NN-Assisted Event De-Spamming for CERF-Based Energy-Awareness Notifications: A Proof-of-Concept Implementation

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***Abstract*—Energy awareness is increasingly important for shaping user behavior in energy communities. The Common European Reference Framework (CERF) targets energy-saving applications for monitoring and managing end-user energy consumption. Within this framework, the present paper investigates notification-based mechanisms for increasing user energy awareness relative to an energy community. The proposed approach combines classical signal filtering with NN-assisted event de-spamming and has been evaluated within the Eclipse Digital project for the Romanian pilot site. The main objective is to reduce excessive daily notifications in order to avoid behavioral saturation while maintaining user engagement in voluntary energy-consumption adaptation. This paper presents a proof-of-concept implementation of an NN-assisted event filtering and notification prioritization mechanism designed to limit redundant alerts generated from smart-meter event streams. Preliminary results indicate that the proposed approach can reduce the number of notifications generated from smart-meter event streams while preserving the operational capability of the monitoring framework.**

Keywords—CERF, energy awareness, human behavior, Notification intelligent engine, end-user

I. Introduction

CERF is a Reference framework for energy saving applications meant to be a blueprint of technical standards and digital rules in order to create a common language for all mobile and web applications which handle the energy consumption of the end-users [1]. It has as one of the main values the empowerment of end-user to apply voluntary energy reduction [2,3] and has been presented to the public also through the Report of the EG3 ad-hoc work stream [4]. Energy awareness relies on smart metering used to increase awareness of the grid participants, as part of the smart grid more complex approach [5]. In this respect, energy platforms and consumer applications have been developed and analyzed [6]. Artificial intelligent is also part of the effort of improving energy awareness and energy-related behavior, as energy domain and its Green Deal policy are already linked to AI having high potential in contributing to its goals [7].

Several studies have been made on the subject. In [8] the energy transition is presented as a social transition and highlights the importance of understanding individual and collective behaviors, aspirations and perceptions regarding energy consumption. In [9] it is shown that, based on new generation meters of production and exchange with the grid it is provided educational feedback that increases the energy awareness of the users and the acquired data is compared with reference profiles. With the aim of fostering energy-saving awareness among the International Islamic University of Malaysia Community, an Energy Management Information System has been used to enhance the level of energy-saving consciousness in the community [10]. In [11] is shown that in the context of energy transition the active involvement of local communities is essential, by analyzing the factors which are shaping positive public attitudes toward community energy in Czechia and that cognitive factors, specifically awareness, are the primary drivers of positive attitudes. Contextual factors such as awareness and social encouragement ~~is~~are shown to outweigh demographic predictors and independently shape efficiency behaviors [12], as social influence significantly increases the likelihood of one-off efficiency upgrades in the home.

The paper treats energy awareness as an input for voluntary energy consumption change at end-user level - by considering CERF It is implemented by using smart meters for real-time power and energy readout and a specialized energy platform for increasing awareness capable of generating appropriate in-time messaging for end-user, which is able to decide on voluntary basis on changing his energy behavior.

II. IT approach

The increase energy awareness through appropriate messaging to address CERF Reference Framework, the following architecture has been introduced, as presented in Figure 1. The applied CERF Architecture uses an "Advanced Notification Generation Intelligent Engine (ANGIE)" which is processing in real-time data coming from end-users belonging to an energy community and based on an sophisticated comparison it generates meaningful events which are basis for the end-users to change their energy behavior in quasi-real-time.

Moreover, data security and privacy have been highly considered in the approach. Data security is obtained through a special VPN for data acquisition, database storage and for the awareness engine.

Several measures have been considered for addressing privacy issues, e.g. only the end-users belonging to a certain measuring point have access to their data and the consumption of other users is given only through average power over a group / community.

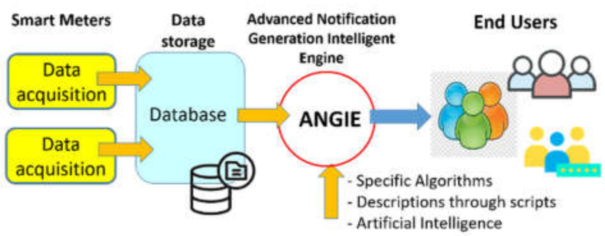

Fig. 1. Applied CERF Architecture using an Advanced Notification Generation Intelligent Engine (ANGIE) between database and users

III. Efficient Energy Use through Community Energy Awareness

Energy communities are starting to be more and more important for addressing self-sufficiency and resilience. Part of this purpose is the efficient use of the energy, in addition to increased local production and storage. While users are aware that they belong to a community, mechanisms to enforce through digitalization are necessary.

