Buildings Guide
Upgrade to ultra-low-energy buildings

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What causes cooling and heating demand in buildings?

Why has space conditioning become indispensible?

Authors
Christopher Moore
Sriraj Gokarakonda

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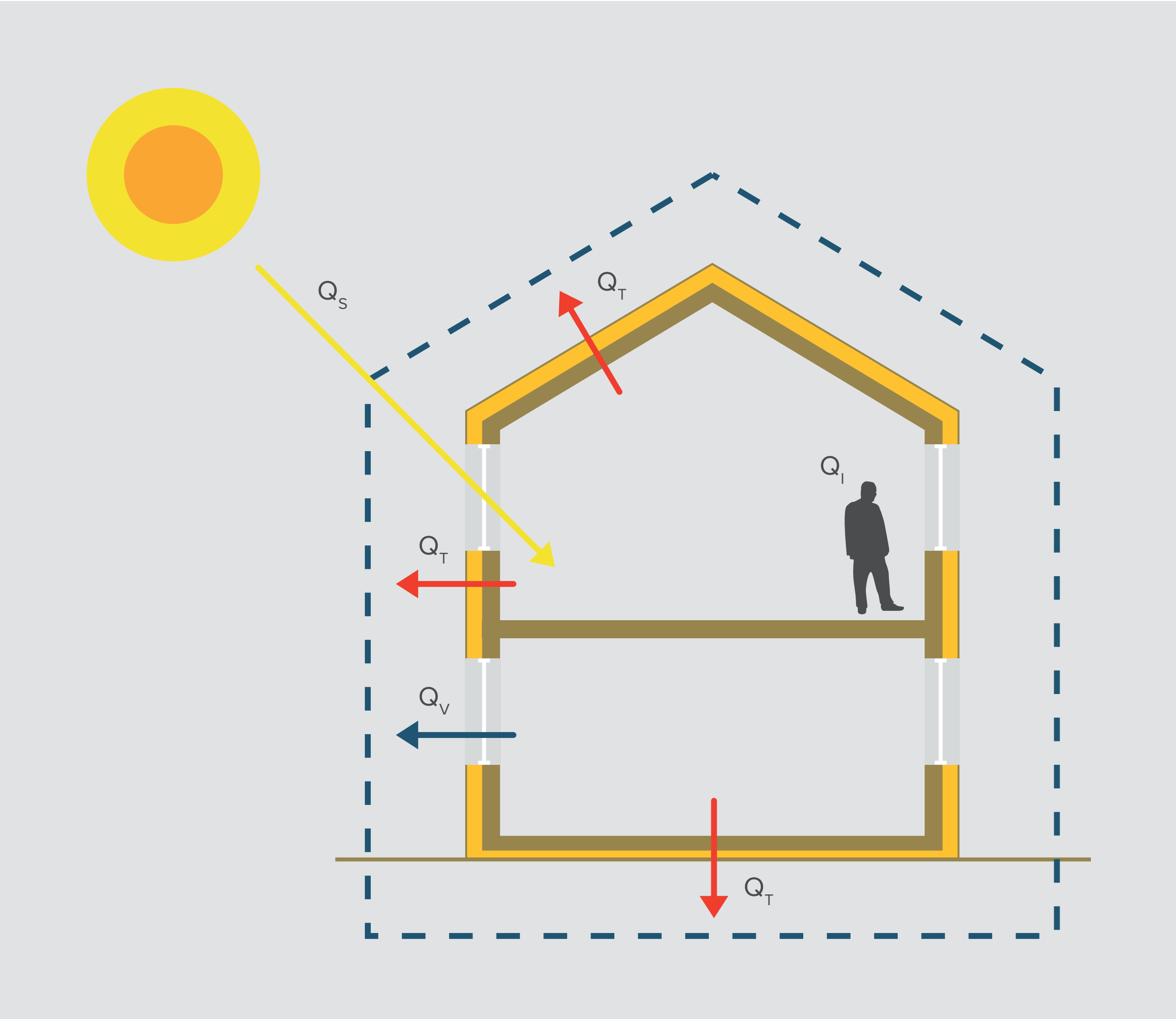
Air conditioning and space cooling are all terms to describe the reduction of indoor temperatures, humidity and/or air quality to comfortable levels for habitation or work in buildings. At its most basic, air conditioning improves comfort levels in buildings and makes space more comfortable in hot and/or humid conditions. However, in extreme temperatures for the climate (such as in Europe in 2003) air conditioning plays an important public health role in reducing the health dangers of very high temperatures on the at risk, such as the very young, elderly and sick.

1 Air conditioning - space heating and space cooling

External heat gain from solar activity is the major reason for the corresponding increase of indoor air temperatures and thus the cooling loads in residential buildings. In addition to external heat gains, in most modern commercial buildings various indoor sources are responsible for significantly adding to the building's internal heat gains compounding the external gains. This includes lighting, computers and other office equipment. The internal gains are much higher in case of industrial and production buildings.

Figure 1: Heat transfer in a building



Q_I – Internal heat gains is the total amount of internal energy gains. This includes heat emitted from humans, equipment and electrical lighting

Q_T – Conductive heat transfer is energy lost by transmission of heat *through* the building envelope to the surroundings

Q_S – Solar heat gain the total amount energy input induced by incoming solar radiation that heats up the indoor air and thermal mass in the building

Q_V – Ventilation heat transfer is caused by supply of fresh air, by removal of stale indoor air to remove smells, CO_2 and other contaminants, infiltration of cold air of exfiltration of warm indoor air through cracks in the building envelope, mixing of air of different temperature zones, and mechanical ventilation

Heat Losses: $Q_T + Q_V = Q_{sink}$

Heat Sources: $Q_S + Q_T + Q_V + Q_i = Q_{source}$

Thermal equilibrium exists when $Q_{sink} = Q_{source}$

If $\mathbf{Q_{sink} < Q_{source}}$ the temperature inside the building rises and the building needs **cooling**.

