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RAMP: stochastic simulation of user-driven energy demand time series

Francesco Lombardi [1¶], **Pierre-François Duc** [2], **Mohammad Amin Tahavori** [3], **Claudia Sanchez-Solis** [4,7], **Sarah Eckhoff** [5], **Maria C. G. Hart** [5], **Francesco Sanvito** [1], **Gregory Ireland**[2,6], **Sergio Balderrama**[7], **Johann Kraft**[2], **Gokarna Dhungel**[2,8], **and Sylvain Quoilin**[4]

1 TU Delft, Faculty of Technology, Policy and Management, Delft, The Netherlands **2** Reiner Lemoine Institut, Berlin, Germany **3** VITO, Mol, Belgium **4** University of Liège, Integrated and Sustainable Energy Systems, Thermodynamics Laboratory, Liège, Belgium **5** Leibniz Universität Hannover, Information Systems Institute, Hannover, Germany **6** University of Cape Town, Cape Town, South Africa **7** Universidad Mayor de San Simon, Centro Universitario de Investigacion en Energias, Cochabamba, Bolivia **8** University of Applied Sciences Nordhausen, Nordhausen, Germany ¶ Corresponding author

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Summary

The urgency of the energy transition is leading to a rapid evolution of energy system design worldwide. In areas with widespread energy infrastructure, existing electricity, heat and mobility networks are being re-designed for carbon neutrality and are increasingly interconnected. In areas where energy infrastructure is limited, instead, networks and systems are being rapidly expanded to ensure access to energy for all. In both cases, re-designing and expanding energy systems in these directions requires information on future user behaviour and associated energy demand, yet this type of data is often unavailable. In fact, historical data are often either entirely missing or poorly representative of future behaviour within transitioning systems. This results in reliance on inadequate demand data, which affects system design and its resilience to rapid behaviour evolution.

Statement of need

RAMP is an open-source, Python-based software suite that enables the stochastic simulation of any user-driven energy demand time series based on few simple inputs. In fact, the software is designed to require only a basic understanding of the expected user activity patterns and owned appliances as inputs, which are provided in tabular format (`.xlsx`). For instance, a minimal definition of a user type (e.g., a certain category of households) requires only information about which energy-consuming devices they own, when, on a typical day, they tend to use them, and for how long in total. Then, the software leverages stochasticity (using the `random` package) to make up for the lack of more detailed information and to account for the unpredictability of human behaviour (see Figure 1). This way, RAMP allows generating and visualising synthetic data wherever detailed metered data does not exist, such as when designing systems in remote areas (Lombardi et al., 2019) or when looking at future electric-vehicle fleets (Mangipinto et al., 2022).

Reliance on simple inputs distinguishes RAMP from comparable tools. For instance, other popular open-source demand simulation tools, such as CREST (McKenna et al., 2015) and demod (Barsanti et al., 2021), are based on extensive and context-specific input datasets from the UK and Germany, respectively, which populate the occupancy model at the core of their approach. Similarly, the Load Profile Generator model (Pflugradt et al., 2022), also openly