Journal of Energy

VOLUME 72 Number 4 | 2023

journal homepage: http://journalofenergy.com/

Local Aggregator Enhanced Possibilities Coupling Energy Savings and Demand Response Activations

L. Luttenberger Marić, D. Borić, H. Keko, J. Aranda, M. Kirinčić

***Summary* — This paper explores the role of energy communities and local flexibility aggregators in decentralized and decarbonized energy systems. Challenges in the technical and regulatory frameworks of aggregators, with an emphasis on data collection issues, are identified. This work focuses on the essential considerations of coupling long-term energy savings and short-term flexibility activations within a unified program. The paper highlights potential conflicts in optimization goals and emphasizes the necessity for a clear and user-friendly communication between aggregators or energy communities and consumers in order to maintain consumer engagement. The importance of accessible applications for consumer engagement is stressed, with a prioritization of semantic data integration over increased sampling frequency. Sustainable business models are argued for, centred on consistent monitoring of energy savings. Not all consumers are comfortable with in-depth data analysis. The paper suggests the adoption of user-friendly applications for straightforward program monitoring. Emphasis is placed on meaningful data interpretation through semantic integration, rather than a mere increase in data sampling frequency. The argument supports sustainable business models that prioritize consistent monitoring of energy savings and flexibility over reliance on large datasets with limited analytical value. In conclusion, the paper contributes insights into user-centric approaches for sustainable energy communities, emphasizing the integration of long-term energy savings and short-term flexibility within a coherent program.**

***Keywords* — aggregator, demand side flexibility, energy savings, monitoring and verification, data collection**

I. Introduction

The energy system is undergoing continuous changes in the paradigms of energy trading from various heterogeneous sources. At the same time, distributed energy sources (DER) provide diverse aggregation opportunities for the newly emerging energy communities and local flexibility aggregators [1]. By aggregating the granular contributions of individual sources, flexibility aggregators appear as innovative and respectable at system scale flexibility sources at the local level [2]. The amalgamation of various DER, properly selected, categorized, aggregated, and optimized, is opening the path for local flexibility aggregators and energy communities to explore new revenue opportunities on the energy market. Additionally, flexibility aggregators overcome sociological and technological obstacles and activate final consumers in the demand response flexibility programs, where consumers adjust their energy usage based on power grid conditions or price signals.

The limiting factors to unleash their market potential are numerous: challenging assessment of the actual flexibility potential in households due to scarcity or absence of historical data with the desired granularity, overall lack of information of the installed loads in households [3], the inconsistency between quality and quantity of collected data, low level of interoperability between the installed equipment [4], response of consumers to external stimuli, varying socio-economic conditions of consumers [5] and investment possibilities in home equipment, availability of the energy infrastructure (i.e. district heating networks), different building energy performances [6] and climatological conditions, etc. The creation of a sustainable business model for a local flexibility aggregator is a demanding task, especially while considering investment costs which are essential to provide an adequate information and communication framework for data collection, processing, and direct load control for home equipment. In addition, flexibility aggregator should establish a fair compensation for the activation of flexibility of their users (consumers), therefore creating a programme which is adapted to the needs of users, based on their specific characteristics, needs and requirements [7].

The fragmented and very often diverse household market represents both a challenge and an opportunity for the introduction of new business models [8]. The synergetic approach that combines long-term energy savings achieved through energy efficiency measures and short-term energy savings achieved through flexibility activations opens an opportunity for flexibility aggregators to participate in both energy and energy savings markets. In the paper, the principal challenges of participating in both of these markets are assembled and the most indicative approach given the current technical and regulatory situation is discussed.

