Powering the future in a finite world: Housing, energy, fuel poverty and Thermal Comfort

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DEPARTMENT OF ARCHITECTURE
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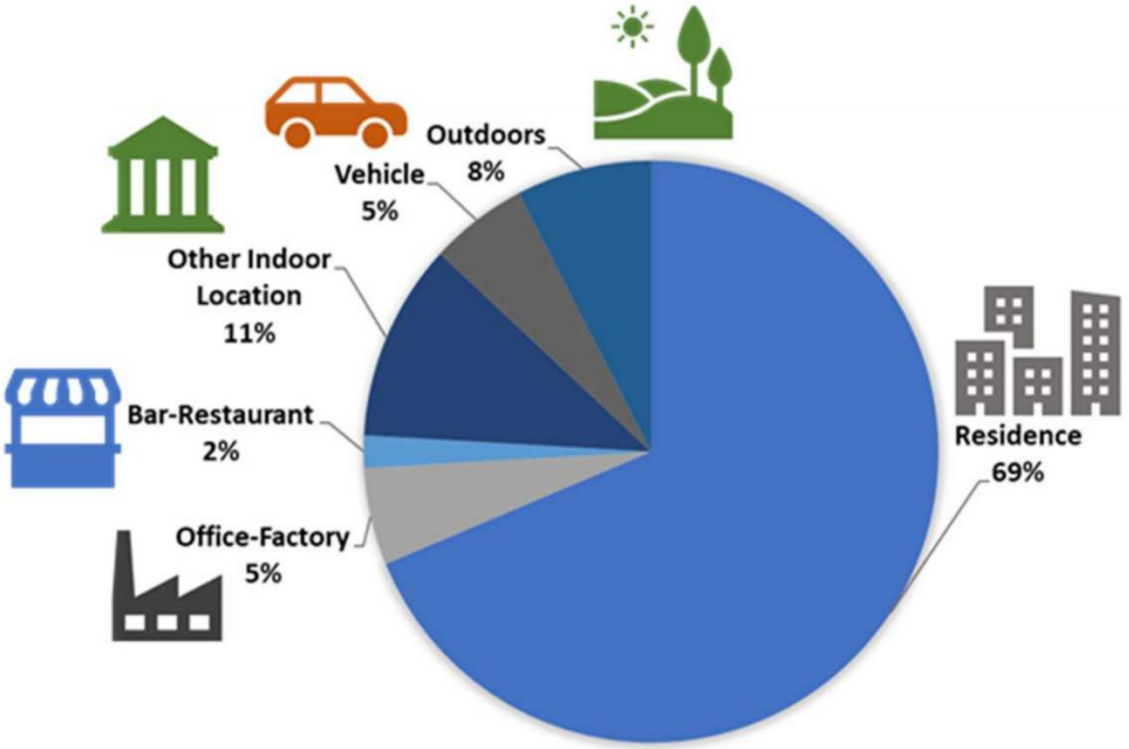
Why do we build buildings?

- **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?

UN SDGs

UN SDGs, 2015

Pakistan SDGs

17 Goals | **Priority-I** | Priority-II | Priority-III

17 Goals | Priority-I | **Priority-II** | Priority-III

17 Goals | Priority-I | Priority-II | **Priority-III**

Source: Pakistan SDGs

Housing

A **good house** or living facility improves the **quality of life** while a **faulty** and **poorly designed** house does not fulfil the demands of its inhabitants.

Rapid growth in housing and construction sector

- increasing **population**,
- **technological development**,
- **professionals**, and skilled labour

Many countries are still facing the problems and challenges:

- housing **shortage**,
- lack of **policies**,
- poor **planning and design**,
- improper **facilities and services**,
- **unaffordability** of housing,
- unavailability of **low-cost housing,** etc.

(Mahar, 2012)

Housing

Number and Proportion of Households Living in Congested Conditions

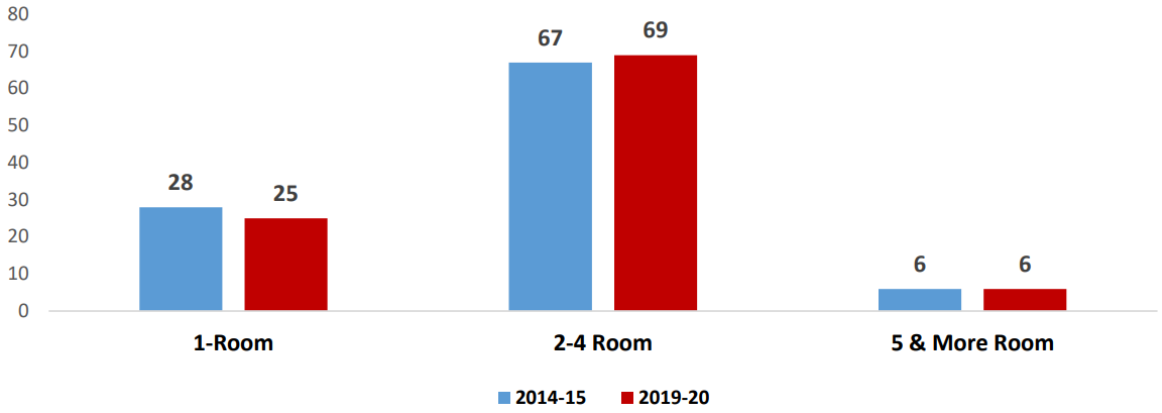
	Total number of households *(million)*	Households with occupancy of over 3 persons per room *(million)*	Proportion living in crowded conditions *(%)*
Rural	21.8	3.04	14.0
Urban	13.7	1.33	9.8
Pakistan	**35.5**	**4.37**	**12.3**

Quality of Structure and Access to Amenities (%)

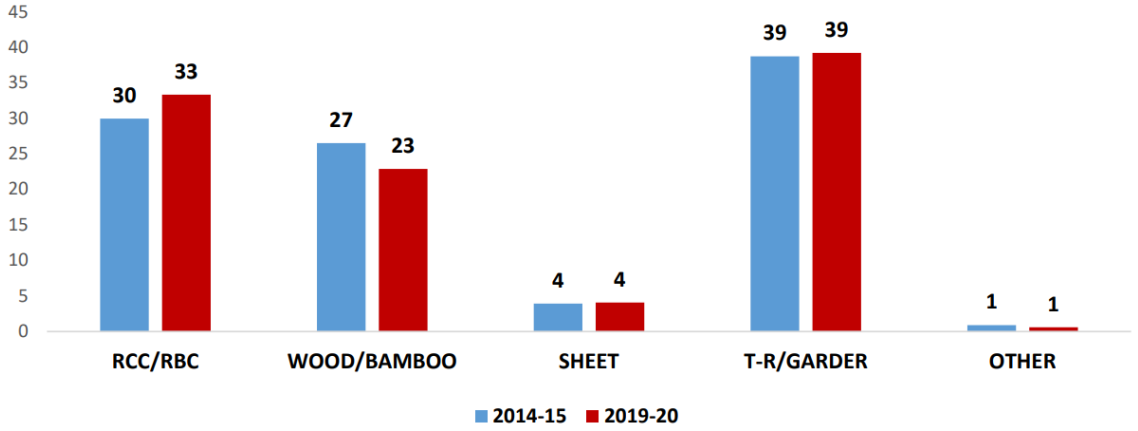
	Floor	Roof	Walls	Fuel for cooking	Source of light	Waste disposal	Drinking water	Toilet
Standard[1]	63.0	77.1	83.1	48.5	96.0	23.6	67.2	72.5
Sub-standard	37.0	22.9	16.9	51.5	4.6	76.4	32.8	27.5

