# Integrating Ecovisor into Mosaik Co-Simulation

Marvin Steinke and Henrik Nickel
*Technische Universität Berlin*

***Abstract*—**

## I. Introduction

THE surge of cloud platforms has had a significant impact on many businesses and individuals, offering access to innovative and valuable applications that frequently require significant computational resources. A notable example for this is represented by OpenAI's chat generative pre-trained transformer (ChatGPT) cloud platform, which is based on the GPT-3 model developed by Brown et al. [1] and achieved more than a million users within the first five days of its launch [2]. The increasing demand for more computational power has lead cloud platforms to become an essential part of the digital landscape [3]. These platforms allow for the storage, processing and management of large amounts of data and computational resources, which can be used to run applications and services that are beyond the capabilities of traditional hardware systems.

However, while the growth of cloud platforms has brought many benefits, it has also raised concerns about their environmental impact. As the demand for computational resources increases, so does the carbon emissions generated by the energy consumption of these platforms [4]. Despite their ecological impact, the growth of cloud platforms shows no signs of slowing down. According to Gartner Inc. worldwide end-user spending on public cloud services is forecasted to grow 20.7% to total $591.8 billion in 2023 [5]. To mitigate their impact on the environment, cloud platforms are now looking for ways to reduce their carbon footprint [6, 7]. It is imperative to adopt cleaner energy sources for powering data centers, both in the cloud and at the edge.

Although clean energy offers numerous advantages, it is perceived as being unreliable due to two key factors. One, the generation of renewable energy sources such as solar and wind is affected by environmental changes, and two, the carbon-intensity of grid power fluctuates as the grid uses different types of generators with varying carbon emissions to meet demand [8]. The field of computing possesses a distinct advantage in terms of reducing its carbon impact through the utilization of cleaner energy sources [9]. However, current cloud applications are unable to apply these benefits to optimize their carbon efficiency. This is because the energy system obscures the instability of clean energy with a reliability abstraction, which gives no control or visibility into the energy supply. As a result, applications cannot adjust their power usage in response to changes in the availability and carbon-intensity of renewable energy [10].

Souza et al. [10] proposed a solution to this issue by creating an "Ecovisor", which virtualises the energy system and provides software-based control over it. This Ecovisor enables each application to manage the instability of clean energy through software, customized to meet its unique requirements. However, even their small-scale prototype is intricately designed and incorporates several expensive components, such as a DC power supply equipped with a solar array simulation capability that costs almost $10,000.

Though the creation of the Ecovisor is a promising solution to the issue of reducing the carbon footprint of cloud platforms, a large scale prototype for research and development purposes would not only be significantly cost intensive, but also time consuming. An alternative approach to consider is to simulate *only* the Ecovisor infrastructure for real applications. This would allow for the optimization of energy usage in response to changes in the availability and carbon-intensity of renewable energy, without the need for a physical implementation. By simulating the Ecovisor, applications can still manage the instability of clean energy through software, but at a lower cost and with less time investment.

To this end, we propose the utilization of a co-simulation tool, Mosaik, to integrate this Ecovisor simulation into and evaluate its impact on the carbon footprint of cloud platforms. Mosaik is a simulation framework for power systems, communication networks, and building automation, which can be used to model and analyze the performance of the Ecovisor in real-world applications [11]. The use of Mosaik brings several benefits compared to traditional simulation methods. It offers a more flexible and scalable simulation environment, enabling the integration of multiple components and the simulation of large-scale systems. Furthermore, it offers a more accurate representation of the energy system, incorporating real-world data and parameters, which can be used to validate the performance of the Ecovisor.

## II. Background

## III. Related Work

The Software- (SIL) or Hardware-In-The-Loop (HIL) methodology is commonly utilized during the development of intricate systems as a means of conducting repeatable and manageable component testing. For instance, Beilharz et al. [12], introduce Marvis, a framework that provides a comprehensive staging environment for testing distributed IoT applications. Marvis orchestrates hybrid testbeds, co-simulated domain environments, and a central network simulation to create a representative operating environment for the system. However, Marvis does not provide a virtualized energy system, which is crucial to meet the requirements of our problem statement.