II. Approach

The paper analyses the requirements for establishing a business model which blends the opportunities for obtaining energy savings on one side and to activate the available demand flexibility and make it available to network operators on the other. The two services are independent and complementary, enabling building residents to enjoy energy savings derived from behavioural

Leila Luttenberger Marić, Donata Borić, and Hrvoje Keko are with the Končar - Digital Ltd., Zagreb, Croatia
(e-mails: leila.luttenberger@koncar.hr; donata.boric@koncar.hr; hrvoje.keko@koncar.hr)
Juan Antonio Aranda Uson is with the Fundacion Circe Centro de Investigacion de Recursos y Consumos Energeticos (CIRCE), Zaragoza, Spain (e-mail: jaaranda@fcirce.es)
Mateo Kirinčić is with the Smart Island Krk Ltd., Krk, Croatia (e-mail: mateo.kirincic@sikrk.hr)

L. Luttenberger Marić, D. Borić, H. Keko, J. Aranda, M. Kirinčić, Local Aggregator Enhanced Possibilities Coupling Energy Savings and Demand Response Activations, Journal of Energy, vol. 72 Number 4 (2023), 28–32
https://doi.org/10.37798/2023724476

change recommendations based on advanced data analytics, and direct remuneration from demand side flexibility aggregated by demand response aggregators and traded in open markets operated by network operators for grid management and balancing. Both services can be delivered simultaneously using the same real-time building data and are not contradictory. Savings come from direct choices made by resident users as a result of behavioural recommendations while aggregated demand flexibility is requested and remunerated by network operators benefiting from short-term flexibility for congestion management and grid balancing. Demand response can be triggered via short term activations delivered by households' consumers, paying specific attention to robust approach in terms of low availability of the data. The introduction of energy efficiency measured in households and the implementation of demand response flexibility programmes are occurrences that could be monitored synergistically for the purpose of achieving common goals in the energy transition. The values of both energy efficiency and demand response directly depend on daily, seasonal, and annual factors which are influencing energy consumption patterns.

A. The Aspects for Establishing a Business Model of A Local Flexibility Aggregator for Residential Consumers

The results of the in-depth analysis for establishing a business model of a local flexibility aggregator for households' consumers are summarized in table 1 and divided in different phases (Phase 0 – Feasibility analysis; Phase 1 – Implementation; Phase 2 – Evaluation and continuous monitoring).

Aspects	*Phase 0 (Feasibility analysis)*	*Phase 1 (Implementation)*	*Phase 2 (Evaluation and continuous monitoring)*
Regulatory framework	Existing regulatory framework enabling the activation of final consumers by flexibility aggregators and market access	Continuous	Continuous
Input data and processing	Data collection and application of proper estimation methods for initial program feasibility assessment	Load profile data and key parameters measurements collection Application of load baseline estimation methods	Continuous evaluation and calibration
Information, communication, and technological framework	Assessment of existing ICT framework and preliminary cost analysis for the installation of new hardware, software and its mutual deployment and calibration Feasibility analysis for setting up a functional standardizes and interoperable framework for data collection and assets control	Establishment and implementation of a functional ICT framework enabling direct load control, with specific accent on scaling and per-user costs	Correct semantic dana interpretation enabling continuous program evaluation and monitoring
Socio-economic	Identification of the main motivational drivers for the consumers involvement and establishing adequate strategies	Application of tailor-made strategies for the program users Continuous customers support	Long-term benefit identification for final consumers
Business and financial	Finding optimal trading modalities for the aggregated flexibility on the energy market markets	Settlement program for the final consumers, trading and	Continuous re-programming of the flexibility settlement methods

The regulatory framework for establishing relationships among different stakeholders must be taken into consideration in the feasibility assessment, implementation, and evaluation phases. Additionally, clear roles and responsibilities among different stakeholders (aggregator, consumers, and flexibility user i.e., DSO) should be regulated and monitored.

In Phase 0, available flexibility should be assessed based on existing input data, and estimation methods should be developed to evaluate the practicability of a demand response flexibility program on the scrutinized portfolio. The development of proper extrapolation methods is particularly important in cases where there is a consistent gap between data quality and quantity.

In Phase 1, the aggregator should collect energy consumption data as well as data linked to parameters affecting consumption in the desired granularity. Usually, such key parameters affect both users' comfort and energy savings, which is something to consider in monitoring and verification processes for both flexibility calculations and energy savings assessments.

In Phase 2 – the evaluation and continuous monitoring phase, the collection of verified load profiles (usually provided by the DSO) and demand response activation data is imperative. The existence of a technological and communication infrastructure for data collection and storage, as well as the establishment of a standardized architecture for demand response activation, is mandatory in the implementation phase (Phase 1). The ability to monitor information through its semantic interpretation is one of the key features to enable continuous evaluation of flexibility programs (Phase 2).