(PSLM, 2019-20)

Housing



%age of household by number of rooms



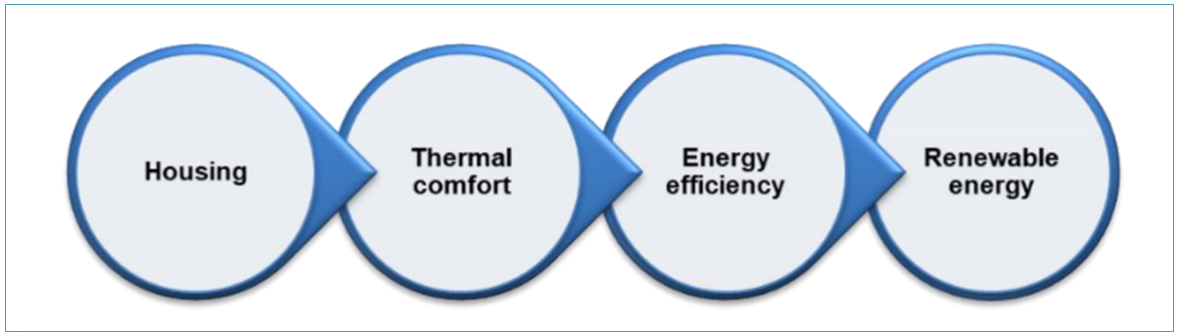
Material used for roof

(PSLM, 2019-20)

Housing Issues

Housing shortage

- We are short of **10 million** houses in Pakistan (PLSM, 2019-20).
- Housing gap in **Punjab** was **2.3 million** units in 2017. It will be **11.3 million** units by **2047** (World Bank, 2022).
- The annual housing demand in **2025** will be **1.24 million** units (ilaan, 2023).

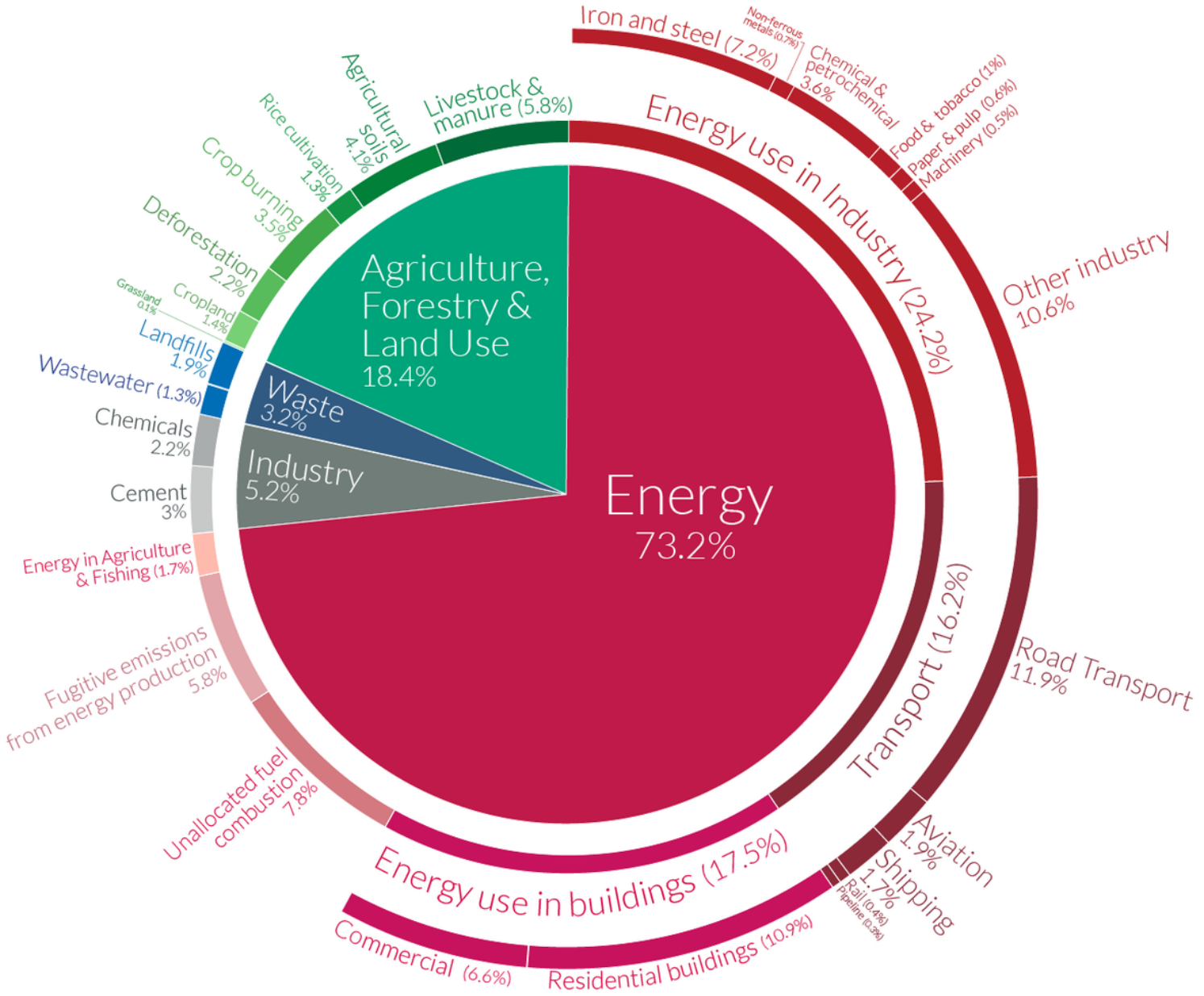


Housing paradigm shift model (Mahar et al., 2019)

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



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:

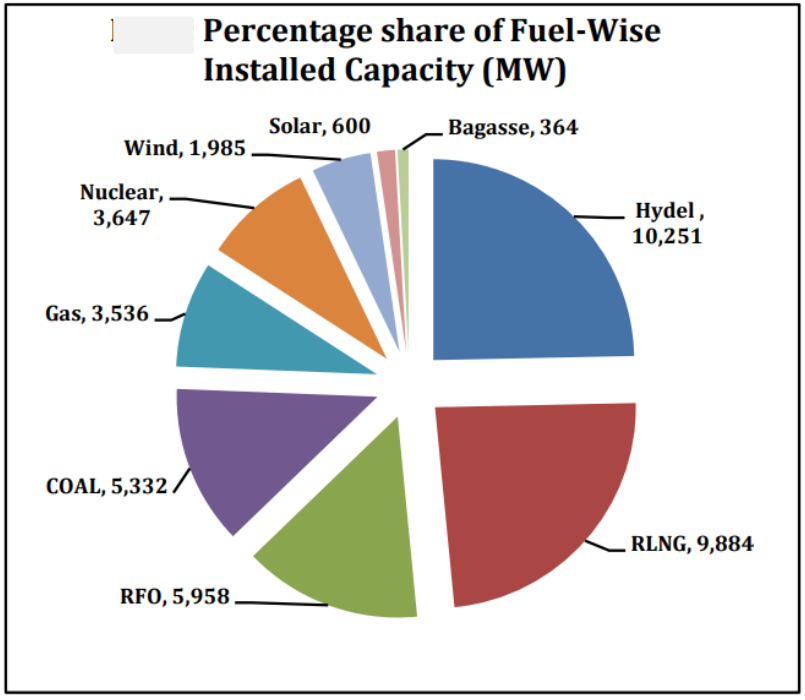
- **HVAC** (almost 35% of total building energy);
- Lighting (11%);
- Major appliances (water heating, refrigerators and freezers, dryers)-18%;
- remaining 36% in miscellaneous areas including electronics.