Hagenmeyer et al. [13] investigate the interplay of different forms of energy on various value chains in Energy Lab 2.0. The focus is on finding novel concepts to stabilize the volatile energy supply of renewables through the use of storage systems and the application of information and communication technology tools and algorithms. The smart energy system simulation and control center is a key element of Energy Lab 2.0 and consists of three parts: a power-hardware-in-the-loop experimental field, an energy grid simulation and analysis laboratory, and a control, monitoring, and visualization center. While this smart energy system simulation is similar to the simulated Ecovisor in our approach, the control center is the only entity with software-based control over this energy system. The Ecovisor infrastructure, however, provides multiple applications with the ability to manage their energy supply themselves which is an essential factor for our approach.

## IV. Approach

## V. Evaluation

## VI. Conclusion

## References


[1] T. Brown, B. Mann, N. Ryder, M. Subbiah, J. D. Kaplan, P. Dhariwal, A. Neelakantan, P. Shyam, G. Sastry, A. Askell *et al.*, “Language models are few-shot learners,” *Advances in neural information processing systems*, vol. 33, pp. 1877–1901, 2020.

[2] G. Brockman, “Chatgpt just crossed 1 million users,” Twitter, dec 2022, accessed: 16.02.2023. [Online]. Available: https://twitter.com/gdb/status/1599683104142430208?s=20&t=-7V8elwpZ93qiIhwxnzVBA

[3] Q. Zhang, L. Cheng, and R. Boutaba, “Cloud computing: state-of-the-art and research challenges,” *Journal of internet services and applications*, vol. 1, pp. 7–18, 2010.

[4] M. A. B. Siddik, A. Shehabi, and L. Marston, “The environmental footprint of data centers in the united states,” *Environmental Research Letters*, vol. 16, no. 6, p. 064017, 2021.

[5] Gartner Inc., “Gartner forecasts worldwide public cloud end-user spending to reach nearly $600 billion in 2023,” oct 2022, accessed: 16.02.2023. [Online]. Available: https://www.gartner.com/en/newsroom/press-releases/2022-10-31-gartner-forecasts-worldwide-public-cloud-end-user-spending-to-reach-nearly-600-billion-in-2023

[6] Google LLC, “Building a carbon-free future for all,” accessed: 16.02.2023. [Online]. Available: https://sustainability.google/commitments/carbon/

[7] Amazon.com, Inc., “Sustainability in the cloud,” accessed: 16.02.2023. [Online]. Available: https://sustainability.aboutamazon.com/environment/the-cloud

[8] N. Scarlat, M. Prussi, and M. Padella, “Quantification of the carbon intensity of electricity produced and used in europe,” *Applied Energy*, vol. 305, p. 117901, 2022.

[9] S. Murugesan, “Harnessing green it: Principles and practices,” *IT Professional*, vol. 10, no. 1, pp. 24–33, 2008.

[10] A. Souza, N. Bashir, J. Murillo, W. Hanafy, Q. Liang, D. Irwin, and P. Shenoy, “Ecovisor: A virtual energy system for carbon-efficient applications,” in *Proceedings of the 28th ACM International Conference on Architectural Support for Programming Languages and Operating Systems, Volume 2*, 2023, pp. 252–265.

[11] C. Steinbrink, M. Blank-Babazadeh, A. El-Ama, S. Holly, B. Lüers, M. Nebel-Wenner, R. P. Ramírez Acosta, T. Raub, J. S. Schwarz, S. Stark, A. Nieße, and S. Lehnhoff, “Cpes testing with mosaik: Co-simulation planning, execution and analysis,” *Applied Sciences*, vol. 9, no. 5, 2019.

[12] J. Beilharz, P. Wiesner, A. Boockmeyer, F. Brokhausen, I. Behnke, R. Schmid, L. Pirl, and L. Thamsen, “Towards a staging environment for the internet of things,” in *2021 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops)*, 2021, pp. 312–315.

[13] V. Hagenmeyer, H. Kemal Çakmak, C. Düpmeier, T. Faulwasser, J. Isele, H. B. Keller, P. Kohlhepp, U. Kühnapfel, U. Stucky, S. Waczowicz, and R. Mikut, “Information and communication technology in energy lab 2.0: Smart energies system simulation and control center with an open-street-map-based power flow simulation example,” *Energy Technology*, vol. 4, no. 1, pp. 145–162, 2016.