In this respect, an Energy Awareness System meant for energy communities has been developed in the project, targeting 2 different use-cases dealing with consumption based messaging:

- First UC is dealing with the awareness of an individual consumption versus the consumption of the whole community or of a selected common consumption

- The second UC had improved the awareness of individual consumption versus the richness of the PV production in the community. Such UC has the purpose to increase the synchronicity between the consumption and the renewable production, in order to increase self-consumption for a given storage.

- Other CERF-based use-cases, not presented in this paper, are also part of the ANGIE ecosystem (UC3 and UC4 are two additional extensions targeting the same end-user awareness, but for the purpose of preserving the grid against congestions and during extreme grid situations).

The application has been designed to be uploaded from Google Store and the user can connect using its google account.

Fig. 2. User interface examples for increasing awareness and for allowing to receive notifications

It can be seen that in the standard implementation the notification status can have to levels: advice and alert. This allows a better psychology-based transmission of the information, allowing the end user to be more or less cautious on the possible measures he may take.

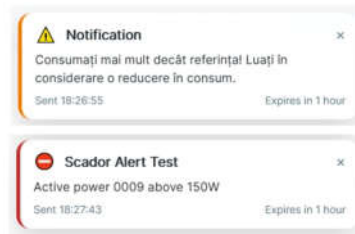

Fig. 3. Implementation of various nitifications or alert messages

IV. Privacy in Data Handling

Privacy and data security are key requests for data manipulation and awareness services need to cover such requirements as well.

The considered notifications presented here need input data which preserves privacy of individuals.

For comparing user consumption with other users consumption it is needed to solve the following issues:

- Personal data should be used only by the person which has a specific consumption

- The data for comparison need to be enough anonymized to blur or even hide one-person energy behavior. This can be done at least in two ways:

  - Data is mediated over time and becomes less relevant for a real-time observation. For instance, real-time data is not given, but integrated energy or average power on a certain period, e.g. one hour instead of real-time (to be considered at a granularity between seconds and one minuet). Figure below shows the difference between such situation, covering real-time behavior from external view
  - Cumulated power of several individuals is also diluting the information, making less effective an intrusion in the behavior of each individual.

Comparison with longer-time periods averages has also the advantage of giving a more stable vision of the other's behavior in terms of consumed power, thus making potentially a more robust notification process.

For the second issue, it has been considered that the comparing power belongs to a group of at least 8 users, which makes much less predictable the individual behavior.

A third used mechanism has been the anonymization of sources. Thus, the receiver knows only his consumption, but cannot directly corelate it with other individuals, instead the others are considered as being an entire energy community to a subset of it.

V. CERF'S NOTIFICATION GENERATION FOR USER ENERGY AWARENESS WITHIN A COMMUNITY – STUDY WITH A CLASSIC APPROACH

Although a user awareness can be addressed in many ways, the paper describes the user energy awareness comparing to a community of users.

In this respect, notifications can be generated when user average consumption exceeds community average consumption. However, individual consumption evolutions are frequently extremely dynamic and may bring difficulties in using them as such in comparison with a community behavior. To address these issues, various filtering strategies have been used: EWMA, Butterworth LPF order 1 (BTW-LPF-1), Butterworth LPF order 2 (BtW-LPF-2).

EWMA formula has a simple implementation;

$$y[k] = 0.99 \times y[k-1] + 0.01 \times x[k] \quad (1)$$

Where $y[k]$ is the current filtered output power, $y[k-1]$ is the filtered power calculated one step before (dT =10s) and $x[k]$ is the raw data of the consumed power, sampled each 10 seconds. According to theory, the time constant for this filter is τ=990 seconds, which correspond to 16.5 minutes.

