Mapping Business Process Modeling with the Business Models of Several Energy Community Members

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Energy communities (ECs) play a major role in energy systems by enabling decentralized production and distribution of renewable energy. This article applies business process modeling to enhance and align the business models of various EC members. Using Business Process Model and Notation (BPMN), it maps the operational workflows of key participants, including prosumers, storage owners, EV charging stations, aggregators, and entities involved in Local Energy Markets (LEM) and Local Flexibility Markets (LFM). Proposed BPMN models provide a structured perspective on essential tasks, decision points, and interactions within the energy market, capturing processes such as energy forecasting, trading, flexibility transactions and daily operations. Through process visualization, the models offer valuable insights for optimizing energy usage, enhancing grid stability and maximizing economic benefits. This approach highlights BPMN's capability to support more efficient, sustainable, and resilient ECs within decentralized systems.

Keywords: *energy communities, business models, business process models, BPMN*

1 Introduction

ECs are groups that aggregate individual and shared resources to participate collectively in energy production, consumption, and management. This model enables distributed energy resources, such as solar panels or shared battery storage, to be pooled among members, who then interact with the grid as a single entity. The cooperative structure enables energy and financial transactions with utility companies, aligning individual incentives with broader community goals and providing members with benefits beyond those available individually [1].

Designing business models for energy markets and ECs is critical because it enables the efficient, sustainable and equitable distribution of electricity, especially as the market adapts to new technologies and renewable energy sources. With the rise of electric vehicles (EVs), renewable integration, and decentralized energy systems, traditional utility models are no longer sufficient to meet dynamic demand and ensure grid stability.

While a business model is strategic and describes what the business does to create, deliver and capture value [2], a business process model is operational in nature and describes how specific workflows and tasks support those strategic goals. Therefore, a business process model provides a functional perspective, outlining how value is generated within the organization by detailing each step involved in achieving desired outcomes [3].

2 Literature review

Existing business process models in the energy sector are designed to streamline, standardize, and optimize various operational workflows within energy production, distribution, and consumption. Scientific research provides a variety of models (both strategical or operational) focused on various aspects of the energy market and ECs. The following highlights some of the most relevant studies in this area.

A comprehensive study explores the growing field of electric vehicle (EV) destination charging, emphasizing critical aspects like charging tariffs, business models, and coordination strategies essential for expanding and sustaining these networks [4]. It identifies destination charging as a crucial complement to residential and public charging, assessing models such as network operator, owner-operator, and integrated approaches for their profitability, user engagement, and feasibility, alongside pricing tactics like time-of-use and real-time options. The findings emphasize the value of user-cantered and flexible pricing models to better synchronize EV charging infrastructure with both demand patterns and operational requirements.

The analysis in [5] focuses on a method for integrating IoT devices into business models using Business Process Model and Notation (BPMN), emphasizing the streamlined, inclusion of real-time data from appliances like sensors and actuators. This approach allows business processes to directly interact with Internet of Things (IoT) devices, such as temperature sensors and automated robots, without increasing BPMN’s complexity. The BPMN framework models the overall process flow, while an ontology system manages detailed IoT data, enabling business models to adapt based on real-world conditions. The proposed microservices-based architecture supports these interactions by decoupling IoT devices from the BPMN models, enabling flexible execution that’s compatible with varied IoT appliances and technologies.

In [6] the authors are presenting an "energy-as-a-service" business model, targeting aggregators who manage prosumers equipped with distributed energy resources (DERs) such as solar panels and battery storage. Moving beyond traditional volumetric pricing, this model provides prosumers with free electricity through a fixed monthly fee, while aggregators optimize DERs across wholesale markets, including energy and ancillary services. By focusing on predictability and ease, the model offers prosumers a straightforward, risk-free way to engage in energy markets with assured outcomes. Findings show a significant boost in aggregator profitability and a reduction or elimination of energy costs for prosumers.

Another research examines how innovative business models are essential for integrating prosumers into decentralized energy systems [7]. With increasing digitalization and a shift toward sustainability, the energy sector is transitioning from centralized models to flexible systems that empower individuals to locally generate, manage, and trade energy. This shift is supported by technologies like smart grids, IoT, and blockchain, as well as regulatory frameworks promoting prosumer involvement. Business models such as self-consumption, leasing, demand response, and peer-to-peer trading are discussed, each offering distinct benefits and facing challenges shaped by regulations, technology, and market structures. Although these models present economic and environmental benefits, obstacles like costs, infrastructure demands, and regulatory inconsistencies limit widespread adoption.