The correct identification of motivational aspects for triggering customers' interest to participate in demand response flexibility programs should be performed in Phase 0, and appropriate strategies to raise customer awareness should be set up and applied in Phase 1. Moreover, in the implementation phase, such programs require the setting of adequate technical and customer support. Consumers must recognize the long-term benefits of participating in flexibility programs (Phase 2). Finally, for the creation of a financially sustainable business model implementable in the long term, program settlement goals need to be continuously updated and verified (Phases 0 to 2).

While this paper does not explicitly focus on the socio-economic aspects of such programs, it identifies key considerations for their implementation. These include factors such as income levels, cost sensitivity, technological access and literacy, housing conditions, work flexibility, education levels, cultural considerations, and perceived value. The study reveals that, even when analysing a use case with consumers having similar income levels, there can be significant variations in the perceived value among individuals.

B. Load Baselining Approach for Assessing the Engaged Flexibility

In the electricity market environment, transactions are happening continuously between various participants. Consumers can participate in those transactions by offering their flexibility via intermediaries, in exchange of financial compensations [8]. To include a meaningful number of consumers on the electricity market, incentive fees need to be attractive to the consumers and profitable to aggregators. Ultimately, this should result in stable market confidence. Fairness in setting the price is destabilised by the fact that the reduction in consumption cannot be exactly calculated but only estimated. Various load baselining methods simulate the estimated »no event« load, i.e., in absence of a demand response (DR) event [9]. Estimates are primarily based on historical consumption data thus it is necessary to determine

L. Luttenberger Marić, D. Borić, H. Keko, J. Aranda, M. Kirinčić, Local Aggregator Enhanced Possibilities Coupling Energy Savings and Demand Response Activations, Journal of Energy, vol. 72 Number 4 (2023), 28–32
https://doi.org/10.37798/2023724476

the grid user's consumption curve. Ideally, at least one year monitoring of energy consumption data should be considered before entering the electricity market [10]. With their specific consumption curve, grid users are classified into categories that are valued differently. The different categories primarily imply their commercial or non-commercial purpose (whether they are in the private or public sector) and how much flexibility they can offer on the market. The volume of energy necessary to enrol on the market is usually set by the difference between consumer's historic peak load and a demand level that he commits not to exceed during an event. Based on customer's load data it is recommended to determine the weather sensitivity of loads, seasonality (not related to weather conditions) and variability (not related to season or weather conditions) due to different types of methods used in these cases.

Once registered on the market, historical performance can be used to estimate when forecasting the amount of demand response [10]. Based on the theoretical load, the aggregator can calculate the reduction, i.e. difference between the theoretical baseline load and the observed load. This difference is used for assessing payments and penalties for customers. To avoid manipulations by aggregators, load baselining methods should be realistic and transparent to all flexibility providers [9]. Likewise, to avoid manipulations by users, rules and calculation methods should be well defined.

Unlike analytic methods, estimation methods can rarely give exact solution, ergo measurement errors should be included and permitted. However, the error in determining the theoretical baseline increases proportionally in the estimated flexibility engaged as load reduction. In some cases, if load baselining method continuously tends to overstate or understate baseline, it will result in overstated or understated load reduction estimate. Therefore, incentive payments will also be unfairly increased, or reduced.

Load baselining method can be performed in many ways, depending on consumer's category, consumption curve and aggregator's decision. The approach can be summarized in five main steps, visually shown in figure 1.

Baseline window usually includes the last 10 non-holiday weekdays, 10 most recent non-event days, current season or even the whole previous year. Some of these days are not representative or not similar to the day of the event and should be excluded. Exclusion rules usually exclude days with DR events, extreme weather, or days with the lowest or highest loads. Once the data for creating baseline is selected, calculation type of method needs to be specified. Four most used calculation types evaluated on the selected dataset are: average value for each hour of the day, regression, taking the maximum value of the load and rolling average. Created baseline can be further adjusted for conditions of a day-of-event. Most common are additive adjustments which can closely match calculated baseline with measured load. Scalar adjustments are also used but can give more volatile result. To avoid single manipulations, it is recommended that adjustment window relies on a few hours before the time of notification. Other approach is to use weather characteristics for tuning parameters of adjustment method.