For the same time constant, a BTW-LPF-1, noted as BTW1, has the following transfer function for $\tau = 990$

$$H(s) = \frac{1}{1+\tau * s} = \frac{1}{1+990s} \quad (2)$$

and applicable real-time formula:

$$y[k] = 0.05025 \ * x[k] + 0.05025 \ * x[k-1] + 0.98995 \times y[k-1] \quad (3)$$

The BTW-LPF-2, noted as BTW2, has the transfer function (4) and the real-time implementation (5):

$$H(s) = \frac{1}{980100 * s^2 + 1400.07 * s + 1} \quad (4)$$

$$y[k] = 0.000025 \ * x[k] + 0.000051 \ * x[k-1] + 0.000025 \ * x[k-2] \ 1.985715 * y[k-1] + 0.985816 * y[k-2] \quad (5)$$

Figure 4 shows a real user evolution, which is presented as sampled with a smart meter each 10 seconds (blue line) and by applying an EWMA method (orange line).

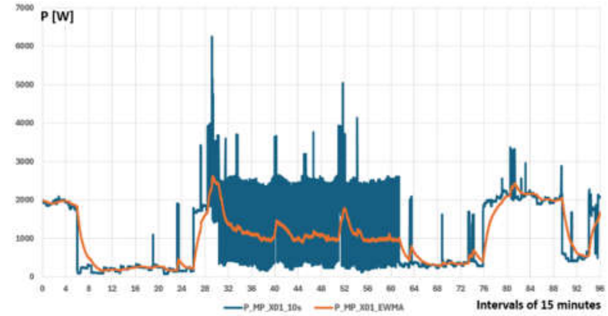

Fig. 4. Power evolution for the selelected user over a whole day: raw data at each 10 seconds (blue) and EWMA filetered (orange)

It can be seen that EWMA is dramatically improving the evolution towards a smooth and usable set of values.

The evolution of the community energy consumption, in raw values and with EWMA filtering, is presented in Figure 5 and Figure 6 shows the filtered evolution for the 3 types of filtering: EWMA, Btw-1, Btw-2.

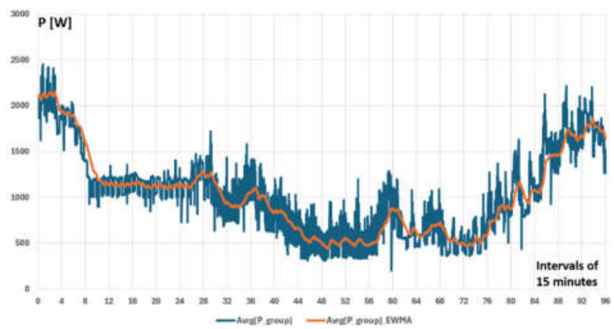

Fig. 5. Evolution of unfiltered community avareag power (blue line) compared with the same evolution filtered with EWMA (orange line)

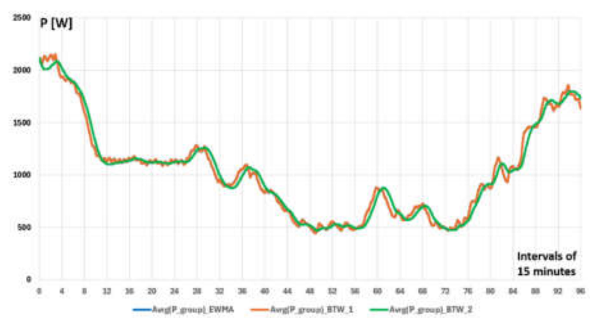

Fig. 6. Evolution of consumed power filtered with EWMA, BTW1 and BTW2

A superposition of EWMA-filtered of user X01 and of average community power is presented in Figure 7.

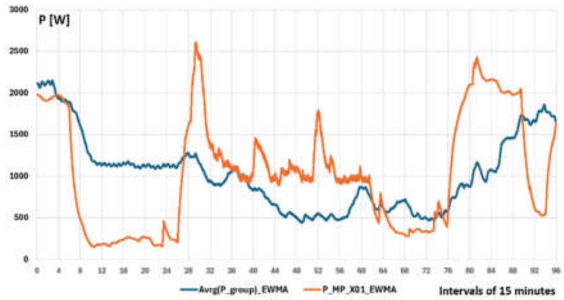

Fig. 7. Average community versus specific user power

A direct comparison of the values during the day brings a set of generated events as per Figure 8.