A different perspective in this area is examined in [8]. The study investigates business models for ECs, including prosumers, storage, EV charging, and aggregators. Six models are proposed to enhance value through local flexibility markets, optimize costs, and drive the energy transition. By shifting energy use to off-peak times, EC members can reduce costs, earn additional revenue, and aid grid operators in load balancing. A case study of 114 apartments in a local flexibility market demonstrates significant financial benefits: consumers earn income from flexibility contributions, while retailers save on energy costs. The potential of these models to support sustainable energy practices, encourage decentralized systems, and provide economic benefits to EC members is emphasized.

Additional relevant research [9] explores emerging business models in LEMs, focusing on peer-to-peer trading, community self-consumption, and transactive energy systems. These decentralized models empower prosumers, consumers, and aggregators to engage more actively in energy trading and management, fostering a collaborative and flexible energy ecosystem. Using the Business Model Canvas framework, the study examines nine key actor categories, shedding light on critical components such as value propositions, customer relationships, revenue streams, and key partnerships. The findings highlight the strengths of these models in increasing flexibility and empowering users, enabling them to contribute to energy sustainability at the local level. However, the review also identifies challenges, particularly in ensuring economic sustainability, regulatory compliance, and technical interoperability.

Our findings indicate that, while there is ample support for describing the roles of ECs and their members, research on business process models for ECs remains limited, suggesting significant potential for further exploration.

3 Methodology

This article applies business process modeling to map the business models of EC members, with a focus on using Business Process Model and Notation (BPMN) as the primary tool.

Business process modeling serves as an effective method for visualizing, understanding, and improving complex processes, particularly in sectors like energy markets where workflows are highly dynamic and require frequent adjustment in response to real-time data. The use of BPMN is specifically selected due to its standardized and intuitive notation, which enhances both communication and operational clarity across stakeholders. It also can be seen as a means to communicate across different languages and cultures [10].

For most BPMN users, graphical representation of models is essential. BPMN provides three main types of diagrams. The process or collaboration diagram is commonly used to depict the flow of a process, including activities, splits, and parallel flows, as well as collaborations between multiple processes with exchanged messages. A single-process version is typically called a process diagram, while a version with interacting processes is referred to as a collaboration diagram. Other types are choreography and conversation diagrams for visualizing complex protocols or an overview of partners and their interactions [11].

Process diagrams are the most widely used and the most intuitive type of BPMN diagram. Three main categories of notations for a process diagram are depicted in Fig. 1.

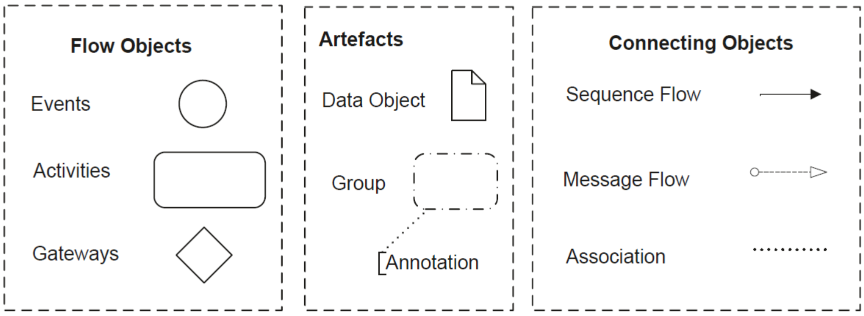

Fig. 1. Detailed sequence diagram for General Settings configurations

In BPMN, flow objects are essential components that include events (signifying process-relevant occurrences), activities (work units within a process), and gateways (controlling path divergence and convergence). Artifacts provide additional details, such as data objects and annotations, adding context without affecting process execution. Connecting objects link these elements: sequence flows outline the order, message flows represent exchanges between participants, and associations connect artifacts to other flow elements [3]. Events are represented by circles, activities by rounded rectangles, gateways by diamond shapes and arcs (called sequence flows in BPMN process diagram) are represented by arrows with a full arrowhead [12].

Business process modeling offers a structured approach for capturing detailed operational steps within an energy market, allowing a clear illustration of each task, decision point, and interaction between entities. This clarity is critical in energy markets where actors, such as energy producers, aggregators, consumers, and market operators, must operate within tightly regulated frameworks while also responding flexibly to fluctuating supply and demand. The visual representation provided by business process models enables both technical and non-technical stakeholders to engage in the workflow, promoting a shared understanding and alignment of objectives [13].

