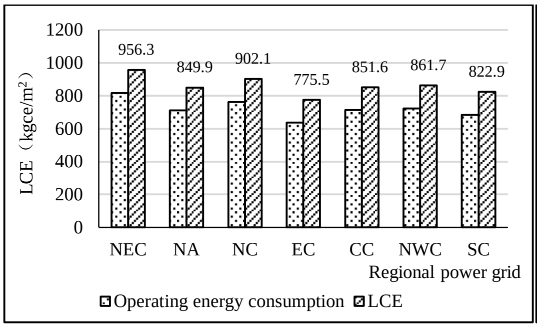
**Table 1.** *Abbreviations used in Figure 2 and Figure 3*

| Regional power grids | Northeast China | National average | North China | Eastern China | Central China | Northwest-ern China | South China |
|---|---|---|---|---|---|---|---|
| Abbreviations | NEC | NA | NC | EC | CC | NWC | SC |



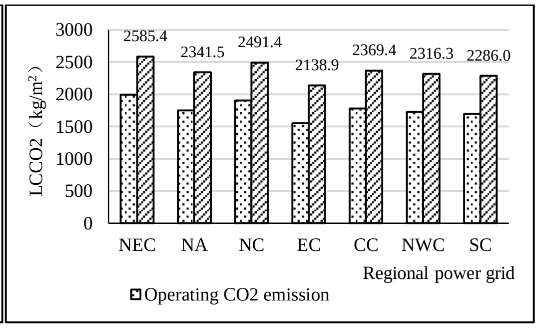




***Figure 2 (left).*** *LCE calculated by using electric power energy consumption factors for regional power grids*

***Figure 3 (right).*** *$LCCO_2$ calculated by using electric power emission factors for regional power grids*

The figures show that the building LCE and $LCCO_2$ results calculated by using Northeast power grid data (956.3kgce/m$^2$ and 2585.4kg$CO_2$/m$^2$) are respectively 12.52% and 10.42% higher than those calculated by using national average data (809.5kgce/m$^2$ and 2341.5kg$CO_2$/m$^2$). Therefore, it will be much more accurate using the local electric power factors than using the national average in the calculation of this case, and it also indicates that it is a must to consider the representativeness of the data used in building LCA analysis. Therefore, the conclusions of researches that have not taken this factor into consideration may not be accurate [8,9].

**Technical difference**

Compared with data time-effectiveness and regional representativeness, the technical difference of data is much more complicated. It is reflected in all aspects of the building such as building envelope and equipment, and its impact on LCE and $LCCO_2$ varies due to different technical factors. This research mainly analyzed the influence of wall insulating layer and window.

· **Wall insulation**

There has been a lot of studies about the influence of thermal insulation material and insulation layer thickness on building LCE and $LCCO_2$ in the existing literature, however, there are no consideration of the insulation performance worse with time.

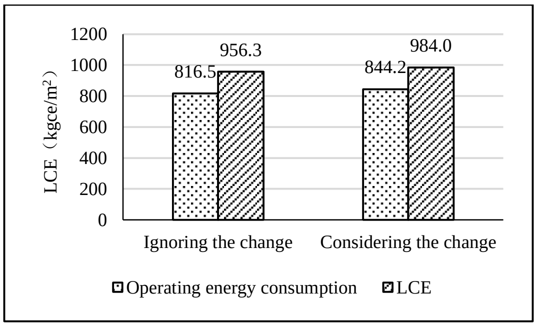



**Figure 4.** *Impact on calculated LCE*

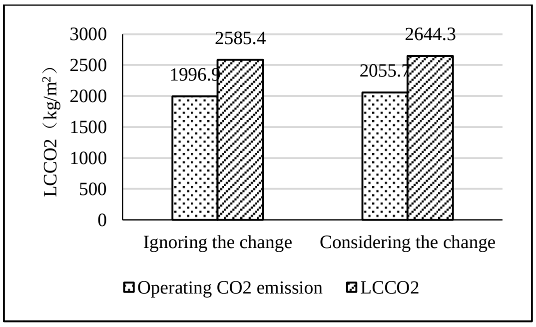



**Figure 5.** *Impact on calculated $LCCO_2$*

The material of the thermal insulation in this housing case is a kind of polyurethane foam with the service life of 25 years, and the U-value of the external wall is 0.6W/(m²•K). Assuming that the U-value of the external wall increases by 2% linearly every year, then the equivalent U-value of the wall in insulation's life cycle is 0.79W/(m²•K). The calculated LCE and $LCCO_2$ results under the above hypothesis are shown in Figure 4 and Figure 5.

