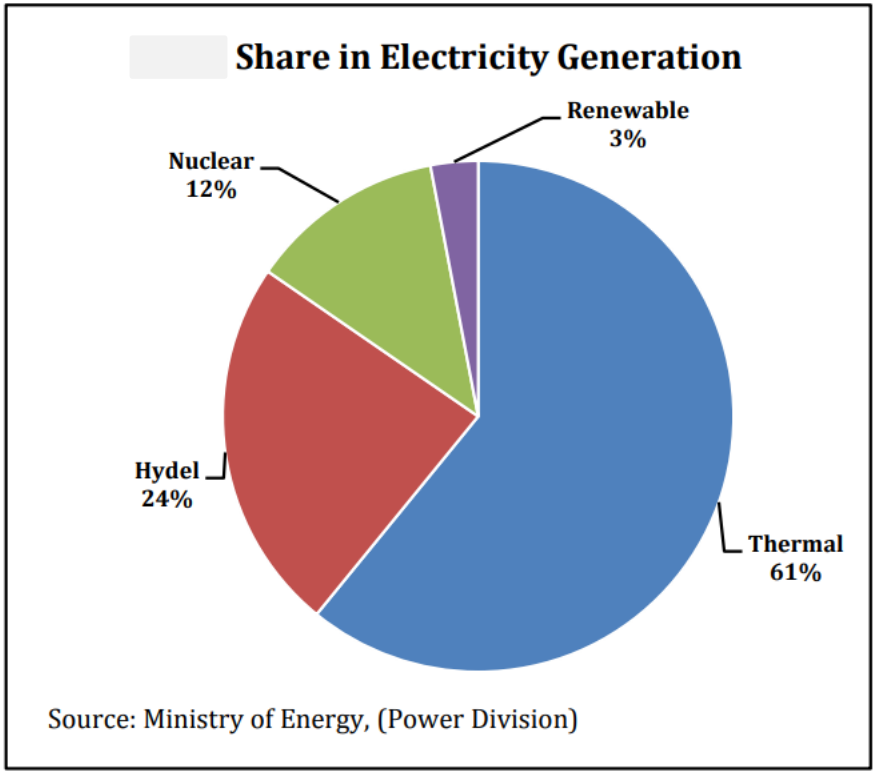


RLNG: Regasified Liquefied Natural Gas

RFO: Residual Fuel Oil

Source: PES, 2022

Electricity Generation and Mix in Pakistan



Energy Consumption

Energy usage and demand is increasing globally due to:

- Increasing urban population
- Use of latest devices and technologies
- Expansion in the user's net

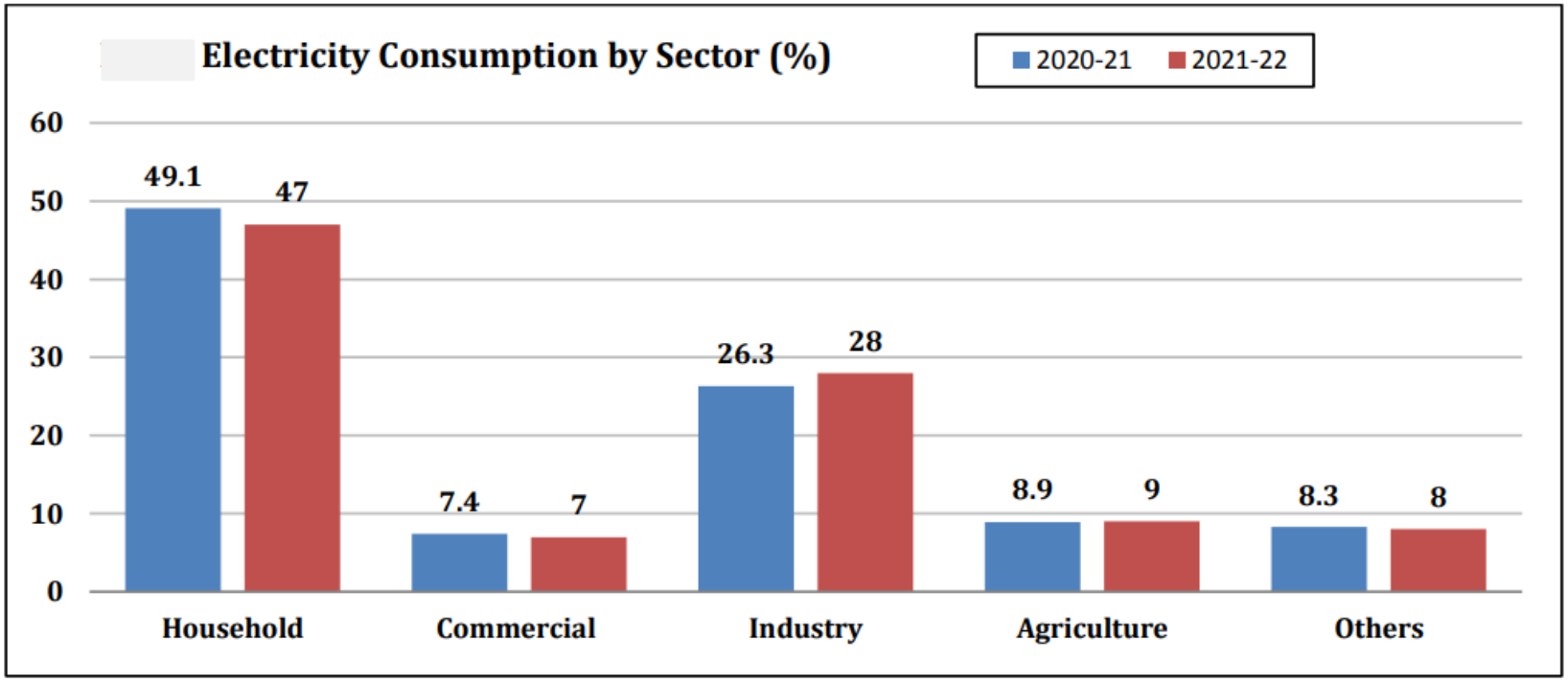
Several countries including Pakistan are facing problems such as; energy shortage, distribution, demand and supply gap and line losses.