BPMN is chosen as the modeling standard in this research for several reasons. First, BPMN's standardized notation facilitates interoperability, allowing models to be interpreted consistently across different organizations. This is particularly valuable in energy markets, which involve diverse participants with varying levels of technical expertise. BPMN's visual syntax, with its distinct elements for tasks, decision points, events, and gateways, allows complex processes to be represented comprehensibly, thereby reducing ambiguity and improving accuracy in process interpretation.

Second, BPMN's flexibility allows it to capture both simple and highly complex workflows, making it suitable for a range of energy market scenarios, from straightforward trading procedures to intricate decision-making processes that involve real-time adjustments. The ability of BPMN to represent conditional flows and event-driven gateways is especially relevant for energy markets, where processes must adapt dynamically based on market conditions, demand, and resource availability.

The research methodology aims to analyse and design BPMN models tailored to various members in ECs, such as prosumers or aggregators. Each developed BPMN model illustrates specific operational workflows and interactions within the energy market ecosystem. The methodology can be divided into the following steps: (1) Members identification, which involves identifying relevant members of ECs, such as prosumers, EV charging stations, and aggregators, who participate in the energy market; (2) Process analysis, which details the operational processes of each member, including forecasting, energy trading, flexibility transactions, and daily management cycles. Each process flow is analysed based on tasks, events, and decisions required to achieve energy optimization and economic benefits; and (3) BPMN modeling, which creates BPMN process diagrams for each member's processes, emphasizing workflow, decision points, and interactions with local and flexibility markets.

4 Results

Scientific literature provides a comprehensive overview of several key roles within ECs, with each role contributing uniquely to the production, consumption, storage, and management of energy resources [1], [8], [14], [15], [16]. These members can be classified as follows: (a) active energy participants within the local energy system, such as prosumers, storage owners, or EV (electric vehicle) charging stations; (b) entities and mechanisms that support a decentralized energy ecosystem, including Aggregators, Local Energy

Markets (LEM), and Local Flexibility Markets (LFM); and (c) facilitators and enablers, such as Community Operators, Investors or Sponsors, and Regulatory Bodies or Advisors. In this paper, we focus on the first two categories of EC members, as business models for these roles are generally applicable across global energy markets. While facilitators and enablers, such as Community Operators or Regulatory Bodies, are critical to ensuring compliance and financial stability, their roles often vary significantly based on regional policies and specific community setups. By concentrating on the first two categories, we aim to address the most broadly applicable and impactful aspects of ECs, enabling our findings to be relevant and adaptable across a wider array of markets and regulatory landscapes.

In the remainder of this section, we introduce and provide detailed descriptions of several BPMN business process models to outline the business requirements for the following categories of EC members: prosumer, battery-based storage, EV charging station, aggregator, LEM and LFM.

4.1 Prosumer

Prosumers are consumers who both use and generate energy, distributing any excess electricity to others within the grid [16]. Grids that incorporate prosumers bring notable benefits and opportunities that set them apart from traditional grids. For example, smart prosumer grids improve efficiency by integrating advanced control and communication technologies to optimize the energy use of home appliances.

The BPMN process diagram in Fig. 2 is tailored for a prosumer, depicting a systematic approach for managing appliance control and handling energy surplus within a renewable energy-based structure. The process starts with an event labeled "Each day," marking the beginning of the prosumer’s daily operational cycle.