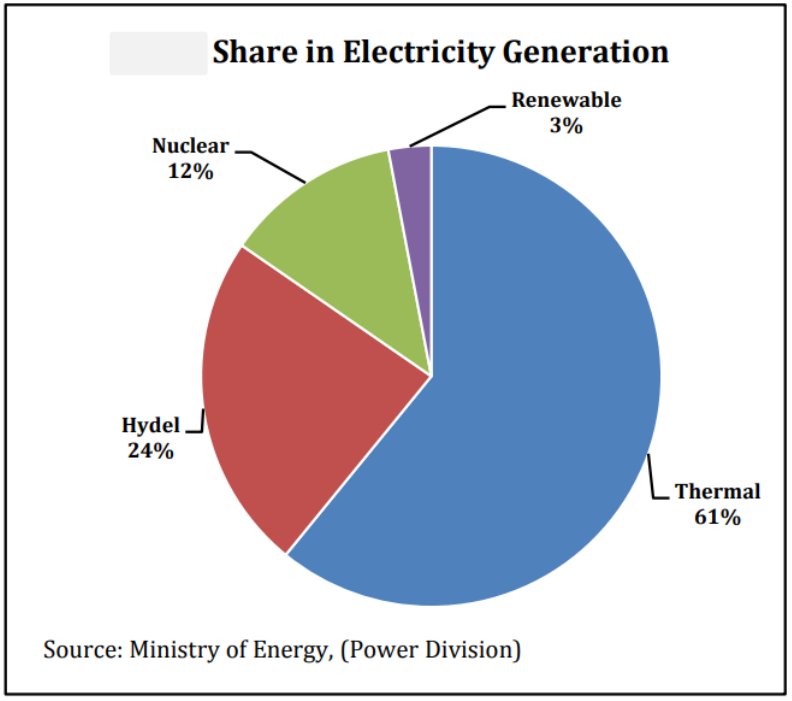
Energy

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.

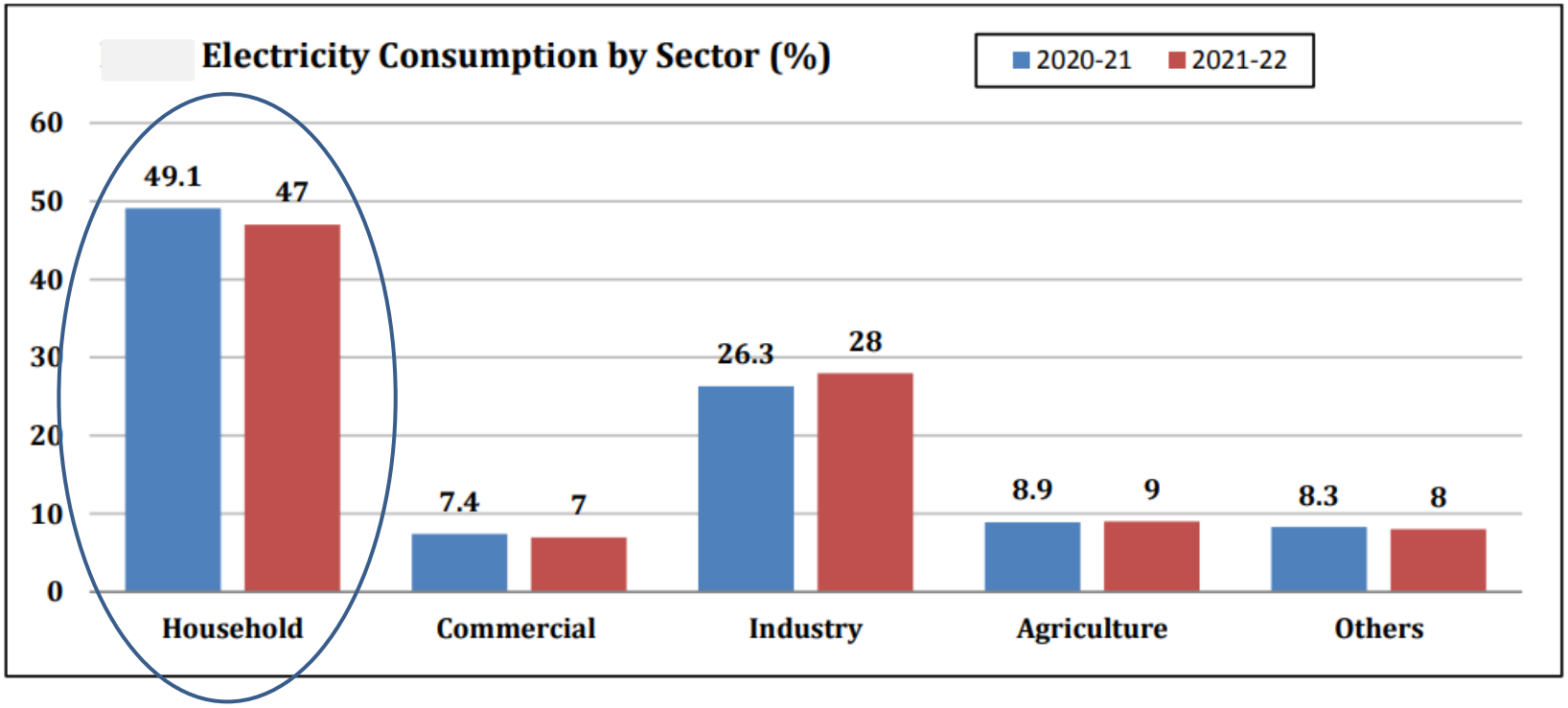




Source: PES, 2022

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

CNN BUSINESS Markets Tech Media Success Perspectives Videos

Nearly 220 million people in Pakistan without power after countrywide outage

Bloomberg Asia Edition

Live Now Markets Economics Industries Technology **Politics** Wealth Pursuits Opinion Businessweek Equality Green