It turned out that LCE and $LCCO_2$ increase by 2.90% and 2.28% respectively when considering the insulation performance's change over time, so this factor could be neglected in LCA analysis because error within 5% is acceptable.

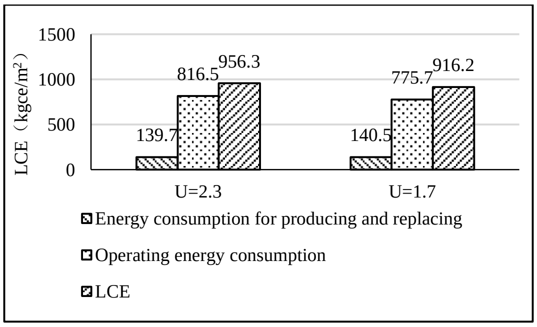
· **Window**

Similarly, the thermal characteristics of the window are also studied for comparison. The choice of the window should firstly satisfy the U-value specification for the area where the building is located. It is required that the U-value of the window should be no higher than 2.3W/(m²•K) in cold areas of China, which means windows satisfying the above regulations are feasible in this housing case.

Given that the U-value of the window equals to 2.3W/(m²•K), there still exists a variety of standard configurations. Different configurations will not affect the building operation stage, but will affect the materials production stage. The production energy consumption and $CO_2$ emission per unit are respectively 51.71kgce/(m²window) and 114.6kg$CO_2$/(m²window) for aluminum wood composite windows, while the values are 83.28kgce/(m²window) and 188.7kg$CO_2$/(m²window) for bridge cut-off aluminum alloy windows. The calculated LCE and $LCCO_2$ results of the above two options are shown in Table 2, but the deviation is only about 1%, which is acceptable.

***Table 2.*** *Calculated LCE and $LCCO_2$ for different standard configurations of window*

| | LCE（kgce/m²） | $LCCO_2$（kg/m²） |
|---|---|---|
| Aluminum wood composite windows | 956.3 | 2585.4 |
| Bridge cut-off aluminum alloy windows | 967.7 | 2612.2 |
| The increasing proportion (%) | 1.19 | 1.04 |



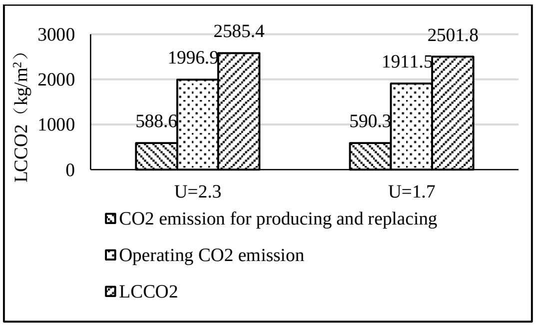




***Figure 6 (left).*** *Calculated LCE for different U-values of window*

***Figure 7 (right).*** *Calculated $LCCO_2$ for different U-values of window*

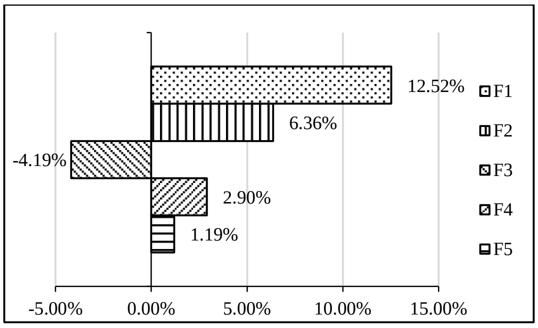
In addition to the different standard configurations, there is another common situation when choosing windows: in order to better satisfy the requirements of the design specifications, engineers usually choose windows with lower U-value than required. This difference of choices will not only affect the materials production stage, but also have a great influence on the building operation stage. This research carried out a comparison analysis on LCE and $LCCO_2$ when the U-value of aluminum wood