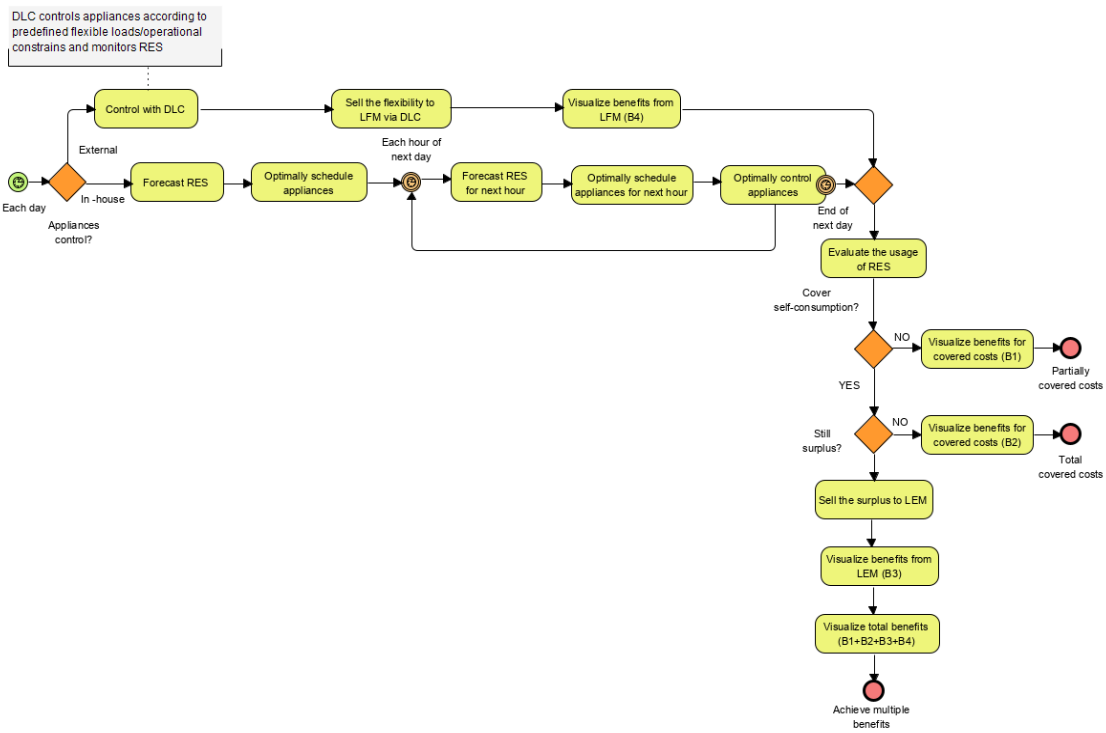

Fig. 2. Business process diagram for a prosumer

The initial decision gateway guides the workflow depending on whether control is managed internally or externally. If the decision is for in-house control, the prosumer manages their own appliances, and the process moves to the task of forecasting reusable energy sources (RES), where the availability of renewable energy for the following day is forecasted. Following this, the "Optimally schedule appliances" task organizes appliance usage based on the forecast to maximize energy efficiency.

An intermediate timer event named “Each hour of next day” initiates a loop where hourly adjustments are made. Inside this loop, three tasks are performed sequentially: “Forecast RES for next hour,” where the forecast is refined for the coming hour; “Optimally schedule appliances for next hour,” which adjusts the schedule to align with the updated forecast; and “Optimally control appliances,” where real-time adjustments are made to optimize appliance performance according to RES availability. This loop continues until the “End of next day” event, which signals the end of the hourly adjustment cycle.

For external appliance control in the initial decision, the workflow bypasses internal scheduling and controlling steps, proceeding directly to the task named "Give control to DLC." Here, appliance control is delegated to the Direct Load Control (DLC) system, which operates appliances based on predefined flexible load and operational constraints while monitoring RES availability, as stated in the note next to the task. Following this, the task “Sell the flexibility to LFM via DLC” comes next, where the prosumer sells flexibility to the LFM using DLC. This path then flows to the “Visualize benefits from LFM (B4)” task, where the benefits obtained from selling flexibility to LFM are summarized and visualized.

Once the hourly adjustments are completed, the workflow advances to the “Evaluate the usage of RES” task, where it is assessed if the renewable energy usage has successfully covered the prosumers’ s self-consumption needs. If the answer is NO the process continues to the “Visualize benefits for covered costs (B1)” task, followed by an end event indicating that some but not all costs were covered.

If renewable energy sources do cover self-consumption, the workflow advances to another decision gateway that checks for remaining surplus energy. If no surplus exists, the prosumer visualizes benefits for covered costs (B2), leading to an end event which confirms that the prosumer’s needs were completely met with no surplus energy left.

If surplus energy remains after self-consumption is covered, the process flows into the task “Sell the surplus to LEM,” where the surplus energy is sold to the LEM, generating additional revenue from the surplus. The benefits gained from this sale are envisioned in the following task, “Visualize benefits from LEM (B3)”. Lastly, a comprehensive task named “Visualize total benefits (B1+B2+B3+B4)” aggregates all benefits obtained across the various stages: covered costs, surplus sales, and flexibility transactions. This overall visualization provides a summary of the financial and operational gains achieved through the day’s energy management activities of the prosumer. The workflow concludes with an end event named “Achieve multiple benefits,” representing the successful realization of multiple benefit categories, including cost reduction, revenue from surplus energy, and income from flexibility sales.

4.2 Battery-based storage

Battery-based storage uses rechargeable batteries to capture and store electrical energy for later use. In an EC, battery-based storage allows for retaining surplus energy from renewable sources like solar or wind, making it available during peak demand periods or when renewable generation is low [17].