Politics

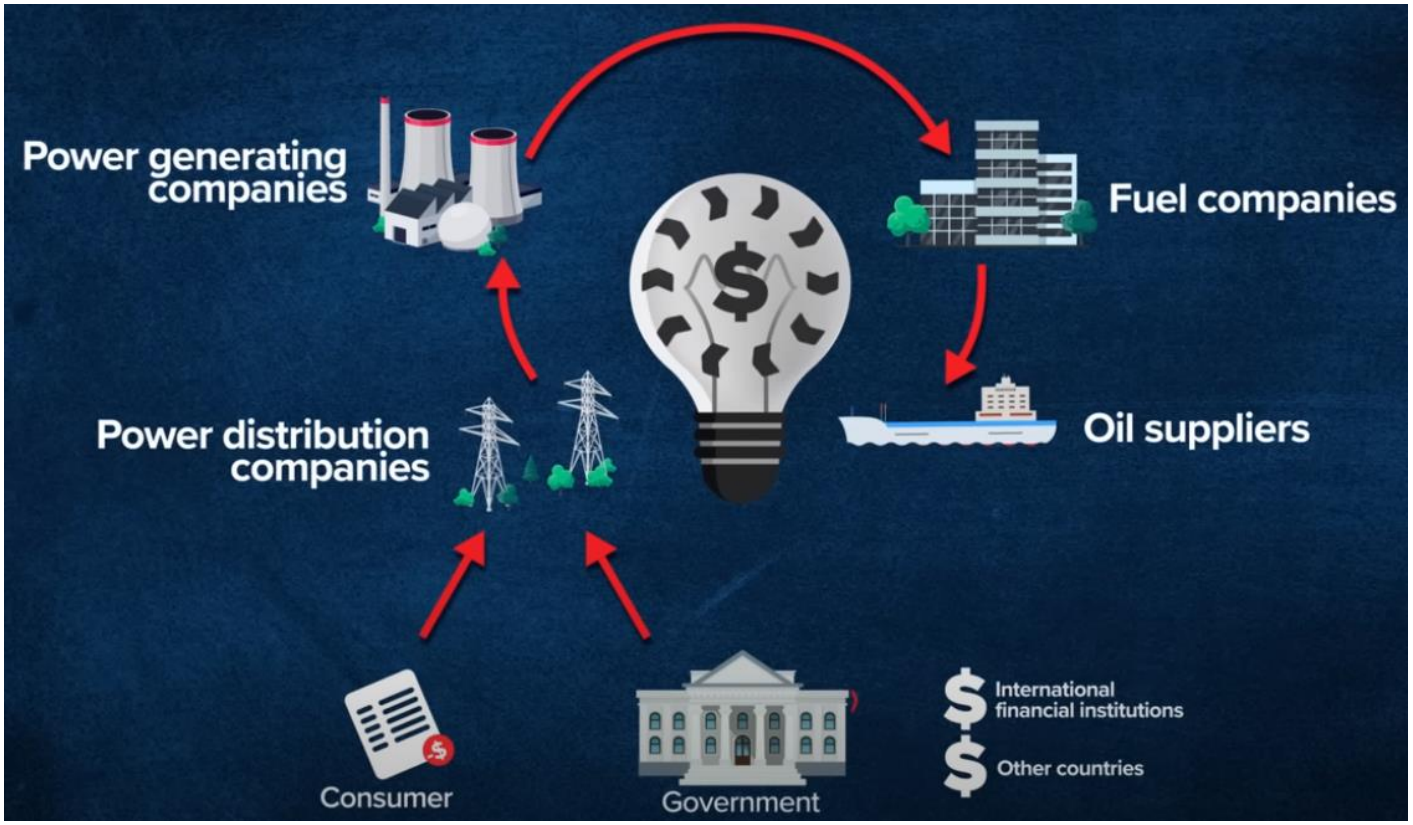
Millions in Pakistan in Nationwide Blackout as Grid Fails

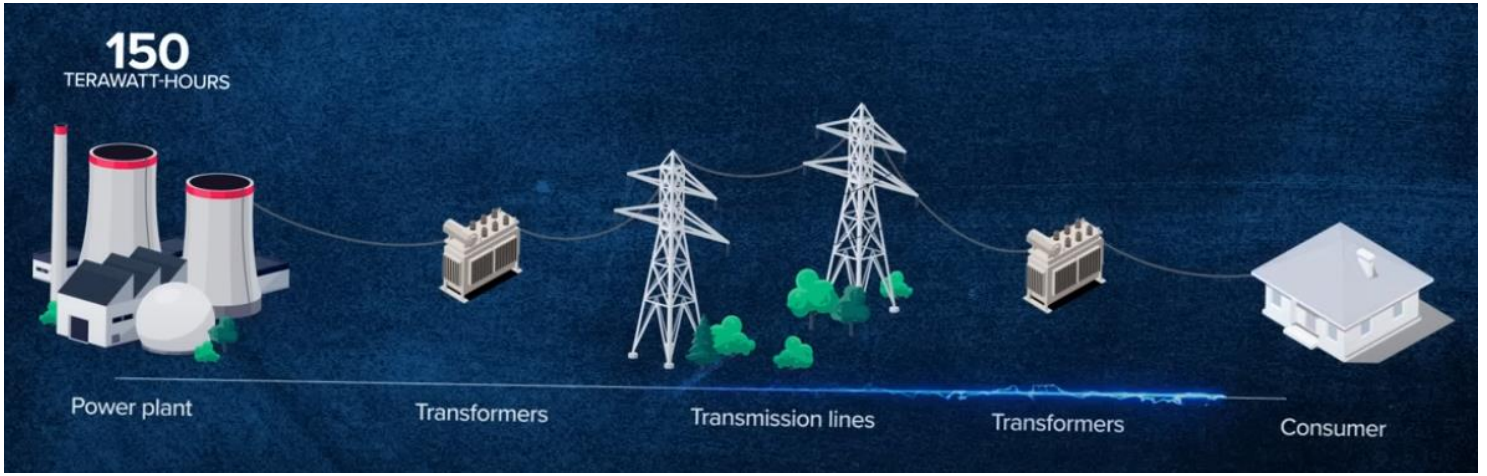
- Reduced frequency caused widespread breakdown: government
- Nation has been contending with squeeze on electricity supply

13 OCT 2022 | 01:24 AM UTC

Pakistan: Power outages occurring in multiple areas of the country, especially in Sindh Province, as of the afternoon of Oct. 13

Power outages occurring in various areas of Pakistan as of Oct. 13. Commercial, transport disruptions possible.