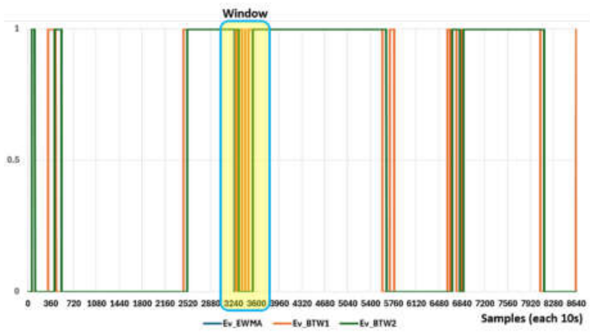

Fig. 8. Events generated on a 24-hour timeframe by applying the three filtering methods to both end-user power and to community average power

The events of the time window shown in Figure 9 are zoomed in figure 9, to better assess the burst of events in a time window with high power change dynamics.

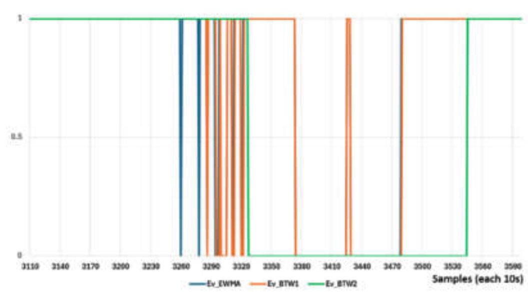

Fig. 9. Generated events in the selected time window

These methods of message generation correspond to a different number of event occurrence in a day, as per Table 1:

TABLE I. GENERATED EVENTS USING TRADITIONAL FILTERS

	Applied filtering technology		
	EWMA	***BTW-LPF-1***	***BTW-LPF-2***
Number of generated events per day	30	26	12
Number of generated events in selected window	18	14	2

This shows that there is no unique solution in producing events, even for such simple tasks as it is awareness of a user regarding the consumption of a community of users. While EWMA and BTW-1 bring a similar number of events – but rather high in number, the BTW-2 brings a small number of generated events, and they are delayed from the real situation in a manner which may affect the efficiency of the awareness.

A flexible method, to bring an acceptable small number of events, but still remaining relevant, is needed in order to implement an efficient CERF-based awareness set of events, which is addressed in the next section.

VI. Improving CERF's Notification Generation through AI-based Messaging

Artificial intelligence is a promising domain which can add value in many energy domains. A basic notification system can be highly enriched by using AI-based decisions which can consider more complex criteria, sometimes even not clearly defined.

In third respect, some additional mechanisms can add quality to the classic approach. For instance, the result of the notification system in relevant of the suggested action is also applied, which goes through the specific reaction of the user – which is highly dependent on the relevance and number of events received. Relevance of the notification can increase if it comes only as an in-time awareness of a situation for which the user is prepared to be applied but without being saturated by too many messages. Improving the user decision can be made by meaningful notifications without bringing saturation and finally rejection of the suggestion.

In this respect, the method applied for this has been to generate a number of notifications in an acceptable range (e.g. between 4 and 6 per day). The evolution presented in previous section has been used to train the output of a NN to get a number of events in this range. Several days of records have been used for the training.

The obtained results are presented in Figure 10.

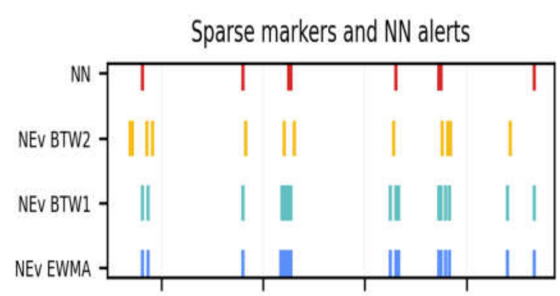

Fig. 10. Events during the day: EWMA, BTW1, BTW2 and NN

By analyzing the NN-based events, their number is diminished compared with the other methods, while their occurrence is still in the time window where multiple events have been generated with the other methods.

A causal threshold recommended deep NN alerting architecture has been used to generate de-noised event generation, this improving CERF notification messaging in the case study.

The following method has been used:

a) Build causal event-state features from the events based on EWMA, BTW1 and BTW2 filtering;

b) Train a compact neural network to produce NN-based alert-levels based on these events *c) Produce AI-based messages if alert levels on the NN oputput overpass a threshold which ensures a maximal number of 8 alerts per day;*

d) Promote such messages as improved notifications.

With this approach, alerts are becoming sparse decisions, which is better and intentionally different from notifying on every anomalous row coming from EWMA, BTW1 and BTW2 simpler methods.