Fig. 3 models a scenario for controlling daily trading and flexibility operations in battery-based energy storage. The workflow incorporates forecasting, trading, and active engagement across several energy markets, including the Day-Ahead Market (DAM), Intraday Market (IDM), LEM, and LFM, to enhance the economic value of stored energy. Each step, task, and decision point are crafted to ensure efficient energy dispatch and revenue optimization for battery-based storage.

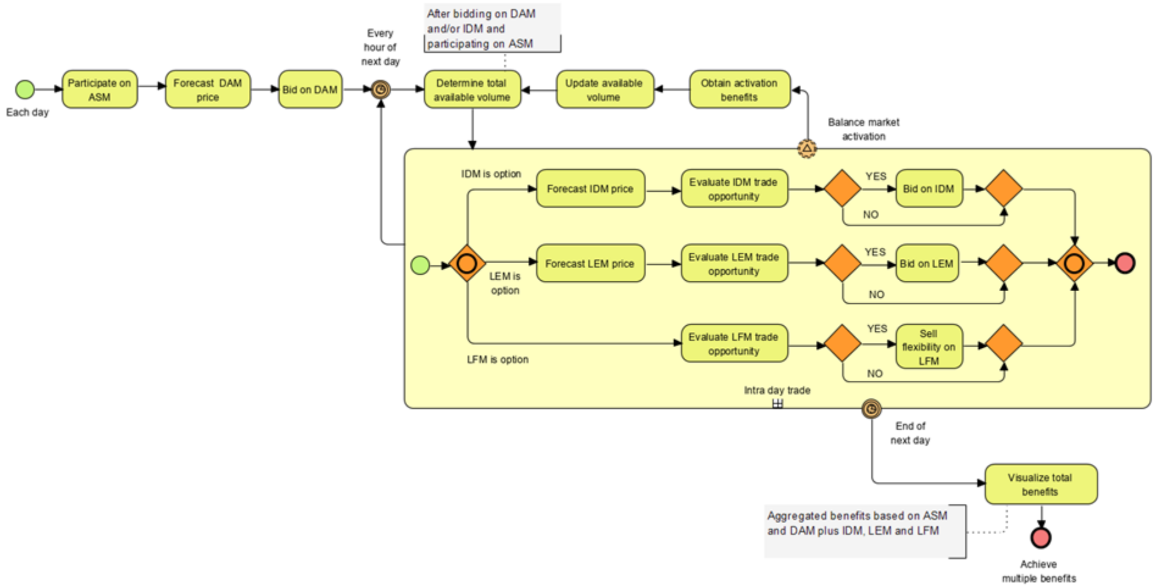

Fig. 3. Business process diagram for a battery-based storage

The process begins with a start time event indicating the start of the daily cycle for managing the battery-based storage's energy resources. The initial task involves participating in Ancillary Services Market (ASM), where the participant provides grid support services, which in turn, generate revenue.

Next, the task "Forecast DAM price" initiates the planning phase for trading in the DAM to determine optimal pricing for energy bids. Following this forecast, bids are submitted to DAM based on anticipated prices and available stored energy.

The process then enters a loop marked by the intermediate timer event "Every hour of next day", to perform hourly assessments and adjustments throughout the day. Within this loop, the first task calculates the amount of energy the battery has available to discharge or store for trading in other markets. Then the flow leads to a subprocess that models the intra-day trade. This subprocess begins with a start event triggered by the need to evaluate an intra-day trade opportunity. The flow then moves to an inclusive gateway, which splits the path based on available options: IDM, LEM and LFM. This gateway has three outgoing paths, each labelled with a condition indicating which option is available, allowing more paths to be taken based on the specific market's availability.

For each of the market options, the subprocess includes two sequential tasks. First, there is a "Forecast Price" task for each option (IDM, LEM, and LFM), where the expected price in the respective market is forecasted. Following the forecasting, the subprocess evaluates the trade opportunity, where the forecasted price is assessed to determine if a trade opportunity on that market is beneficial. After the evaluation, each path encounters a decision point. If the evaluation outcome is positive, the next step involves taking specific trading action in the respective market. For the IDM and LEM markets, this action involves placing a bid, whereas for the LFM market, it involves selling flexibility. If the outcome of the evaluation is negative, no further action is taken on that path, and the flow proceeds towards the end event. After the decision points, the paths converge at a merging inclusive gateway, that brings together all three paths, ensuring that the subprocess only completes after all available options have been evaluated and, if applicable, trade actions taken. The subprocess will repeat, each hour, until the end of the day.