Baseline window	Exclusion rules	Calculation type	Baseline adjustments	Adjustment window
• Selection of a period of time used for estimating a baseline • Selection of days similar to the event day	• Rules for excluding data from the baseline window	• Method used to compute the baseline value • Data from the baseline window are used	• Additional calculation based on different operating conditions • Improvement of the baseline on the day of event	• The pre-event period considered for baseline adjustments • Pre-event period is usually up to 4 hours before an event

Fig. 1. Five steps for load baselining

C. Monitoring energy efficiency measures in a dynamic environment

Monitoring and verification procedures (M&V) are widely used to evaluate the effect of certain energy efficiency measures [11] and the achievement of national energy efficiency goals. The continuous energy transition trends are leading to a progressive digitalization of the energy sector. The integration of automation and management systems in buildings will also provide the means to ESCO companies for better data collection and analysis opportunities of their customer's portfolio [12].

Through an energy performance contracts (EPCs), which is based on achieving client's or consumer's energy savings, an energy service company (ESCO) implements a project to improve energy efficiency or integrate renewable energy sources, by using financial savings obtained from energy savings (as income) to cover investment costs [12]. The ESCOs are responsible for financing and implementing energy efficiency measures and guarantee energy savings. The energy system digitalization and the integration of automation and management systems in buildings should provide the means for better data collection and analysis opportunities of their customer's portfolio.

Monitoring and verification of energy savings and activated flexibility different in approached primarily in terms of data granularity. For any type of user, it is necessary to develop a dedicated load consumption estimate that is directly adapted to user's characteristics, location, typical consumption patterns, etc. Moreover, it is necessary to correctly determine and arrange the main parameters that affect consumption and establish their mutual relations. Figure 2 presents the relation between the typical consumption (with a 15-minute resolution) of two buildings located in the same location and the outdoor temperature. As shown in figure 2 there is no direct correlation between the total consumption of an individual building and the outside temperature, which would mean that regression analysis is not possible.

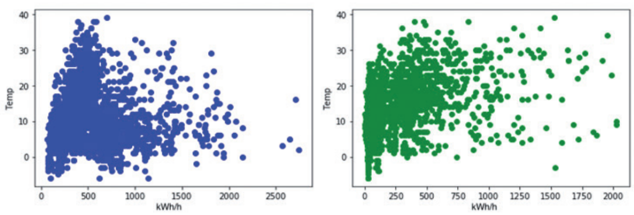

Fig. 2. Outside temperature vs. energy consumption of two different buildings

High data granularity is crucial in the load estimate methods (described in chapter A) necessary for assessing the amount of engaged flexibility, while such approach led to wrong conclusions in determining energy savings.

If a business model considers combined effort opportunities between flexibility and energy savings in a real-time environment, the pay for performance (P4P) models should be considered. Such schemes imply the existence of smart (interval) meters, which register the energy consumption which is therefore normalized and associated with weather conditions [13]. Additionally, with such scheme the uncertainties that a specific measure will lead to savings are minimized, while methods applied for monitoring and verification of energy savings should grant continuous calibration of the calculated savings, therefore minimize errors in assessments.

The monitoring and verification methodology applicable for residential consumers should be based on algorithms that are incorporating both long-term and short-term load reductions that take into account weather and building parameters, seasonal conditio-

L. Luttenberger Marić, D. Borić, H. Keko, J. Aranda, M. Kirinčić, Local Aggregator Enhanced Possibilities Coupling Energy Savings and Demand Response Activations, Journal of Energy, vol. 72 Number 4 (2023), 28–32
https://doi.org/10.37798/2023724476

nal and usual user consumption profiles.

The baseline estimation methods applicable in a P4P scheme could apply regression methods in an environment which is continuously collecting the data. Algorithms should be continuously trained, and load should be estimated, specifically excluding erroneous data and rules should be applied to complete data gaps.

