**Task 4: Socio-economic building energy demand response**

For this experiment we will estimate the changes in building energy response to changes in floorspace and the increased local temperatures in response to the UHI effect from Tasks 1 and 2. We will use the methodology used in the Global Change Analysis Model (GCAM) as documented in several past studies such as Eom et al., 2012, Zhou et al., 2013, Clarke et al., 2018, and Khan et al. 2020. The methodology we will use breaks the building sector into three energy services: heating, cooling, and “other” services, which fits in well with this study as it allows us to investigate the temperature impacts independently of “other” services such as cooking, lighting, refrigerators, and televisions. The building energy demands for heating and cooling per unit of floorspace will be calculated as shown in equations 1 and 2 below, where dH and dC represent the energy demands for heating and cooling respectively. Each of these equations can be divided into three components shown in different colors in the equations and described subsequently.

|  |  |  |
| --- | --- | --- |
|  |  | (1) |
|  |  | (2) |

where = Heating

= Cooling

= Energy demand per unit of floorspace (GJ/m2)

= Unitless calibration coefficient

= Heating degree hours (hour °C)

= Cooling degree hours (hour °C)

= Thermal conductance (GJ/m2 hour °C)

= Unitless average surface-to-floor area ratio

= Internal gain [GJ/m2]

= Region and sector specific demand satiation

= Per-capita income

= Total price of service (Weighted average of technologies used)

The first component shown in blue, represents a calibration parameter (k), that can be calculated for each region of interest. This parameter can be thought to characterize the ratio of a “satiated heating and cooling demand” term (i.e. without economic constraints) for a chosen calibration year, to the local temperature and building characteristics for that year. This is calculated by first setting the per capita income () to infinite which results in the purple part of the equation (representing the economic effect) being removed. The service demands for heating and cooling as well as the remaining elements of the equation are then set for a chosen base year and the kH and kC parameters calculated accordingly.

The second component of the equation, shown in orange, represents the impacts of changes in temperature as well as any changes in building characteristics. Heating Degree Days (HDD) and Cooling Degree Days (CDD) are defined as the summation of temperature differences from a subjective reference temperature which was set at 65oF (18oC) based on the methodology used by National Ocean and Atmospheric Administration (NOAA) [NOAA 2015]. These are typically calculated for each month using the day as a baseline unit but can also be adjusted to be used for any time period as done in the case of Heating Degree Hours (HDH) and Cooling Degree Hours (CDH) in Khan et al. 2021. This component of the equation also represents certain building characteristics captured in the terms: η representing the building shell conductivity; the term R representing the ratio of floorspace to building area; and the term IG representing the internal gains associated with the heat released by “other” energy services such as appliances.

The third and final component in (purple) represents the economic effects on the demands. It indicates the fraction of the “satiated demand” (described earlier) that is achieved, which increases with the affordability of the services. The affordability is measured as per capita income divided by the price of the service (weighted average of the estimate of technologies being used). Therefore, affordability and, consequently, service demands increase if per capita income increases or if the price of the service decreases. The µ parameter is the satiation impedance, and it represents the level of affordability required to achieve half the satiation. This is the second calibration parameter and similar to k, is calculated based on the per capita service demand and the affordability (per capita income and service price) in the chosen calibration year.

The heating and cooling building energy demands will be calculated and combined with the estimates for changes in total floorspace in response to urbanization and urban expansion. Finally, the relative increases in building energy demands will be compared to total energy demands and emissions for the region in order to estimate implications on energy generation and corresponding emissions.

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* NOAA 2005. *Explanation of the weekly and monthly degree day data*. <https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/degree_days/ddayexp.shtml> (2005).

Scenarios

Inputs Needed

* Scenarios – w, w/o UHI?
  + Scope of Project:
    - Base year (2008)
    - Future year without UHI (2018)
    - Future year with UHI
  + Beyond the scope of the
* Spatial Scope:
  + Consider gridded vs.
  + Spatial polygons (Cities, counties, states, Land cover maps w/ urban area)
  + LULC maps for 2008 and 2018 gridded
* Temperature gridded
* HDD/CDD – thermal comfortable temperature, per region
* Floorspace/Area/Average Building heights
  + Hicham – Masterplan assumptions
  + Masterplans available for 2016, 2017
* Building energy demands