When a balancing market activation takes place, represented by an intermediate non-interrupting signal event on the boundary of the subprocess, it creates an opportunity for the battery storage system to respond to grid balancing requests. This allows for increased revenue potential through activation benefits while maintaining the regular flow within the subprocess uninterrupted. Following this activation, the available energy volume must be updated to accurately represent the amount of energy that can be supplied or withdrawn in line with market demands, ensuring that responses to balancing requests are based on current energy availability.

An intermediate timer event named "End of next day" marks the closure of the daily trading cycle. After completing trading and flexibility activities, the battery-based storage proceeds to the "Visualize total benefits" step. In this step, the combined benefits from each market (ASM, DAM, IDM, LEM and LFM) are aggregated to give a complete picture of the day's financial performance. The process concludes with an end event, signifying the successful completion of the activities for the day and highlighting the diverse revenue streams achieved through energy trading, flexibility services, and optimal battery use.

4.3 Electric vehicle (EV) charging station

The business process model in Fig. 4 outlines the operations of an electric vehicle (EV) charging station as an active player in the energy market, effectively balancing energy distribution and customer service. It demonstrates how the charging station engages with customers while leveraging opportunities in energy market trading.

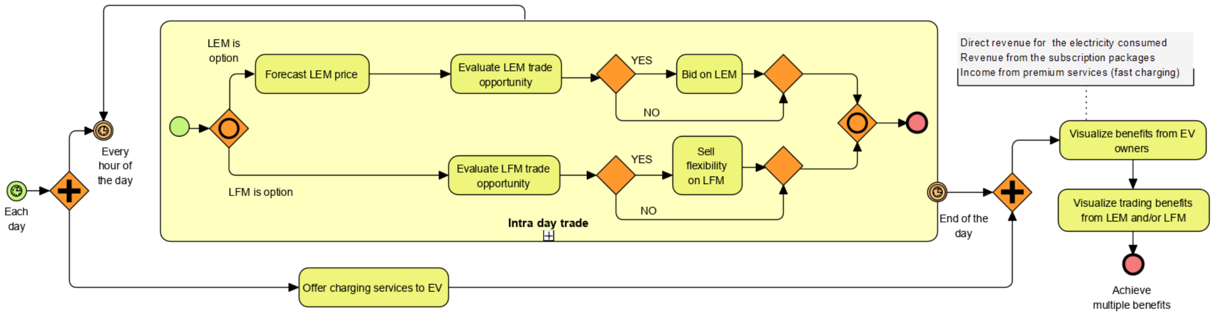

Fig. 4. Business process diagram for an EV charging station

The process starts at the beginning of each day. This daily initiation triggers all subsequent activities and serves as the foundation for the station's activities over a 24-hour period. Following this, a parallel gateway splits the process into two concurrent flows: one for energy market trading and another for EV charging services for EV owners.

In the first flow, the station participates in ongoing energy trading activities. An intermediate time event activates every hour, prompting an assessment of current market conditions. This hourly trigger initiates a trading sub-process, where the station analyses energy market options, forecasts prices, and makes strategic choices to maximize profitability.

Based on trading opportunities, an inclusive gateway divides the process into two paths—one targeting the LEM and the other the LFM—enabling the station to assess and engage with both markets simultaneously. In the LEM path, the station first analyses market data to forecast upcoming energy prices, helping it determine if trading conditions are favourable. A decision gateway then assesses if the forecast justifies placing a bid in the LEM. Similarly, in the LFM path, the station evaluates the potential for selling energy flexibility. If market conditions in either path are favourable, the station proceeds with trading; otherwise, each path concludes for the hour without action.

At the end of each hourly cycle, another inclusive gateway merges both paths, signalling the completion of trading evaluations for that period. The process then resets, preparing to repeat the market assessments in the next hour. An end event marks the conclusion of this hourly trading subprocess.

The second primary flow provides charging services directly to EV customers. Following the initial start event and parallel gateway, the station transitions into the "Offer charging services to EV" task, where it delivers charging based on customer demand, generating revenue from electricity consumption. This charging service operates independently of the market trading activities, allowing the station to meet customer needs while concurrently engaging in energy market activities.

At the end of each day the subprocess stops. Then a second parallel gateway converges both concurrent paths and afterwards, the process initiates the visualization and review of the day’s financial results. First, the station compiles the direct benefits from its charging services. This includes revenue from the electricity consumed, income from subscription packages, and any additional fees collected for premium services, such as fast charging options. This financial overview provides insight into the profitability generated solely from customer interactions.