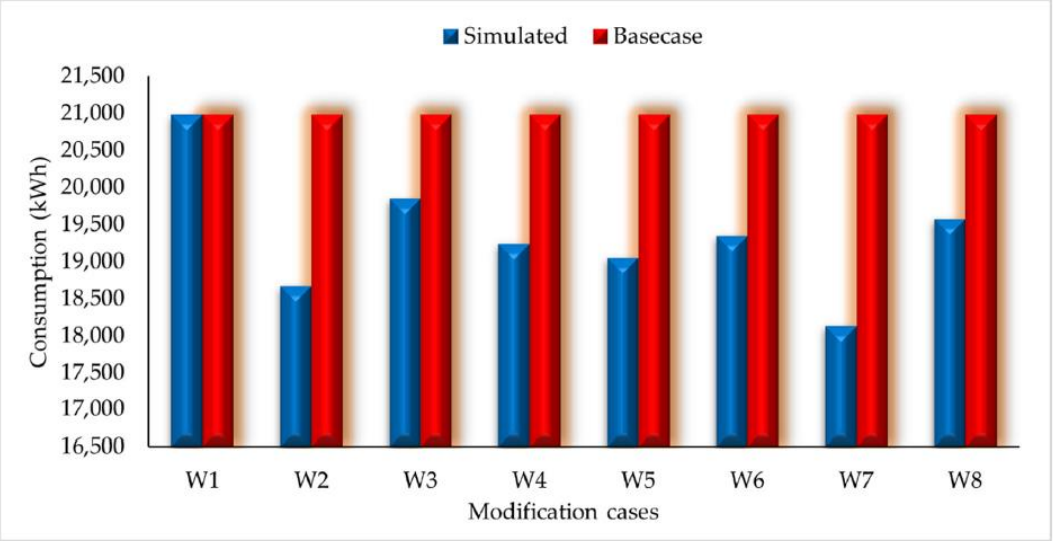




Source: CNBC, 2023

Energy

Impact of passive energy efficiency measures on cooling energy demand



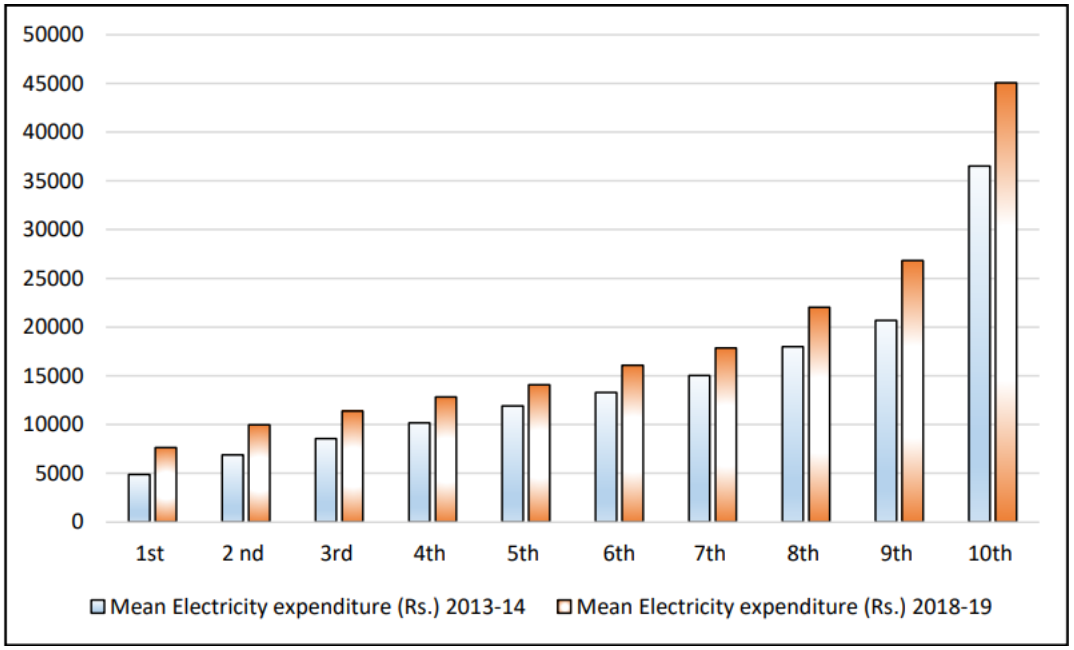
Cases	Insulation	Cost of Insulation in USD	Energy Demand (kWh)	Reduction in Energy Demand (%)
Base case	No	-	20,975.48	0
W1	No	-	20,975.48	0
W2	Loose-fill cellulose insulation	34.54 per kg	18,667.75	11.1
W3	0.05 m EPS (standard)	11–16 per m^2	19,842.35	5.4
W4	Glass mineral wool	1–3 per m^2	19,234.08	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

Fuel (Energy) Poverty

Fuel poverty is the condition by which a household is **unable to afford to heat (or cool)** their home to an adequate temperature.

It is caused by low income, high fuel prices, poor energy efficiency, unaffordable housing prices and poor quality private rental housing.

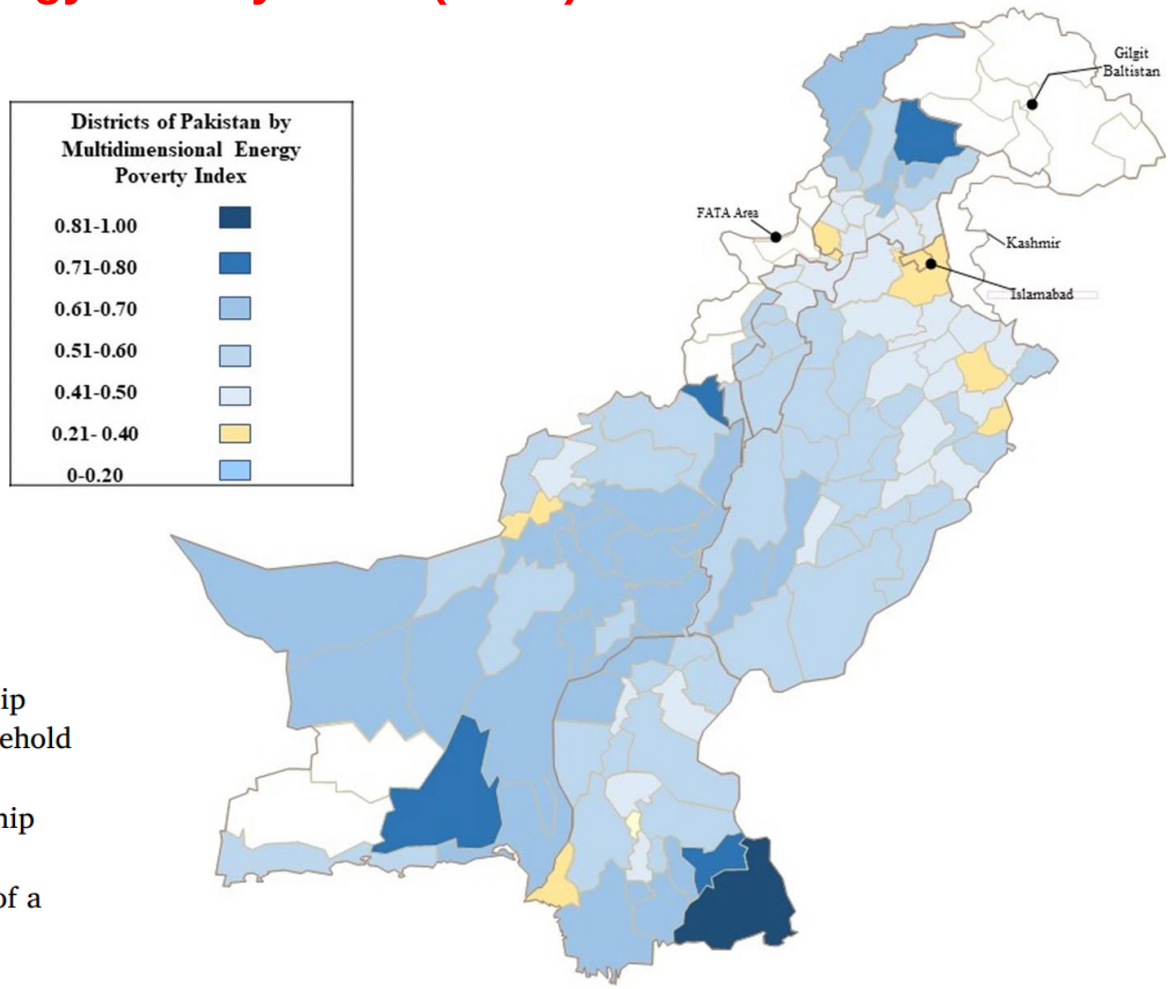


Mean Electricity Expenditure by Income Quintiles

(Sohail and Fatima, 2022)

Fuel (Energy) Poverty

Multidimensional Energy Poverty Index (MEPI)