D. Data semantics and parameters to be continously monitored

In the context of data collection, there are several principal aspects to be considered. The "more data is better" principle does not universally apply – it is highly context dependent. The same is valid considering the higher frequency of data sampling. As shown above, the lack of historical higher frequency data is not necessarily the primary obstacle for the proliferation of energy savings and flexibility schemes. Higher granularity (higher sampling frequency) of collected data does increase the baseline estimation and verification precision, but it does so until a certain point of saturation.

This is highly dependent on the context: for instance, implicit short-term flexibility schemes typically need lesser sampling frequency for baselining and verification than the explicit ones. This is entirely expected as implicit ones require behavioural changes and user engagement. However, prematurely restricting the data collection infrastructure could effectively reduce the potential of both energy savings and demand response. Although higher data volume does not always imply higher information content, it is not a good idea to prematurely assume the optimal sampling frequency: too low sampling frequency could leave the end users out of potentially attractive flexibility aggregation schemes. Also, lower frequency data can always be derived from higher sampled ones via resampling.

Moreover, it is not enough to simply gather the data – the collected data must be interpreted correctly and semantically enriched. Though in different households there may be sources of semantically similar data, with no semantic interoperability or with data tied into manufacturer's impenetrable walled gardens, these data are effectively unusable. There have been recent efforts in order to standardize the semantic interoperability across the demand response value chain [14] to remove this problem. The proposed semantic interoperability schemes depart from the existing and established standards (such as SAREF, OpenADR and IEC 61850). In a recent work by the BRIDGE Data Management Working Group [15], a reference architecture for energy data exchange has been proposed, with a layered approach to interoperability. For full semantic interoperability and the data value chain to work, semantic interoperability must function on all technical and semantic layers. For the purposes of monitoring and verifying the effect of a flexibility programme providing energy savings, additional semantic information tied to the data collected from devices and sensors is critical. With no semantic information tied to the data, *ex-post* analysis of the programme's impact may even be misleading.

As increasing the data collection frequency might require significant increases in the cost of data management (e.g. cellular network provider fees in place of using power line carrier communication easily saturated with higher meter readout frequency), when considering the optimal level of data collection, careful analysis should be performed. As indicated here, consistent, and unambiguous interpretation of data is essential and significantly more important than simple increases in data collection frequency.

Moreover, for aggregators installing their own measuring devices for participants could indeed offer several benefits for the aggregator such as:

- Data Accuracy and Control: Aggregators can enhance the accuracy and reliability of the data collected by installing their own measuring devices. This ensures a more precise understanding of participants' energy consumption patterns, allowing for better-informed decision-making.
- Granularity and Detailed Insights: Aggregator-installed devices can provide more granular and detailed insights into participants' energy usage. This granularity is valuable for optimizing demand response strategies, identifying specific areas for improvement, and tailoring programs to individual needs.
- Independence from DSO Schedules: Aggregators, by having their own measuring devices, can access real-time data and respond promptly to changes in participants' energy consumption, maximizing the effectiveness of demand response initiatives.
- Enhanced Program Flexibility: Aggregator-controlled measurements offer greater flexibility in designing and adjusting demand response programs. The ability to capture and analyse data independently allows for quicker adaptation to changing circumstances and ensures a more responsive and agile program.
- Value-Added Services: Aggregators may leverage their own measuring devices to offer additional value-added services, such as energy efficiency recommendations, tailored insights, or even smart home integration. These services can enhance the overall value proposition for participants.

A careful evaluation of the approach is crucial, though: ensuring the accuracy and calibration of the measuring devices, addressing privacy concerns, and coordinating with regulatory requirements are all required. Additionally, open communication with participants about the purpose and benefits of installing such devices can foster trust and transparency. The Implementing Regulation 2023/1162 [16] is especially an implementing act obliging the metering service operators to provide transparent and accessible user access to near real-time metering data. The users are also supposed to be able to delegate the access to their data to third parties authorized by them. This Regulation applies to metering and consumption data, in the form of validated historical metering and consumption data and non-validated near-real time metering and consumption data. As in most EU countries the DSOs are tasked with metering, this regulation effectively obliges the DSO to open the access to the data discussed in this paper. While there may be notable benefits to aggregators installing their own measuring devices, a strategic and well-thought-out approach is crucial to maximize these advantages and ensure a positive impact on the overall effectiveness of demand response programs, especially in light of European policy on the data access to near real time data, acquired by the metering service operators from the official, calibrated and time-synchronized metering devices.

