# epwshiftr: Create future EnergyPlus Weather files using CMIP6 data

**Hongyuan Jia**[1] **and Adrian Chong**[2]

**1** School of Civil Engineering and Architecture, Chongqing University of Science and Technology **2** Department of the Built Environment, National University of Singapore

**DOI:** 10.21105/joss.04030

**Software**

- Review
- Repository
- Archive

**Editor:** Kristina Riemer

**Reviewers:**

- @mitmat
- @bczernecki

**Submitted:** 21 November 2021
**Published:** 31 December 2021





## Summary

Building energy simulation (BES) has become increasingly applied to assess building performance under climate changes and yield a more sustainable and resilient design (Yassaghi & Hoque, 2019). Multiple morphing-based weather-file modification tools have been developed to integrate climate change predictions (Troup, 2016). Most of the widely adopted weather generators, including CCWorkdWeatherGen (Jentsch et al., 2008), Meteonorm (Remund et al., 2020), and WeatherShift (Dickinson & Brannon, 2016), use GCM (Global Climate Models) data from the CMIP (Coupled Model Intercomparison Project) that covers worldwide locations.

Currently, the CMIP project is in its sixth phase (CMIP6) (Eyring et al., 2016), which has developed new emission scenarios that have a similar range as its fifth phase (CMIP5) but fill critical gaps for intermediate forcing levels (O'Neill et al., 2016). It will be used in the Sixth IPCC (Intergovernmental Panel on Climate Change) Climate Assessments Reports (IPCC, 2021). However, existing tools based on the previous CMIP were unable to utilize the data from the latest climate change research. Currently, there are no tools available that could process user-defined climate simulations in an automated way and allow further statistical analysis.

The epwshiftr package bridges these gaps. It is a free, open-source R package for adapting a whole-building energy simulation EnergyPlus (Crawley et al., 2001) Weather (EPW) files to incorporate climate change predictions using the morphing statistical downscaling method (Belcher et al., 2005). The primary goal is to automatically process large amounts of climate change prediction outputs from the CMIP6 (CMIP Phase 6) GCMs and create future climate data for BES across worldwide locations in a user-friendly and flexible way.

## Epwshiftr R package

Epwshiftr is capable of processing multiple GCM outputs at various spatial and temporal resolutions. Additionally, the package is designed in a modular manner for flexibility and extensibility. There are five modules in total, and the table below lists their corresponding names and functionalities.

**Table 1:** The modules designed in the epwshiftr package

| Module name | Description |
|---|---|
| Query module | Query and store metadata of online CMIP6 GCM outputs via the ESGF (Earth System Grid Federation) Search RESTful API. Meta includes the name of GCM, the institution that developed the GCM, emission scenarios, output interval, nominal resolution, output variable, output unit, etc. |
| Database module | Create and manage a local database of GCM outputs using NetCDF files downloaded in the ESGF portal. |
| Data Extraction Module | Extract climate variable data of desired temporal domain and specified grid distances to the input baseline EPW file |
| Morphing Module | Calculate future weather data under the latest CMIP6 emission scenarios using the morphing method |
| EPW Generation Module | Create future EPW files using various data aggregation strategies using the eplusr package (Jia & Chong, 2021) |

Each module stores climate data in a consistent Tidy (Wickham, 2014) data format, allowing exploring a considerably broad pool of ready-to-use methods available in R for customized statistical analysis. Computational-intensive processes have been designed to run in parallel for speed-up.

The epwshiftr is distributed via CRAN (The Comprehensive R Archive Network). The source code is available on GitHub at https://github.com/ideas-lab-nus/epwshiftr and released under the MIT license.



# Acknowledgements

This research was funded by the Republic of Singapore's National Research Foundation through a grant to the Berkeley Education Alliance for Research in Singapore (BEARS) for the Singapore-Berkeley Building Efficiency and Sustainability in the Tropics (SinBerBEST) Program. BEARS has been established by the University of California, Berkeley as a center for intellectual excellence in research and education in Singapore.

# References

Belcher, S., Hacker, J., & Powell, D. (2005). Constructing design weather data for future climates. *Building Services Engineering Research and Technology*, *26*(1), 49–61. https://doi.org/b4z2gp

Crawley, D. B., Lawrie, L. K., Winkelmann, F. C., Buhl, W. F., Huang, Y. J., Pedersen, C. O., Strand, R. K., Liesen, R. J., Fisher, D. E., Witte, M. J., & Glazer, J. (2001). EnergyPlus: Creating a new-generation building energy simulation program. *Energy and Buildings*, *33*(4), 319–331. https://doi.org/10.1016/s0378-7788(00)00114-6

Dickinson, R., & Brannon, B. (2016). *36 th International Conference on Passive and Low Energy Architecture*. 6.

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. (2016). Overview of the coupled model intercomparison project phase 6 (CMIP6) experimental design and organization. *Geoscientific Model Development*, *9*(5), 1937–1958. https://doi.org/10.5194/gmd-9-1937-2016

IPCC. (2021). *Climate change 2021: The physical science basis. Contribution of working group i to the sixth assessment report of the intergovernmental panel on climate change*. https://www.ipcc.ch/report/ar6/wg1/

Jentsch, M. F., Bahaj, A. S., & James, P. A. B. (2008). Climate change future proofing of buildingsGeneration and assessment of building simulation weather files. *Energy and Buildings*, *40*(12), 2148–2168. https://doi.org/b4n9qc

Jia, H., & Chong, A. (2021). eplusr: A framework for integrating building energy simulation and data-driven analytics. *Energy and Buildings*, *237*, 110757. https://doi.org/10.1016/j.enbuild.2021.110757

O'Neill, B. C., Tebaldi, C., Vuuren, D. P. van, Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R., Kriegler, E., Lamarque, J.-F., Lowe, J., Meehl, G. A., Moss, R., Riahi, K., & Sanderson, B. M. (2016). The scenario model intercomparison project (ScenarioMIP) for CMIP6. *Geoscientific Model Development*, *9*(9), 3461–3482. https://doi.org/10.5194/gmd-9-3461-2016

Remund, J., Müller, S., Schmutz, M., & Graf, P. (2020, September 7). *38th european photovoltaic solar energy conference and exhibition*. https://meteonorm.com/assets/publications/5BV.3.8_pvsec_2020_mn8.pdf

Troup, L. (2016). *Building Performance Modeling Conference*. 8.

Wickham, H. (2014). Tidy Data. *Journal of Statistical Software*, *59*(1), 1–23. https://doi.org/10.18637/jss.v059.i10

Yassaghi, & Hoque. (2019). An Overview of Climate Change and Building Energy: Performance, Responses and Uncertainties. *Buildings*, *9*(7), 166. https://doi.org/10.3390/buildings9070166