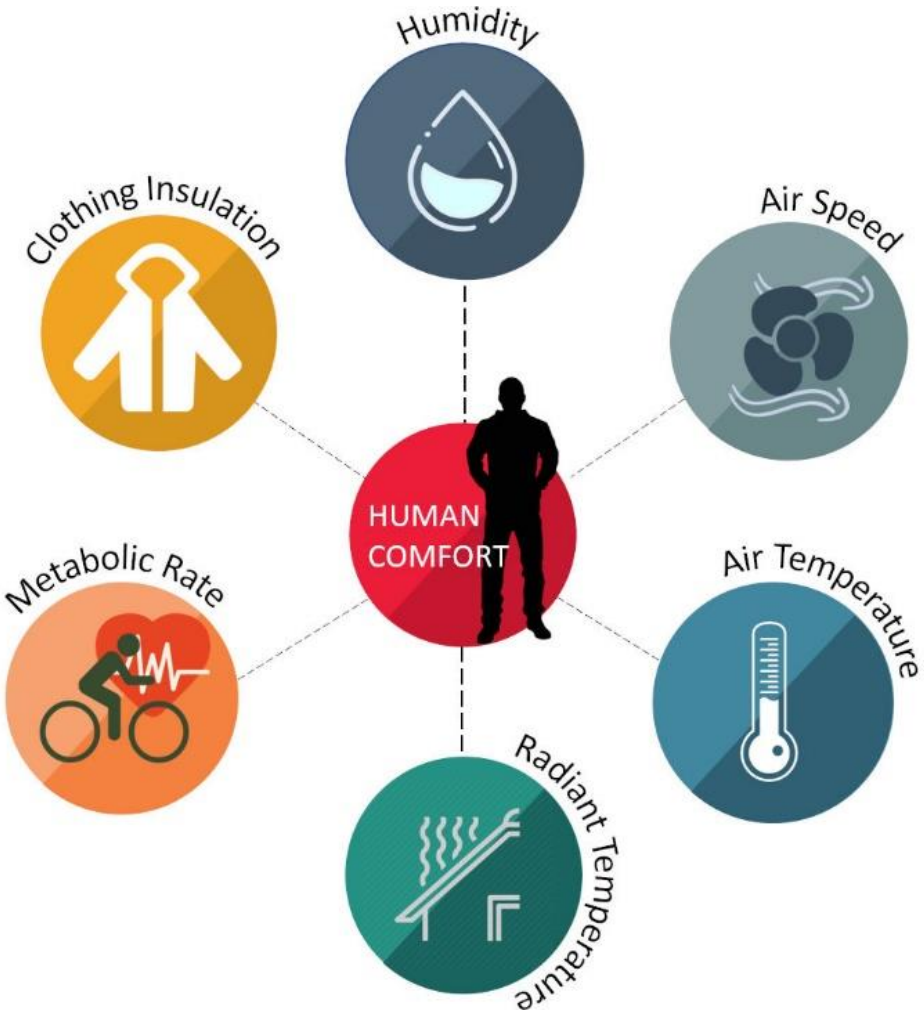


Cooking: Modern cooking fuel
Cooking: Indoor pollution

Lighting: Electricity access
Refrigeration: Household appliance ownership
Entertainment/education/information: Household appliance ownership
Space cooling: Household appliance ownership
Communication:
Telecommunication means; Ownership of a telephone

(Qurat-ul-Ann and Mirza, 2021)