In Pakistan, urban population is increasing at the rate of 3% per annum which is highest in South Asia.

By 2025 nearly half of the population in Pakistan will live in urban areas (Kugelman, 2013).

Energy Consumption

- Household sector consumes nearly half of the electricity
- Most of the buildings are not designed according to climate considerations
- Use of concrete and single glazed glass is very common



Source: PES, 2022

Energy Consumption

- Considering the energy problems and rising energy prices there is a need to reduce the household energy consumption

Sector Wise Natural Gas Consumption in million Cubic Feet Per Day (Mmcfd)

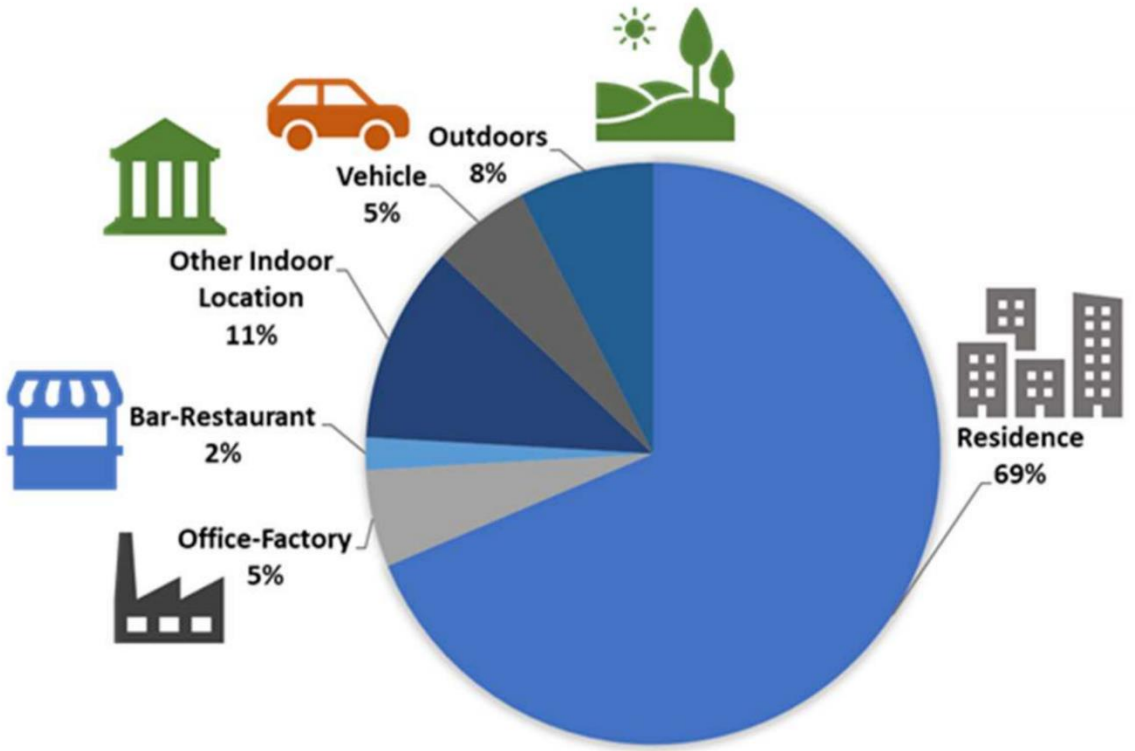
Sector	Gas Consumption	RLNG	Total
Power	560	555	**1,115**
Domestic	907	1	**908**
Commercial	62	8	**70**
Transport(CNG)	49	23	**72**
Cement	1	0	**1**
Fertilizer	684	51	**735**
General Industry	439	225	**664**
Total	**2,702**	**863**	**3,565**

Sources: Ministry of Energy (Petroleum Division)

Source: PES, 2022

Why do we build buildings?