The model is best interpreted as a “neural de-spammer” over existing event logic. It does not use raw power as a direct neural input in the selected run. Raw and filtered power are used in the high-power gate, target construction, and diagnostics, as per Figure 11.

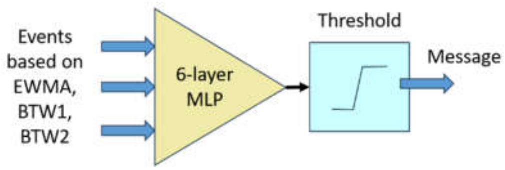

Fig. 11. The causal NN de-spammer pipeline used to generate improved AI-based messaging.

The model has been deliberately considered to be small. A one-hidden-layer network with six-layer MLP is easier to audit and less likely to memorize a single day than a larger network. The temporal information is supplied by causal engineered features rather than recurrent memory.

Figure 12 shows the moments when the AI-based messages have been generated, showing a more condensed number of such events, to keep the end customer in a more convenient environment.

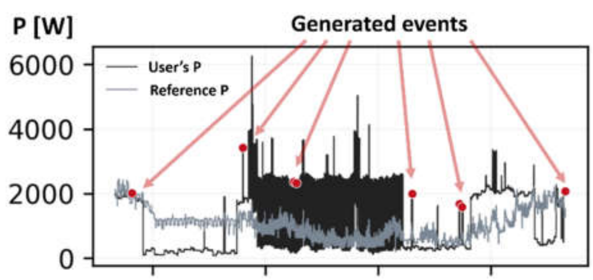

Fig. 12. Events placed on the user power evolution versus average community power

The NN method now produces only 8 events, compared to the 30, 26 and 12 events generated through EWMA, BTW1 and BTW2 methods, or with 111 events if raw data was used unfiltered. Moreover, the messages are better aligned with the cluster of EWMA and BTW1 events, thus reducing the reaction time – as these filtering methods are providing smaller delays for message generation compared with BTW2.

The NN-based method has been tested on another 3 days, with the point X01 having the power evolution as per Figures 13, 14 and 15.

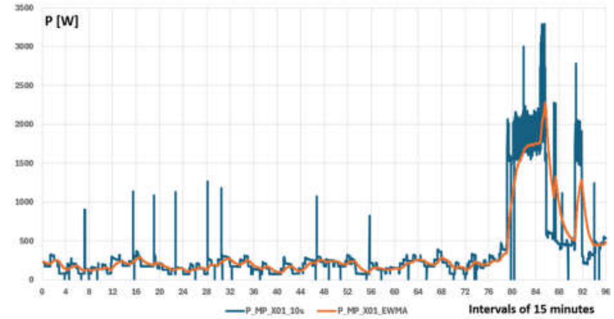

Fig. 13. Power evolution on test day TD1 (raw and EWMA filtered)

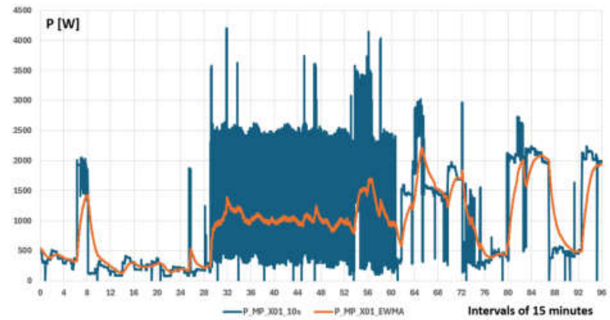

Fig. 14. Power evolution on test day TD2 (raw and EWMA filtered)

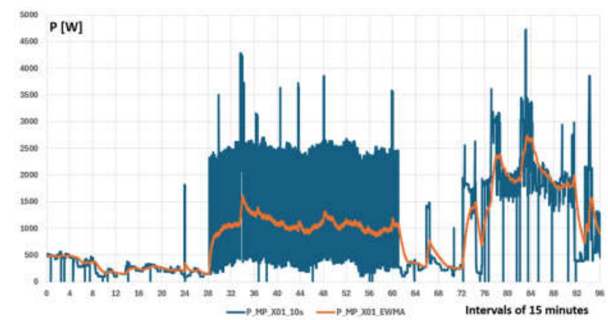

Fig. 15. Power evolution on test day TD3 (raw and EWMA filtered)

The events produced during these days are presented in Figures 16, 17 and 18, while a concise table with the number of events of each method is given in Table 2.