The station then reviews the financial outcomes from its energy market trading activities, examining the revenue generated from bidding in the LEM and selling flexibility in the LFM. This analysis allows the station to evaluate the effectiveness of its intra-day trading strategy and understand the impact of market participation on overall profitability. The end event signifies the realization of multiple benefits, underscoring the station's ability to maximize revenue by balancing customer charging services with agile market trading strategies.

4.4 Aggregator

Aggregators are essential in enabling small consumers, such as those in residential and service sectors, to participate in electricity markets. While individual energy usage or generation from these consumers may be too limited to impact flexibility significantly, aggregators pool these assets to create a larger, tradable resource. By trading this combined flexibility in different electricity markets, aggregators operate on behalf of consumers, allowing them to indirectly engage in energy markets and contribute to grid stability while supporting innovative business models [18].

Fig. 5 presents another BPMN model, showcasing the aggregator's daily trading and forecasting activities within the energy markets. The model is divided into two main flows: a daily forecasting and bidding sequence, and an hourly intra-day trading cycle. Each path supports the aggregator’s ability to capitalize on different market conditions while meeting the consumption and generation needs of its members.

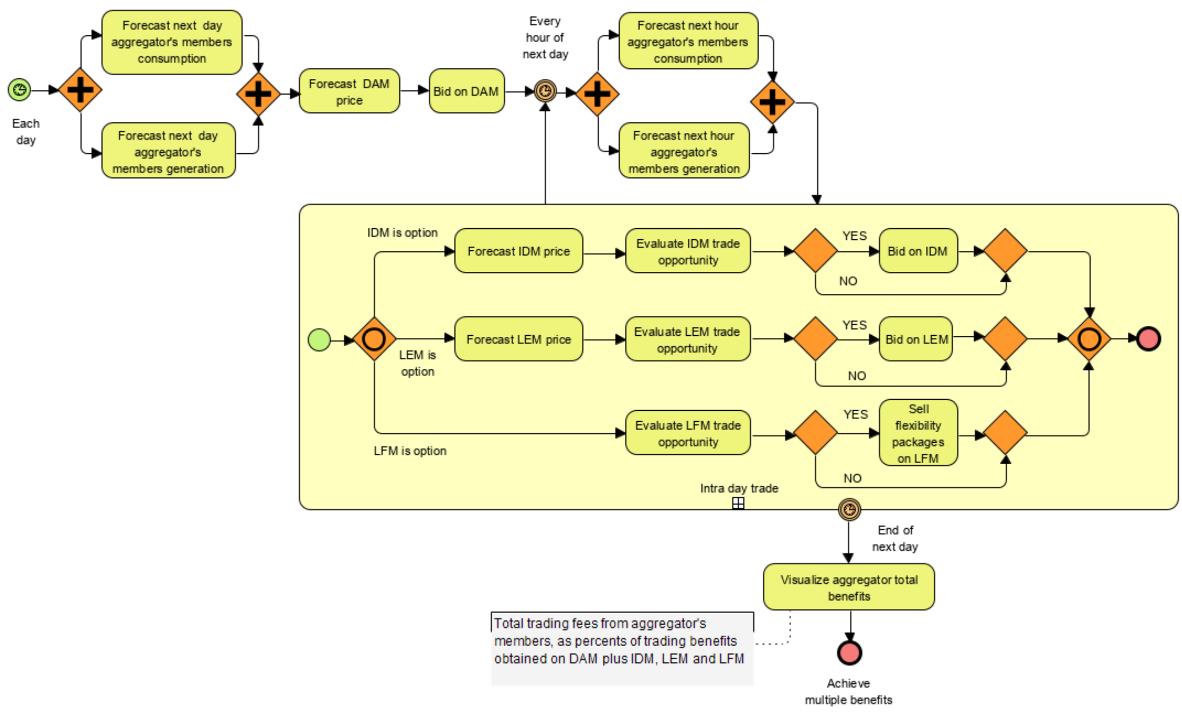

Fig. 5. Business process diagram for an aggregator

At the start of each day, the process initiates with the forecasting of the aggregator's members' daily energy consumption and generation. This step, represented by two parallel tasks, enables the aggregator to anticipate demand and supply for the day ahead. Following this, a forecast for the DAM price is generated, preparing the aggregator to determine if market conditions favour placing a bid. If conditions are favourable, the aggregator places a bid in the DAM.

