Impact of climate change on building energy use in hot humid climate regions

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Introduction

- It is widely known that the energy demand changes due to climate change have economic impacts.
- Historically, **Degree Days (DDs)** have widely been calculated based on daily mean temperature to estimate building energy demand under varying climatic conditions, which is according to ASHRAE standard.

$$HDD_t = \prod_{d=1}^{D_t}(T_{ref} - T_a)_d^+ ,\ CDD_t = \prod_{d=1}^{D_t}(T_a - T_{ref})_d^+$$

- However, this ASHERE approach of estimating DDs may not fully capture the impacts of climatic conditions on building energy demand.
- By considering other factors, such as daily maximum, minimum temperature, and relative humidity, we might uncover a more comprehensive view of the economic impacts stemming from building energy demands in a changing climate
- In this study, we focused on East Asia(China, Japan, and Republic of Korea), regions predominantly characterized by hot, humid summers and cold, dry winters.
- Our aim was to understand better how these distinct climatic factors influence building energy demand and its consequent economic effects

Method

1. Degree Days Calculation Method

- To compare each DD calculation method, we applied four approach : 1)ASHERE 2)UKMO 3)UKMO with HI 4)UKMO with HUM

- ***UKMO***

$$CDD_d = \begin{cases} \bar{T} - T_b & T_{min} \geq T_b \\ 0.5 * \Delta T_{max} - 0.25 * \Delta T_{min} & T_{max} > T_b \text{ and } \Delta T_{max} > \Delta T_{min} \\ 0.5 * \Delta T_{max} & T_{min} < T_b \text{ and } \Delta T_{max} < \Delta T_{min} \\ 0 & T_{max} \leq T_b \end{cases}$$

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- ***Heat Index***

HI = 0.5 · [T + 61 + 1.2 · (T − 68) + 0.094 · RH]

(T : ℉, RH : Relative Humidity, %)

- ***Humidex(HUM)***

$$HUM = T + 0.5555 \cdot (6.11 \cdot e^{5417.7530 \cdot (\frac{1}{273.16} - \frac{1}{T_{dew}})} - 10)$$