Thermal Comfort

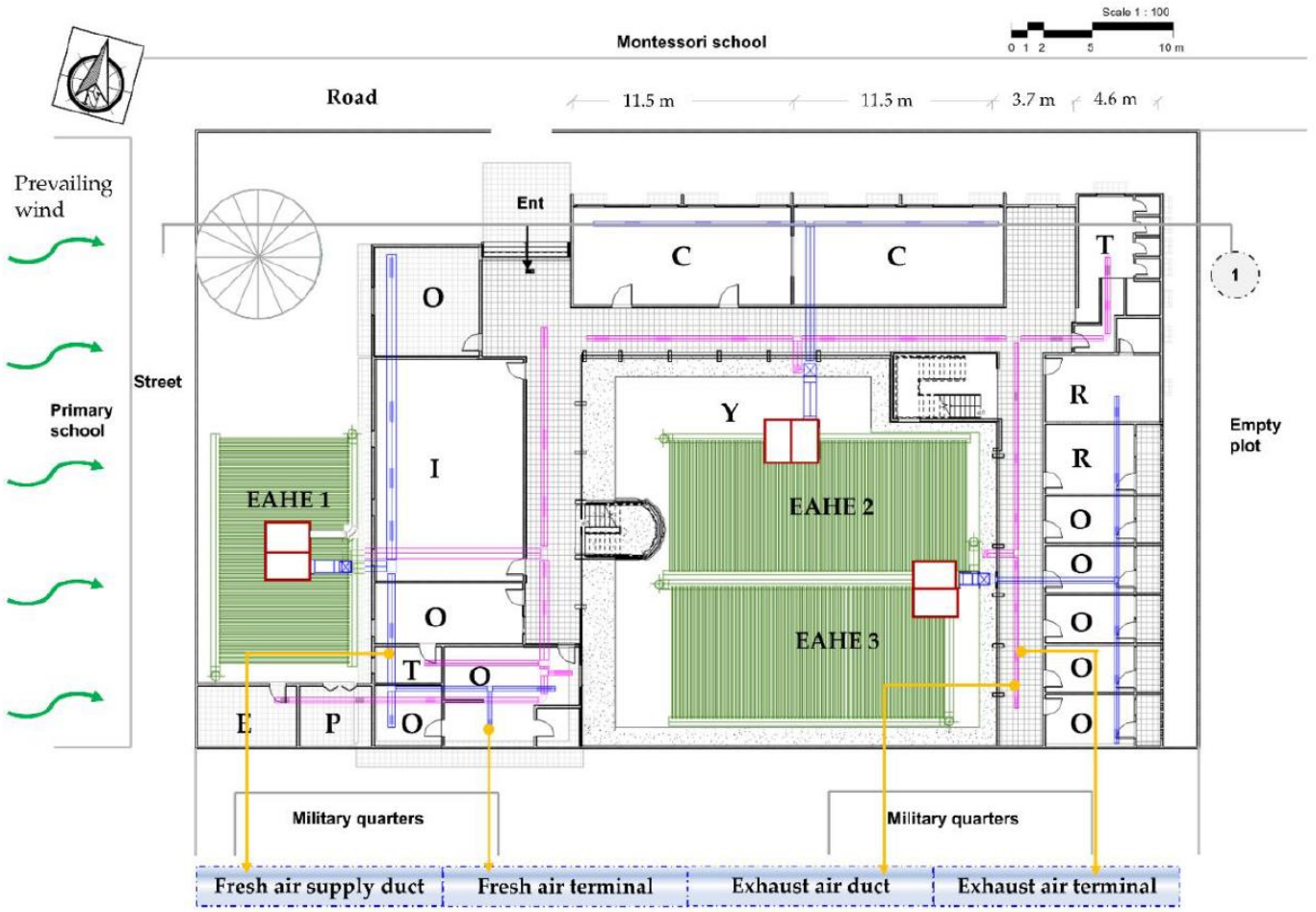


Factors that influence thermal comfort

*Human behavioural adaptations

Thermal Comfort

Cooling Potential of Earth-to-Air Heat Exchangers in Karachi

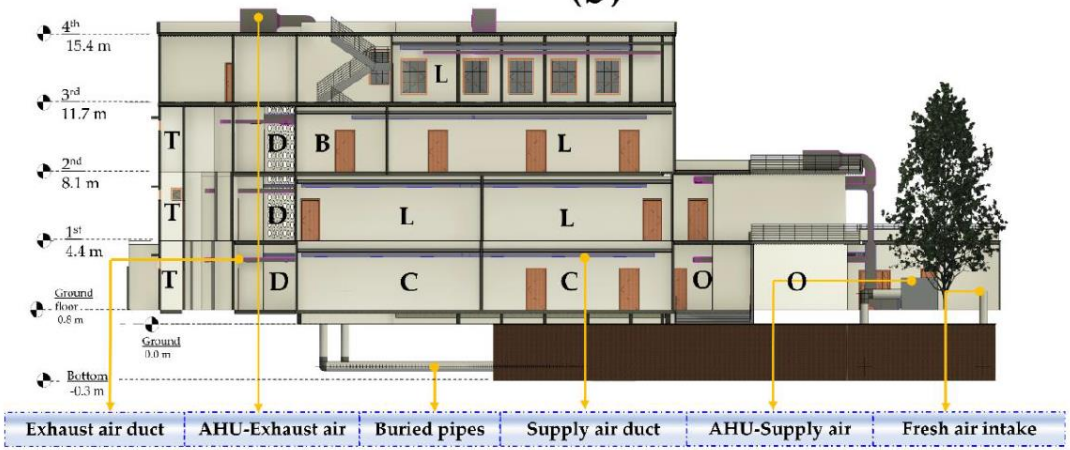


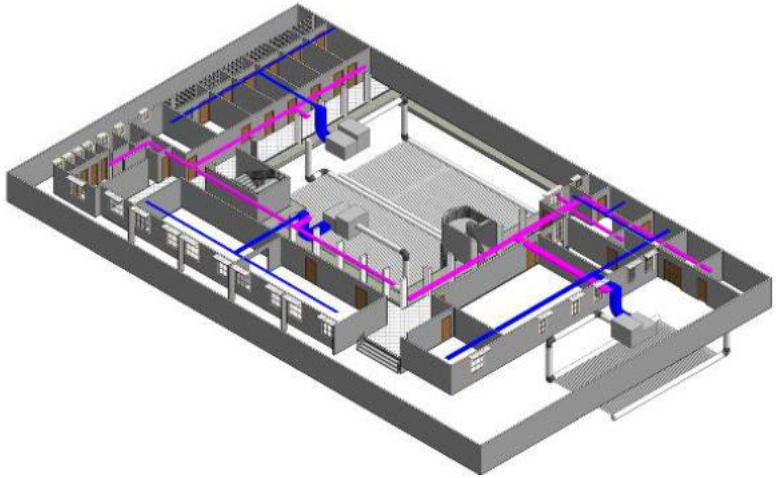
(Bughio et al., 2022)

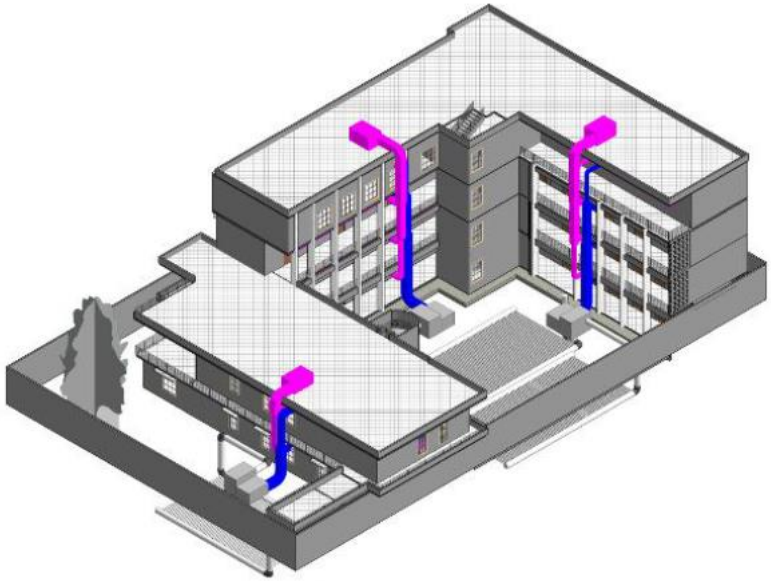
Thermal Comfort

Cooling Potential of Earth-to-Air Heat Exchangers in Karachi

(b)







(Bughio et al., 2022)

Thermal Comfort

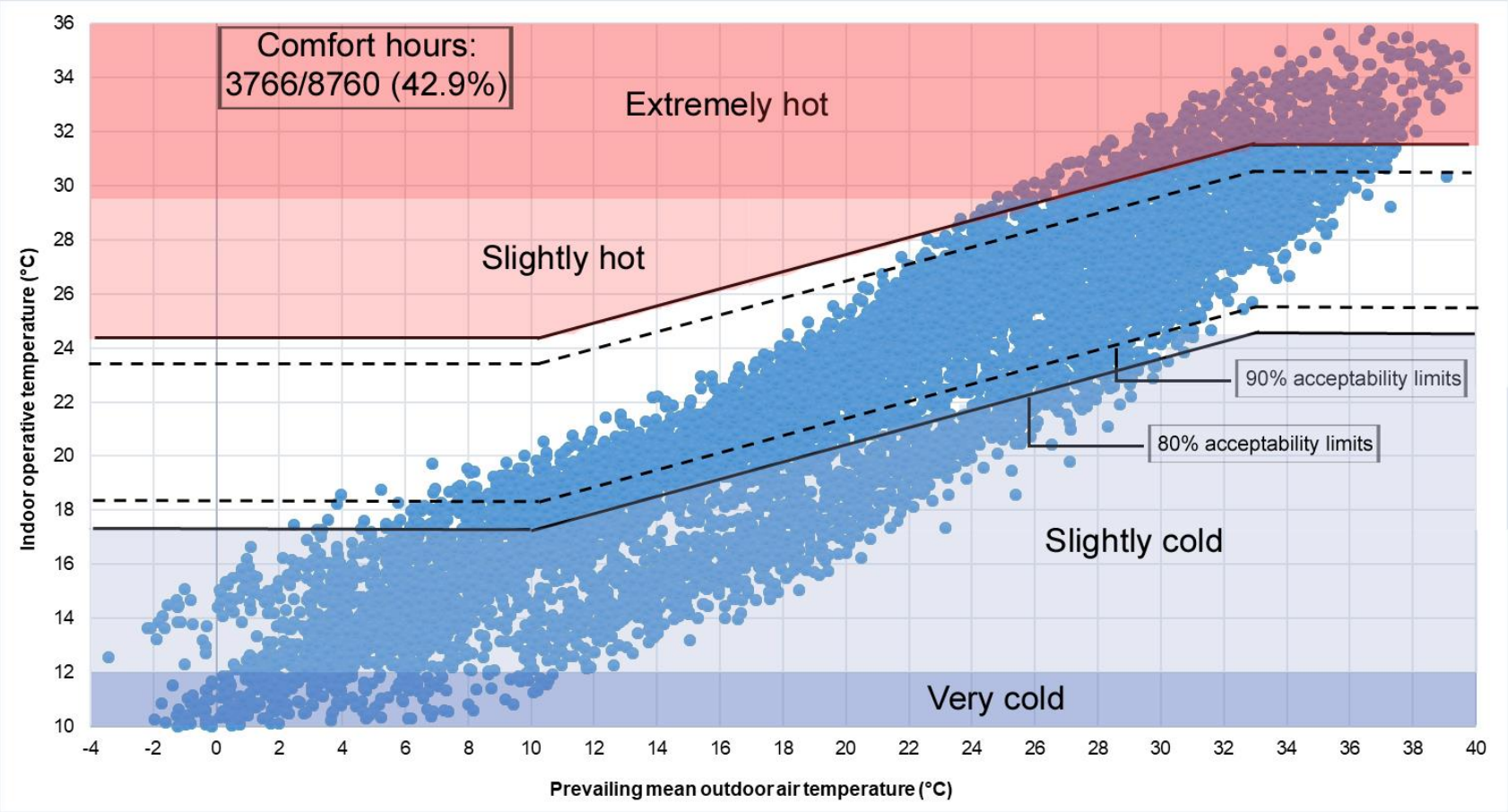
Cooling Potential of Earth-to-Air Heat Exchangers in Karachi