If $\mathbf{Q_{sink} > Q_{source}}$ the temperature inside the building falls and the buildings needs **heating**.

What is considered comfortable and safe indoor conditions for work or habitation is very much a function of the local climate and what people are accustomed to do. Most people feel comfortable in a temperature range between 18 °C and 26 °C. However, heating, ventilation and cooling industry standards will provide guidelines on what are considered the acceptable bounds for temperature, humidity and air quality.

Why do we need air conditioning in buildings? There are multiple reasons, including:

- To maintain comfort levels, as high indoor temperatures can cause inconvenience and also serious health hazards at times
- Reducing damage from high humidity levels to the interiors of buildings and their contents
- Improving productivity levels in commercial buildings and for home based businesses
- Providing necessary conditions for activities which require precise, controlled indoor air conditions (e.g. data centres, operating theatres, food or medicine processing/handling facilities, etc.)
- Reducing the health risks of high temperatures on vulnerable groups

In hot/humid climates, the need for air conditioning is clear as it significantly improves the comfort levels indoors.

However, the demand for air conditioning is also growing rapidly in cold climates where summers tend to be less extreme and heating demand has been the primary focus. This is in part being driven by the lack of holistic building design. Efforts to reduce the heating consumption of buildings have lead to new airtight buildings with high insulation and designed to harvest passive solar heating. The building design should ensure that while heating demand is reduced in winters; care needs to be taken during summers not to comprehend already existing indoor heat gains with external solar gains. Adequate shading and other passive cooling measures should be taken into account to reduce the dependence on active cooling system to reduce indoor temperatures in summer. This especially applies to commercial buildings with high internal heat gains.

The requirement of active cooling required depends on:

- External temperatures and insolation
- Building design, function and orientation
- Desired indoor temperature and humidity levels
- Insulation and air tightness of the building
- Internal heat gains from people, electrical equipment and other sources

- Occupancy patterns
- Impact of passive cooling measures/design

The design, layout and operation of a building have a significant impact on how the external climatic conditions impact internal temperatures and humidity. The required indoor temperature and humidity have a big impact on energy consumption for cooling and ventilation. In addition, very precise temperature and humidity control will require additional energy consumption to actively maintain the desired levels. Greater flexibility in setting acceptable ranges can reduce energy demand for cooling. Various empirical and theoretical studies show that by increasing the thermostat temperature by 1-3 °C could potentially lead to energy savings of approximately 5-30% (Al-Sanea, Sami, & Zedan) (Aragon et al.). However, the savings vary depending on the building, function, occupancy and the type of systems.

Internal heat gains are another important factor in increasing energy use for space cooling. The heat generated by the use of electrical appliances, in particular larger household white goods, can be significant, but lighting and even small electrical appliances in use or standby mode can also generate significant amounts of heat that need to be abated. The selection and installation of energy efficient appliances wherever feasible will help to reduce these internal heat gains. Climate responsive design, commissioning of all critical building systems and orderly operations and maintenance are key factors to minimising energy consumption for space cooling. Simpler systems that aid passive cooling and ventilation features in combination with adequate active cooling controls can significantly reduce energy consumption.

Active and passive cooling

In addition to designing buildings to ensure that cooling loads are as low as possible (link to passive design parameters page), it is possible to provide active or passive cooling solutions to reduce indoor temperatures and humidity, as well as meet ventilation and air quality needs.

The primary passive cooling solutions are:

- **Night cooling:** this is where diurnal temperature differences are exploited, in conjunction with a buildings thermal mass to reduce cooling loads.
- **Soil or ground cooling:** ground cooling uses the fact that temperatures several metres below ground level are significantly cooler than at the surface. Where possible, earth berming and sunken buildings can take advantage from this mode of passive cooling. Also, the air before being drawn inside the building/system can be precooled by exchanging heat with the earth beneath by circulating the air below ground.
- **Groundwater cooling:** this is similar to ground cooling, in that it takes advantage of the lower temperature of groundwater sources (e.g. from a well) to meet or reduce cooling needs.

The primary active cooling technologies can be divided into the following:

- **Combined heating, cooling and power (CHCP):** this is an efficient means of meeting buildings energy needs for heating, cooling and electricity and can be at an individual building level, or providing cooling through a district cooling network.
- **Solar cooling:** uses the power of the sun to heat a working fluid that can be used in thermally driven chillers to provide the cooling of a building.

- **Conventional air conditioning systems:** Room air conditioners and centralised space cooling systems, predominantly based on the vapour-compression cycle is the incumbent cooling technology. The energy consumption for cooling of these systems can be reduced significantly by shifting to the most efficient commercial systems available today.

2 References

Al-Sanea, Sami, A., & Zedan, M. *Optimized monthly-fixed thermostat-setting scheme for maximum energy-savings and thermal comfort in air-conditioned spaces.* Applied Energy .

Peffer, T., Pritoni, M., Meier, A., Aragon, C., & Perry, D. *How people use thermostats in homes: A review.*