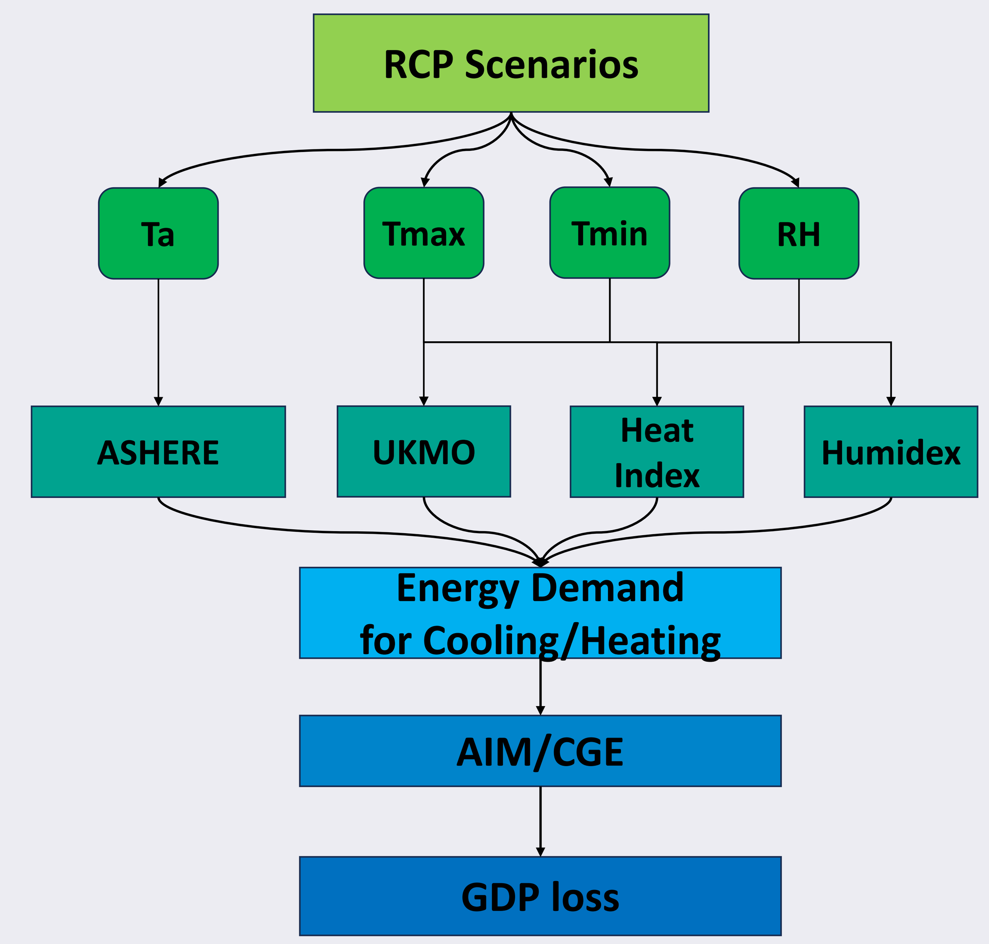
$$T_{dew} = T - \frac{100 - RH}{5}$$

(T : K, RH : Relative Humidity, %)

	Description
Year	• 2006 – 2100
Scenario	• RCP2.6 • RCP4.5 • RCP8.5
Study Area	• East Asia(China, Japan, and South Korea)
Climate Model	• HADGEM2-ES
DD calculation	• ASHERE(Mean temp) • UKMO(Tmax, Tmin) • UKMO + HI(Tmax, Tmin, RH) • UKMO + HUM(Tmax, Tmin, RH)
Reference temperature	• CDD : 22℃, HDD : 18℃
Rescale	• Gridded population- and area-weighted

