# Sustainable Energy System Planning in Developing Countries: Facilitating Load Profile Generation in Energy System Simulations

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## Abstract

*Successful energy system planning is dependent on detailed electricity demand information. Especially in developing countries, pre-generated load profiles are often unsuitable as appliance ownership and usage vary significantly across borders, between urban and rural areas, and on household and industry levels. Synthesizing load profiles is often hindered by the inaccessibility of tools due to cost barriers, global unavailability, or required technical knowledge. As currently, no easily accessible and usable tool is available during energy system planning in rural areas of developing countries, we incorporate the open-source load profile generator RAMP into our web-based energy system simulator NESSI4D$^{web+}$ to provide an intuitive user interface. We conduct an applicability check with self-collected data from a guesthouse in Sri Lanka, analyzing the impact of load distribution and magnitude on the economic, environmental, and reliable energy supply, that validates the artifact's relevance and ability to empower local decision-makers.*

**Keywords:** Load Profile Generation, Decision Support System, Energy System Simulation, Developing Countries, Renewable Energy

## 1. Introduction

In the past decades, governments and development aid agencies have been focusing on providing rural areas in developing countries with reliable, affordable, sustainable, and modern energy (i.e. Sustainable Development Goal (SDG) 7), as it is a key factor to improve living conditions and promote social development (Herraiz-Cañete et al., 2022). Due to their modularity and cost-effectiveness, decentralized renewable energy systems (RESs) have a significant positive impact on these efforts (Balderrama et al., 2020; Few et al., 2022; Herraiz-Cañete et al., 2022). However, selecting and sizing renewable energy technologies (RETs) is challenging (Balderrama et al., 2020). Technical knowledge, the vast amount of needed - but often missing - information, and location-specific characteristics, are prerequisites for RES planning. Therefore, energy system analyses are often conducted using decision support systems such as HOMER, iHoga, or NESSI to facilitate the decision process towards suitable RES and the formulation of energy policies. In addition to site-specific factors, human capital, and market data, expected energy demand has significant impact on the RES' design (Herraiz-Cañete et al., 2022). The magnitude of energy demand, specifically the often observed demand peaks, determines the RETs' size and capacities (Few et al., 2022). Oversizing RETs, as is common in developed countries, increases investment, operation and maintenance (O&M) costs without commensurating benefits (Herraiz-Cañete et al., 2022). Undersizing leads to unreliable supply, stakeholder dissatisfaction, and avoidable use of harmful fossil fuels (Few et al., 2022). The temporal distribution of electricity demand determines the balance between energy generation, distribution, and storage and affects their intricate relation (Few et al., 2022). As detailed demand data is regularly missing or inaccessible, this critical factor is often only roughly estimated in energy system simulations and rural electrification research, leaving out local conditions, temporal variations, and uncertainties. Recent studies have shown that load profiles are neither easily predictable nor modeled, as people's electrical appliance usage patterns vary depending on their schedules and lifestyles (Proedrou, 2021). The independence of energy system simulation and load profile generation tools further impedes the process. Related tools often do not reflect the desired level of detail, are not open-source, or require programming knowledge (see Section 2), which increases the likelihood of inaccessibility or unsuitable load profiles. We, thus, use a user-centric approach and conduct a design science research process according to Peffers et al. (2007) to combine tools for energy system simulation and load profile generation. More precisely, we implement the open-source multi-energy

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