III. Discussion and Conclusions

This article represents a pivotal exploration of a conceptual framework designed to address a significant issue. While the current narrative may give the impression of being centred around existing literature, it functions as the foundational basis for an innovative proof of concept. Moreover, it is imperative to highlight the ongoing efforts within the frESCO project, where similar topics have been rigorously examined. The integration of savings with demand response activations in the framework of the frESCO project has provided valuable insights and practical experiences, establishing a real-world context for the proposed method.

https://doi.org/10.37798/2023724476

The first barrier to overcome in an explicit flexibility programme deployed in residential buildings is the natural rejection of building occupants to grant control of their HVAC equipment to third party companies, thus losing the decision power about their own comfort choices. A human-centric system should be able to forecast users' comfort preferences and assess whether an automated activation may have an effect on the preservation of the users' thermal comfort, either because of a large power shift or a long event duration. In case the comfort boundary conditions are estimated not to be met, the automatic event should not be triggered, and the smart contract rejected prior to the event scheduling. As it stems out of the real tests carried out in the frESCO project demonstration buildings, it is important to avoid user dissatisfaction, or the penalties associated with a failure to deliver the committed flexibility agreed in a market participation smart contract. This is particularly relevant given the fact that short revenues per event are expected considering the low volume of flexibility potential in households.

On the other hand, coupling long-term energy savings and short-term flexibility activations in a same program could lead to conflicted optimization goals. The lack of clarity may result in consumers disorientation and less motivation to enter in such program. This is particularly important within monitoring and verification procedures utilized in transparent ex-post analysis of the program effects. For a user-engaged program to be successful, clarity of its goals as well as consistent and non-ambiguous data interpretation are essential.

It is also not reasonable that an average customer will delve in deep data analysis. Consumers entering the program should be equipped with adequate applications, enabling pragmatic monitoring of current conditions, achieved savings, and activated flexibility. In other words - success of user engagement pay-for-performance program hinges on the palatable presentation of the program benefits. This is valid both in the user engagement and in the operational phase.

For a sustainable business model to be built upon such programs, consistent monitoring of energy savings and activated flexibility is an absolute priority. This is, however, not reachable just by increasing the metering data sampling frequency. Semantic data integration that ensures correct data interpretation across the data value chain is of higher priority than the volume of data. A large-scale dataset that can't be assigned or interpreted has a very low analytic value. Even though higher data granularity certainly increases analysis capabilities, a quite significant part of energy savings benefits can be based upon a quite limited dataset, e.g., monthly or even yearly energy consumption.

Finally, if the short-term flexibility and longer-term energy savings must be opposed, then the implementation of energy savings measures should be prioritized. This means building envelope refurbishment, purchase of energy efficient equipment. Even in medium term horizon, this avoids placing specific focus on the revenue obtained from the market-offered flexibility obtained from short-term activations of engaged loads. In other words, short-term market signals could easily conflict with the total energy savings goals and with generally lower data granularity more significant total effects can be achieved in longer term energy savings domain than in short-term flexibility provisioning.

Acknowledgment

Research leading to these findings has been supported by the frESCO project, which has received funding from the Horizon program under Grant Agreement No. 893857

References

[1] O. Agbonaye, P. Keatley, Y. Huang, O. O. Ademulegun, and N. Hewitt, "Mapping demand flexibility: A spatio-temporal assessment of flexibility needs, opportunities and response potential," *Appl. Energy*, vol. 295, p. 117015, Aug. 2021, doi: 10.1016/j.apenergy.2021.117015.

[2] L. Luttenberger Marić, H. Keko, and M. Delimar, "The Role of Local Aggregator in Delivering Energy Savings to Household Consumers," *Energies*, vol. 15, no. 8, Art. no. 8, Jan. 2022, doi: 10.3390/en15082793.

[3] P. Siano, "Demand response and smart grids—A survey," *Renew. Sustain. Energy Rev.*, vol. 30, pp. 461–478, Feb. 2014, doi: 10.1016/j.rser.2013.10.022.