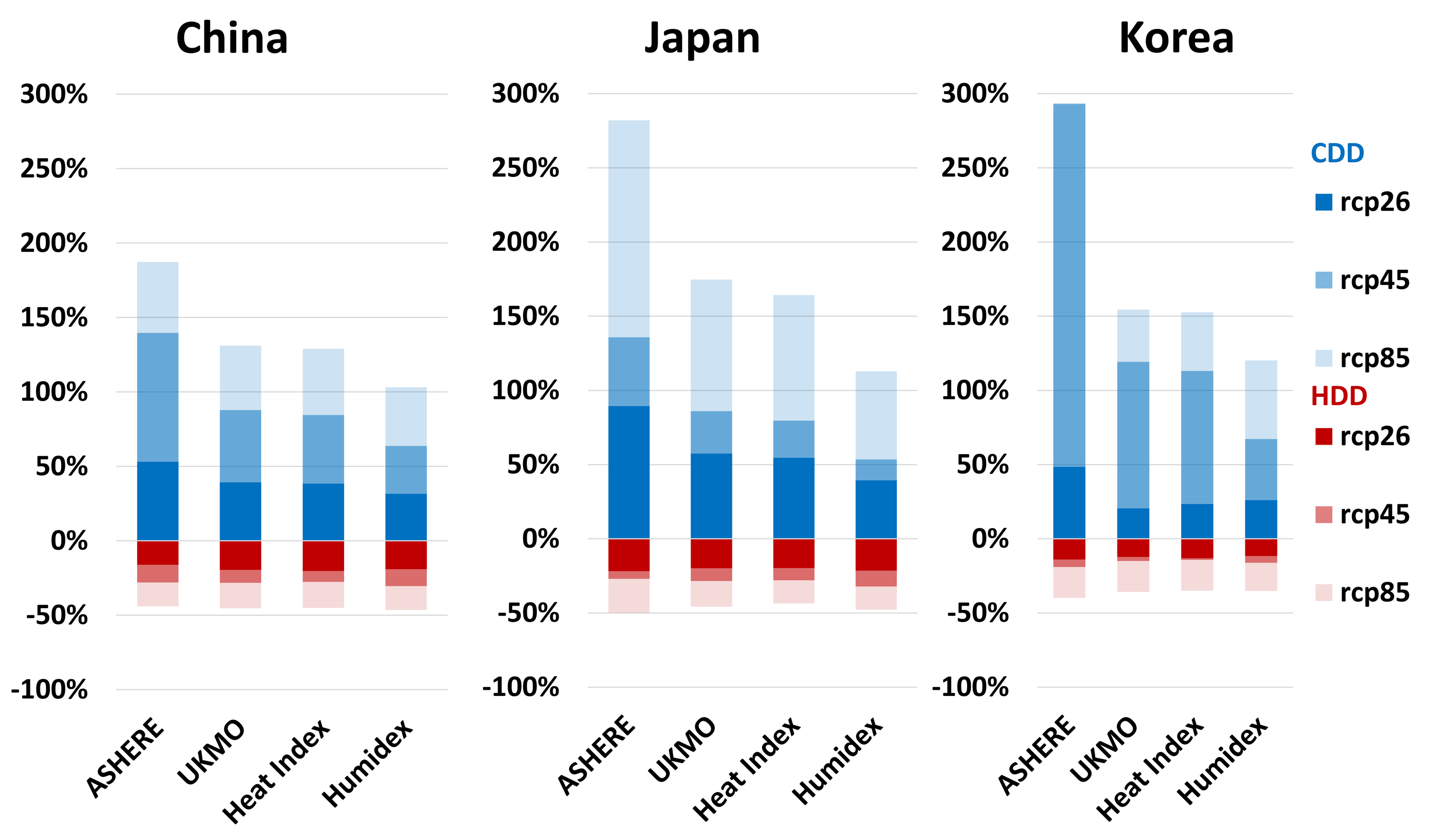
2. Economic Impacts Estimation

- We fixed initial energy demand(2005 from IEA data) and estimated building energy demand along with CDD/HDD (Park et al., 2018)
- Employing building energy demand on the AIM/CGE model, GDP changes between scenarios would be economic impacts