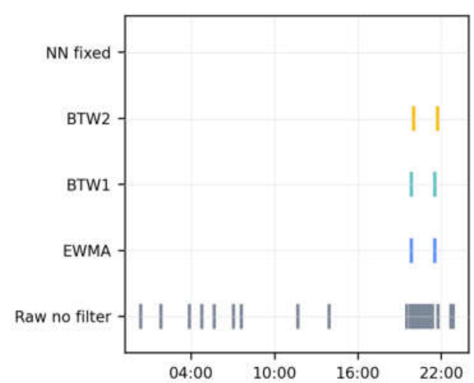

Fig. 16. Events produced in test day TD1 (WMA, BTW1, BTW2 and NN)

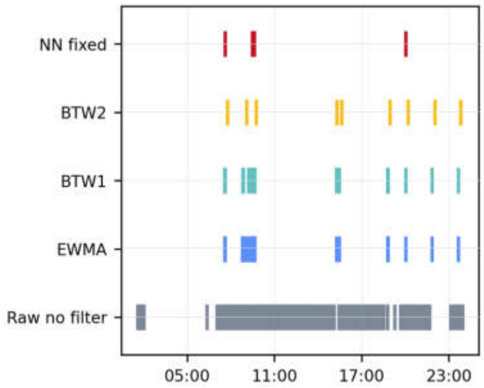

Fig. 17. Events produced in test day TD2 (WMA, BTW1, BTW2 and NN)

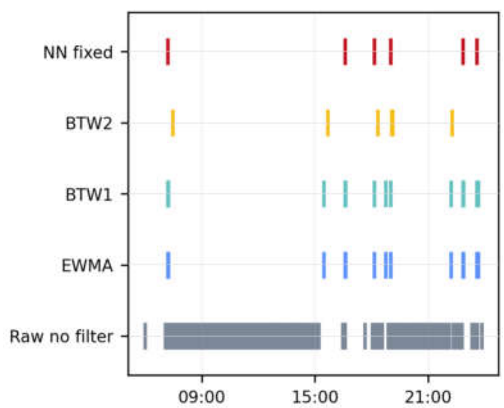

Fig. 18. Events produced in test day TD3 (WMA, BTW1, BTW2 and NN)

TABLE II. GENERATED EVENTS FOR TESTED DAYS TD1, TD2, TD3

	Applied filtering technology				
	RAW	***EWMA***	***BTW1***	***BTW2***	***NN***
Number of generated events during TD1	26	2	2	2	0
Number of generated events during TD2	111	31	29	9	4
Number of generated events during TD3	102	14	14	6	6

It can be seen that in all tested days, the NN-based method of generating events produced a smaller or equal number of events compared with the strongest applied filter BTW2. Moreover, the number of possible alerts by using just simple comparisons on raw data obtained each 10 seconds could bring a quick saturation of the end-user attention, which can drastically impact the responsiveness and can induce fatigue or disinterest in the method.

VII. CONCLUSIONS

This paper presents a proof-of-concept implementation of an NN-assisted event de-spamming mechanism integrated into the CERF energy-awareness framework and evaluated within the Romanian pilot of the Eclipse Digital project. The proposed approach combines classical event-generation methods with a lightweight neural filtering layer designed to reduce the volume of notifications generated from smart-meter event streams.

The obtained results indicate that the proposed notification-management pipeline can reduce the number of generated alerts compared with the considered classical filtering approaches while preserving the operational functionality of the monitoring framework. The work demonstrates the feasibility of integrating adaptive event prioritization mechanisms into CERF-based energy-awareness systems using a simple and computationally lightweight architecture.

The present study should be regarded as an architectural and feasibility-oriented proof of concept. The neural filtering layer was trained using data from a single typical consumption day, and the alert-selection threshold was calibrated on the same dataset. The evaluation focused primarily on notification reduction rather than on user behavioral response. Consequently, the results do not yet allow conclusions regarding long-term user engagement, energy-awareness improvement, or energy-consumption reduction.

Future work will consider a larger number of monitoring days and user profiles, threshold calibration on independent datasets, and further evaluation of alternative neural architectures. In addition, prospective deployment studies will investigate the relationship between notification management, user engagement, and energy-awareness outcomes in real-world energy communities.

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