[4] H. Keko, S. Sučić, L. Luttenberger Marić, P. Hasse, and K. Isakovic, "Widening the Path for Demand-Side Flexibility Services in European Households: Joint findings of the FLEXCoop and HOLISDER projects in standardization and interoperability," 2021. [Online]. Available: https://drive.google.com/file/d/1e4aBUFkA9fIYfVTQwUbQTrVV927VOGtS/view

[5] D. Ribó-Pérez, M. Heleno, and C. Álvarez-Bel, "The flexibility gap: Socioeconomic and geographical factors driving residential flexibility," *Energy Policy*, vol. 153, p. 112282, Jun. 2021, doi: 10.1016/j.enpol.2021.112282.

[6] A. García-Garre, A. Gabaldón, C. Álvarez-Bel, J. L. Martínez-Ramos, L. A. Fernández-Jiménez, and M. Alcázar-Ortega, "Description of a residential Thermal Energy Storage demonstrator: modelling, identification, validation, aggregation and validation of DR performance," in *CIRED 2021 - The 26th International Conference and Exhibition on Electricity Distribution*, Sep. 2021, pp. 1762–1766. doi: 10.1049/icp.2021.1795.

[7] L. Luttenberger Marić, "Modelling of Aggregated Residential Energy Savings Based on Minimal Available Input Data Set," Doctoral thesis, Faculty of Electrical Engineering and Computing, Zagreb, 2022.

[8] C. A. Correa-Florez, A. Michiorri, and G. Kariniotakis, "Optimal Participation of Residential Aggregators in Energy and Local Flexibility Markets," *IEEE Trans. Smart Grid*, vol. 11, no. 2, pp. 1644–1656, Mar. 2020, doi: 10.1109/TSG.2019.2941687.

[9] O. Valentini, N. Andreadou, P. Bertoldi, A. Lucas, I. Saviuc, and E. Kotsakis, "Demand Response Impact Evaluation: A Review of Methods for Estimating the Customer Baseline Load," *Energies*, vol. 15, no. 14, Art. no. 14, Jan. 2022, doi: 10.3390/en15145259.

[10] M. L. Goldberg and C. Goldman, "Measurement and Verification for Demand Response," Electricity Markets and Policy Group, Energy Analysis and Environmental Impacts Division, 2013. [Online]. Available: https://eta-publications.lbl.gov/sites/default/files/napdr-measurement-and-verification.pdf

[11] "Guidelines for Monitoring, Evaluation, Reporting, Verification, and Certification of Energy Efficiency Projects for Climate Change Mitigation | Energy Technology Area." Accessed: Jun. 11, 2022. [Online]. Available: https://energy.lbl.gov/publications/guidelines-monitoring-evaluation-0

[12] L. L. Marić and V. Bukarica, "Combined effort opportunities of aggregated demand response flexibility and energy savings in households," *J. Energy - Energ.*, vol. 70, no. 4, Art. no. 4, 2021, doi: 10.37798/2021704257.

[13] M. Santini, D. Tzani, S. Thomas, V. Stavrakas, J. Rosenow, and A. Celestino, "Experience and Lessons Learned from Pay-for-Performance (P4P) pilots for Energy Efficiency," Zenodo, Jun. 2020. doi: 10.5281/zenodo.3887823.

[14] "Validating SAREF in a Smart Home Environment," springerprofessional.de. Accessed: Mar. 22, 2023. [Online]. Available: https://www.springerprofessional.de/en/validating-saref-in-a-smart-home-environment/18977178

[15] Directorate-General for Energy (European Commission), M. J. Couto, K. Kotsalos, and K. Kukk, *European (energy) data exchange reference architecture 3.0*. LU: Publications Office of the European Union, 2023. Accessed: Oct. 20, 2023. [Online]. Available: https://data.europa.eu/doi/10.2833/815043

[16] "EUR-Lex - 32023R1162 - EN - EUR-Lex - Commission Implementing Regulation (EU) 2023/1162." Accessed: Dec. 29, 2023. [Online]. Available: https://eur-lex.europa.eu/eli/reg_impl/2023/1162/oj