composite window decreases from 2.3W/(m$^2$•K) to 1.7W/(m$^2$•K) (as shown in Figure 6 and Figure 7).
Different U-values of the window have very small impact on energy consumption and $CO_2$ emission for materials' production and replacement, but can greatly reduce the operating energy consumption and $CO_2$ emission, thus reducing building LCE and $LCCO_2$ (see Table 3). This is an effective way of energy saving and emission reduction in engineering practice.

***Table 3.*** *Impact on LCE and $LCCO_2$ when the U-value of window decreases from 2.3 to 1.7 W/(m$^2$•K)*

| | Change of energy consumption (%) | Change of $CO_2$ emission (%) |
|---|---|---|
| Producing and replacing | +0.56 | +0.29 |
| Operating | -5.00 | -4.27 |
| LCE/$LCCO_2$ | -4.19 | -3.23 |

**Influence degree comparison**
It can be concluded from the previous analysis that, in terms of electric power energy consumption factor and emission factor, the influence of data representativeness (*F1*, standing for *"Factor 1"*) on building LCE and $LCCO_2$ is greater than data time-effectiveness (*F2*). By contrast, the deviation caused by technical difference is smaller, the technical factors are, in order of influence degree, U-value of the window (*F3*), change of the insulation performance over time (*F4*) and configurations of window with the same U-value (*F5*) (see Figure 8 and Figure 9).



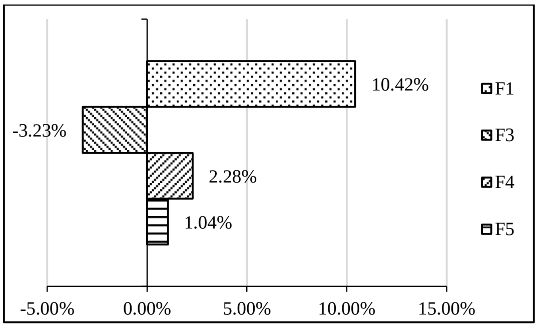



***Figure 8 (left).*** *Impact comparison of different factors on calculated LCE*
***Figure 9 (right).*** *Impact comparison of different factors on calculated $LCCO_2$*

## CONCLUSION AND IMPLICATIONS
In order to analyze the impacts of different factors on building LCE and $LCCO_2$, this research carried out a simulation study with a residential building in cold areas of China from the perspective of the data. Firstly, these impact factors are divided into three categories: time difference, regional difference and technical difference. The time difference of data is caused by the time-effectiveness, the regional difference of data reflects whether the data used in the building LCA are representative regionally, and the technical difference can be indicated by the human designs and choices. Then, we select comparatively typical factors from the above three types and analyze their impacts on LCA results by simulation and calculation.
The detailed conclusions are as follows:
1) The electric power energy consumption factor decreased by 11.1% from 2005 to 2011, and the deviation on LCE caused by using the data of the two different years

can reach 6.36%, indicating that building LCE and $LCCO_2$ should be calculated by using data of the latest four years to ensure the result error within 5%.
2) The building LCE and $LCCO_2$ calculated by using Northeast power grid data are 12.52% and 10.42% higher than those obtained by using national average data respectively. Therefore, in building LCA analysis, it is a must to use the local electric power factors to ensure the results accurate and reliable. In terms of electric power energy consumption factor and emission factor, the influence of data representativeness on building LCE and $LCCO_2$ is greater than data time-effectiveness.
3) It turned out that calculated LCE and $LCCO_2$ increase by 2.90% and 2.28% respectively when considering the insulation performance's change over time, so this factor could be neglected in LCA analysis because error within 5% is acceptable, but further studies about how the U-value of wall changes over time will be needed.

## ACKNOWLEDGEMENTS

This work was supported by China National 12th-Five Project (ID: 2011BAJ04B06-3) and the National Natural Science Foundation of China (ID: No51222814).

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