Month	Airflow (m^3/s)			Outdoor Temperature	Temperature (°C)			Base Case ACB Energy Demand (kWh)	Renovated ACB Energy Demand (kWh)	Reduction in Energy Demand (%)
	North Wing	East Wing	West Wing		North Wing	East Wing	West Wing			
Jan	0.35	0.35	0.36	29.06	27.5	27.7	27.9	1331.1	1277.8	4
Feb	0.35	0.35	0.36	31.91	27.8	28	28.2	2073.17	1699.9	18
Mar	0.35	0.35	0.36	35.41	28	28.2	28.4	2176.84	936.04	57
Apr	0.35	0.35	0.36	36.28	28.8	29	29.2	2073.17	663.4	68
May	0.35	0.35	0.36	44.11	28.9	29.1	29.3	2111.01	358.8	83
Jun	0.35	0.35	0.36	41.75	28.6	28.8	29	337.29	64.08	81
Jul	0.35	0.35	0.36	37.33	28.4	28.6	28.8	2384.15	643.7	73
Aug	0.35	0.35	0.36	34.83	28.2	28.4	28.6	2280.49	1277	44
Sep	0.35	0.35	0.36	35.03	28	28.2	28.4	2176.84	1001.3	54
Oct	0.35	0.35	0.36	34.91	27.8	28	28.2	390.54	210.8	46
Nov	0.35	0.35	0.36	34.66	27.6	27.8	28	2176.84	1262.5	42
Dec	0.35	0.35	0.36	29.45	27.5	27.7	27.9	1464.04	1390.8	5

(Bughio et al., 2022)

Thermal Comfort

Thermal comfort of houses in Quetta



Comfort analysis of a house in Quetta

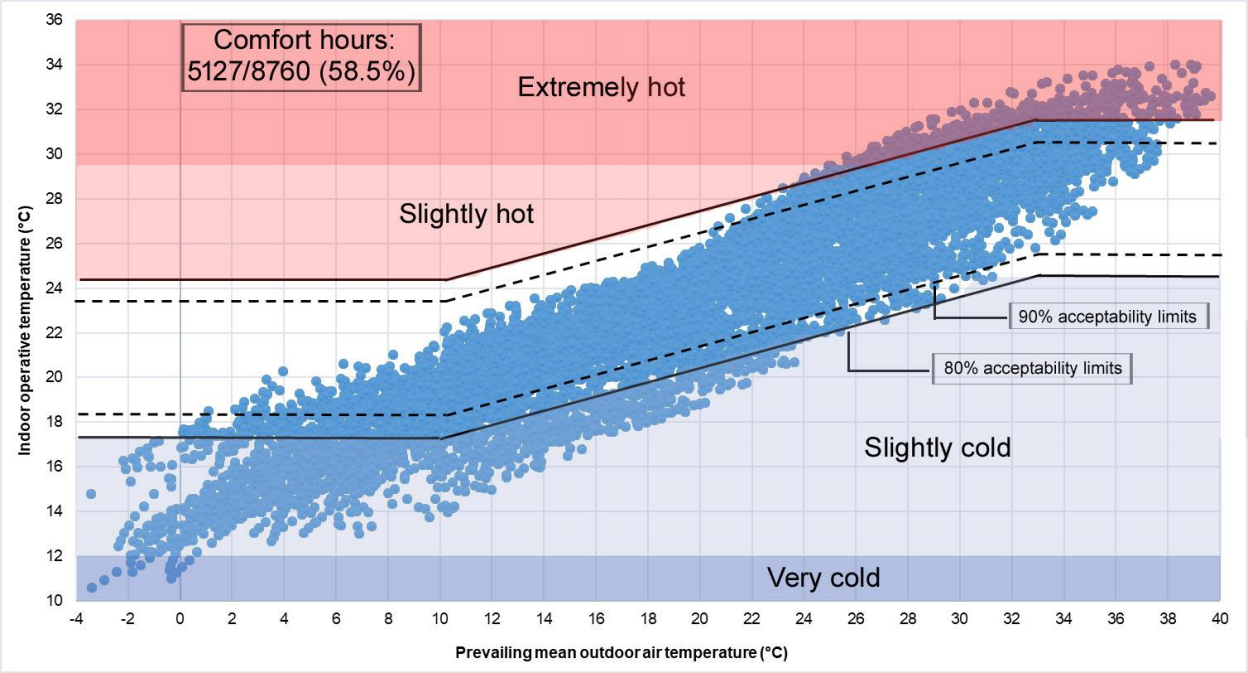
Based on ASHRAE 55 adaptive comfort model

(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)

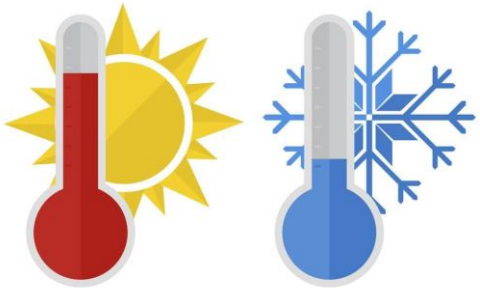
Parametric analysis

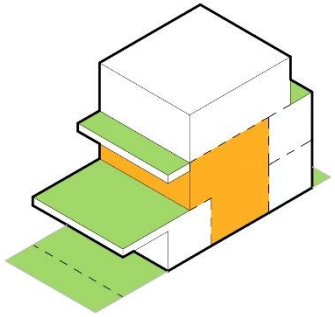
(Mahar et al., 2019)



Challenges

Real challenges (Pakistan)





Barriers

Barriers to EE and Conservation in Pakistan

- **Institutional and Regulatory Barriers**
- **Economic and Financial Barriers**
- **Technical and Operational Barriers**
- **Informational Barriers**

What we should be doing?

Characterization

Benchmarking

Measurement

Monitoring

Assessment

Auditing

Way Forward…

- Knowledge **creation** and knowledge **sharing**
- Revision of the **National Housing Policy 2001**
- Houses: **Comfortable, Energy efficient, climate responsive**
- Focus on **Alternative and Renewable energy** resources
- Active role and participation of **building/ planning and energy** experts
- Building and Energy codes and **compliance** (new and existing buildings)
- **Energy labelling** of appliance and devices.
- **Research**, innovation, promoting **local industries** and **awareness programs**

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