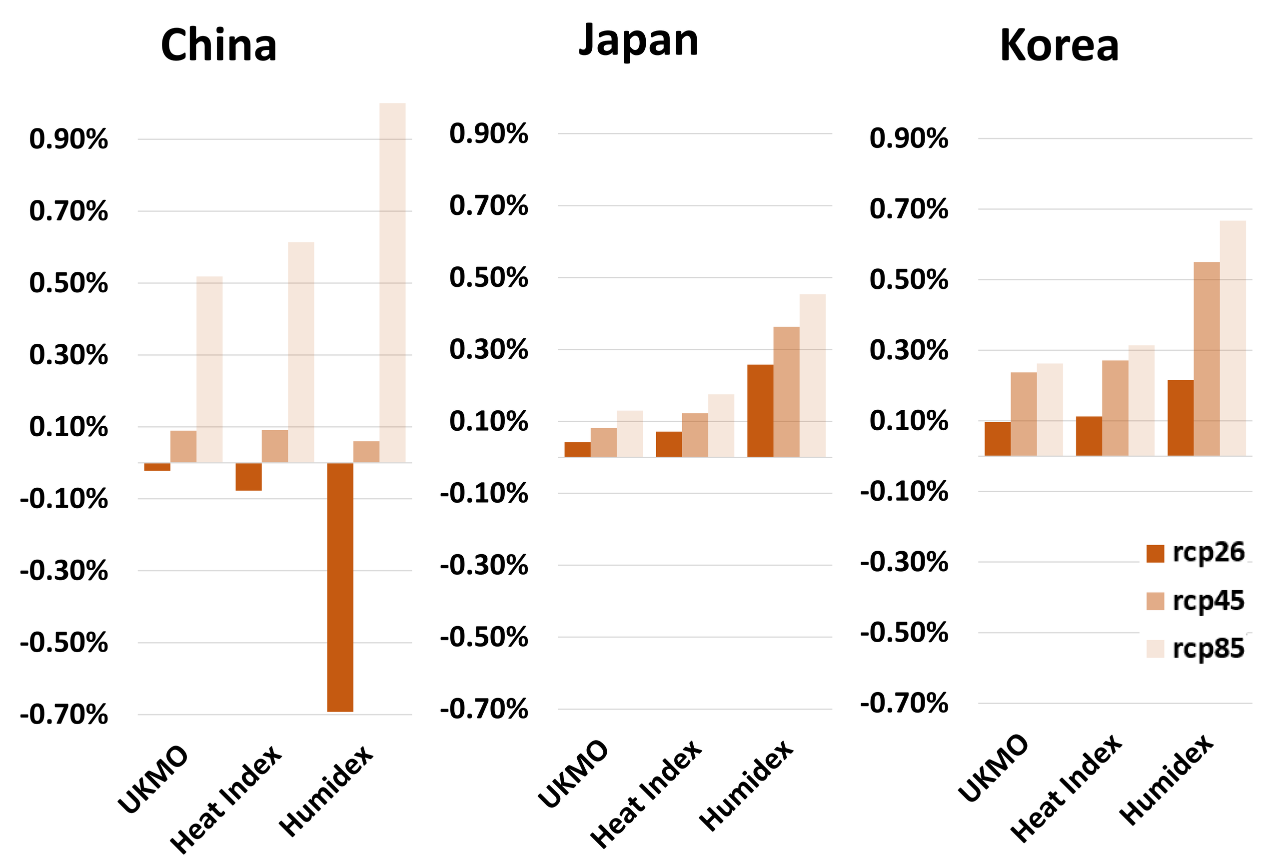
Results

1. Degree Days changes compared to 2005 and 2100



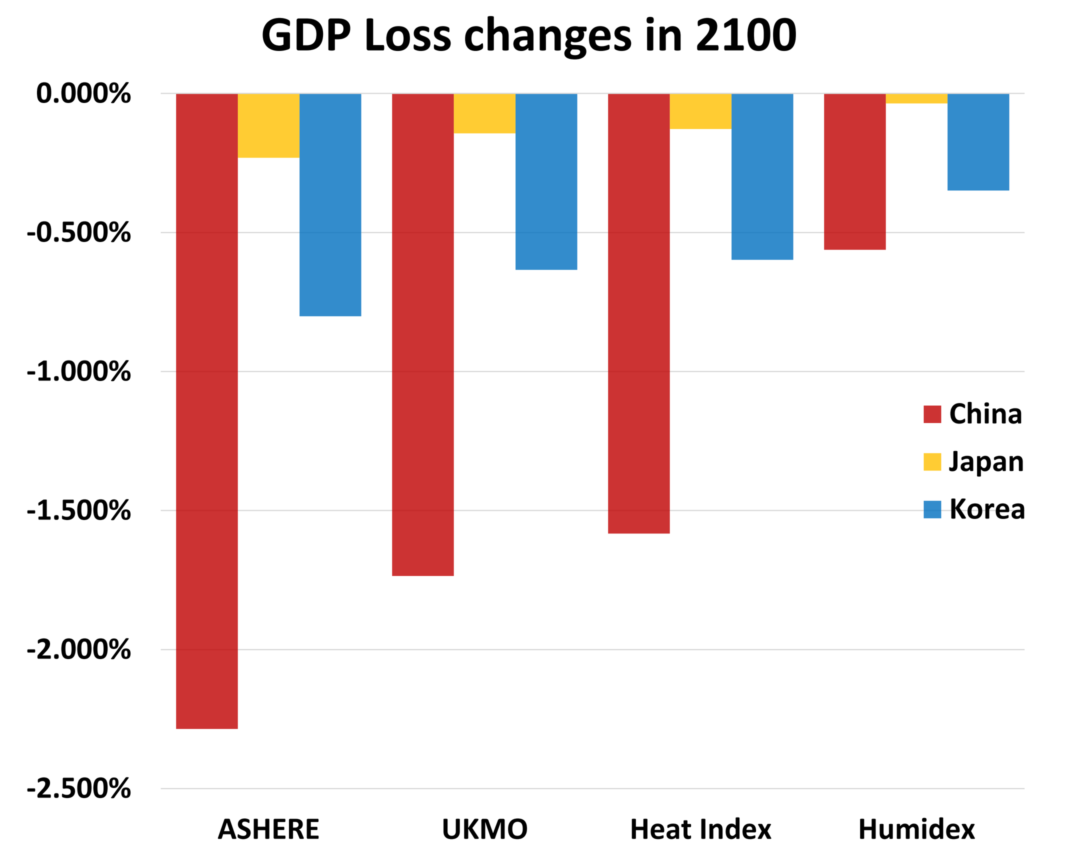
- All countries in East Asia showed consistent changes in Degree Days (DDs), revealing that Cooling Degree Days (CDD) would be increased and Heating Degree Days (HDD) decreased
- It also showed that ASHERE methods tend to overestimate CDDs and underestimate HDDs compared to other methods(UKMO, HI, HUM)

2. GDP changes in each climatic scenario compared to the ASHERE method in 2100



- Most results indicated that GDP would be highly estimated without using the ASHERE methods.
- Furthermore, considering relative humidity when estimating building energy demand resulted in reduced GDP loss; however, China showed opposite trends under the RCP2.6 scenario due to variations in HDD over yearly intervals.

3. GDP loss compared to RCP2.6 and RCP8.5



- Compared to RCP8.5 and RCP2.6 in each method, regardless of deviations between countries, all results indicated that GDP loss due to climatic conditions may be overestimated under ASHERE DD calculation, which only uses daily mean temperature

Discussion & Conclusion

- In regions like East Asia, the economic damages from increased energy demand might be overestimated if additional weather variables are considered.
- Given that human thermal comfort is a primary determinant of heating and cooling energy demand, it is essential that Degree Day (DD) estimations incorporate these factors.
- It remains crucial to determine if such findings hold consistent across different climatic zones
- Also, evaluating these economic impacts within contexts such as carbon-neutral societies and amidst technological advancements might yield a broader spectrum of narratives regarding energy demand changes
- Limitations include the necessity to use a climate model ensemble and to verify findings across diverse climatic regions
- Future research is pivotal in addressing these challenges

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