- Safety, security and protection against extreme outside weather
- Therefore: High exposure to indoor environment



Source: Mannan and Al-Ghamdi, 2021

Why do we build buildings?

- Safety, security and protection
- Comfort
- Productivity
- Health
- Happiness?

NEECA

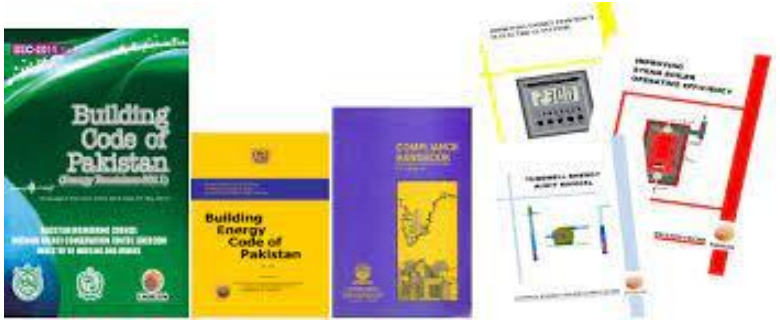
Building Energy Codes

Building Energy Code of Pakistan (BECP)

- Developed in 1990 by National Energy Conservation Centre (ENERCON)
- ASHRAE standard 90.1
- Five (5) climatic zones

Building Code of Pakistan (Energy Provisions-2011)

- Developed in 2011. In 2013 added in Building Code of Pakistan (BCP)
- ASHRAE standard 90.1
- No climate-based recommendations

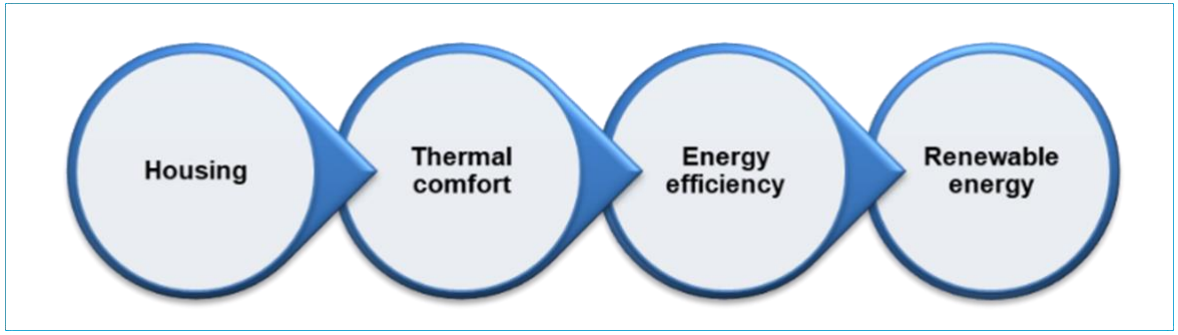


(BECP,1990)

Key Issues

Housing shortage

- The estimated housing shortage in Pakistan is up to 10 million units (WB, 2015), and about 40 percent of which is in urban areas (IGC, 2016).
- In a study took place in 2015, it was mentioned that annual housing demand in Pakistan was 0.6 million units while only 0.37 million units were being built annually and mostly in urban areas (MoCC, 2015).
- Housing finance is particularly low in Pakistan, with a mortgage-finance-to-GDP ratio of 0.25 percent which is lowest in South Asia, whereas it is 3 percent in Bangladesh and 11 percent in India (IMF, 2015).



Housing paradigm shift model (Mahar et al., 2019)

Conclusion

- Most of us are living in **inefficient and poorly designed houses** and using **active cooling and heating** systems.

- These **systems are expensive**, need more energy and increase the overall energy costs which can be reduced by taking alternative measure, **design interventions, changing building materials** or using insulation, etc.

- **Comfort is a basic need** of for a nation dominated by youth, since comfortable environment provides healthy environment and increases the productivity.

- With **energy efficiency** and conservation, a good sum of energy can be saved which will bring long term economic and environmental benefits.

Way Forward…

- Knowledge **creation** and knowledge **sharing**
- National **Urban and Regional Development Policy**/ Framework
- Revision of the **National Housing Policy 2001**
- **Public Participation** and community development
- Active role and participation of **building/ planning and energy** experts
- Building and Energy codes and **compliance** (new and existing buildings)

Way Forward…

- Establishment of **material** testing laboratories. Directory of EE materials
- **Characterization**, Benchmarking, Measurement, Monitoring, Assessment and Auditing
- **Financial incentives** and subsidies for construction/ deep energy renovation
- Exemption of import duties for EE equipment and materials
- **Energy labelling** of appliance, devices, fixtures
- **Research**, innovation, promoting local industries and awareness programs

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Thank You

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