Next, an hourly loop begins. Every hour, forecasts are generated for the next hour's expected consumption and generation levels of the aggregator's members. This data feeds into an hourly trading sub-process called "Intra-day Trade," which is designed to take advantage of market opportunities in IDM, LEM, and LFM.

Within the intra-day trading sub-process, an inclusive gateway first checks the options available for each market (IDM, LEM, and LFM). If IDM is an option, the process forecasts the IDM price, allowing the aggregator to evaluate potential trades. A decision point then assesses if IDM trading is beneficial; if so, the aggregator places a bid on the IDM. If conditions are not favourable, the IDM path ends for the hour.

Similarly, the aggregator forecasts LEM prices if LEM is an option, evaluating potential trades and deciding whether to bid based on forecasted profitability. If the forecasted conditions are favourable, the aggregator places a bid in the LEM; if no, the step is bypassed.

For the LFM, the aggregator assesses whether selling flexibility packages is viable, adjusting consumption or generation as needed. If the market conditions in the LFM are favourable, the aggregator sells flexibility packages; if not, the LFM path also ends without action.

At the end of each trading cycle, all market paths converge through an inclusive gateway, signaling the completion of the hourly intra-day assessment. This cycle repeats every hour, adapting continuously to real-time market dynamics throughout the day.

At day’s end, the trading results are

compiled. The "Visualize Aggregator Total Benefits" task consolidates the financial outcomes from trading in the DAM, IDM, LEM, and LFM markets, including any fees collected from participants. This visualization offers a summary of the total benefits gained by the aggregator through its trading plan.

4.5 Local Energy Market (LEM)

A LEM provides a decentralized business model enabling participants within a defined geographic area, such as a neighbourhood or community, to trade energy directly with
one another. In LEM, prosumers, consumers, and other local stakeholders can engage in buying and selling energy, often sourced from renewables like solar or wind, reducing their reliance on the main electricity grid [8], [15], [16]. Fig. 6 models a business process that describes specific activities for LEM, focusing on integrating, forecasting, optimizing, and trading for local members, such as storage units, prosumers, and EV charging stations.

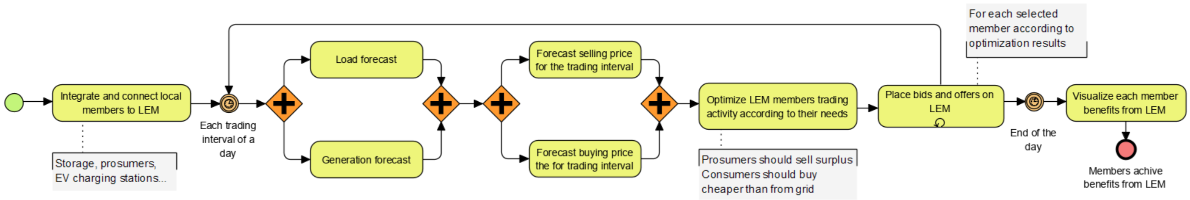

Fig. 6. Business process diagram for LEM

The flow begins with integrating and connecting local members to the LEM. This is followed by a loop that runs for each trading interval within the day, involving separate forecasts for load and generation. These forecasts help in predicting the energy requirements and available generation capacity for that specific interval.

Next, selling and buying prices for the trading interval are forecasted. These forecasts lead to the optimization step, aligning trading activities with the needs of LEM members. Prosumers are encouraged to sell their surplus energy, while consumers are advised to purchase energy at a lower cost than from the grid.

After optimization, bids and offers are placed on the LEM for each selected member, aligned with the optimization outcomes. This is represented as a repetitive task. At the end of the day, the results are visualized, showcasing each member's benefits from the day's trading. This final step provides insights into the gains achieved by each member through their participation in the LEM.

4.6 Local Flexibility Market (LFM)

In the energy sector, LFM creates opportunities for participants in a defined area to trade flexibility services, helping to balance grid supply and demand. These services involve adapting electricity use, generation, or storage in response to real-time grid needs. Through LFM, decentralized actors such as residential prosumers, commercial buildings, and battery storage owners can provide demand response and other flexibility options, supporting the local grid's stability and ensuring efficiency [1], [8]. Activities specific to energy retailers and consumers on LFM are described in Fig. 7. The model outlines a method to managing LFM and it is repeated on an hourly basis throughout the day. The process begins with connecting local members, including consumers and prosumers, to the LFM platform, establishing a foundation for trading flexibility options aligned with real-time electricity demands. The hourly cycle begins with forecasting the electricity load ($Load_e$) that must be delivered to customers, alongside estimating the hourly electricity price ($price$).

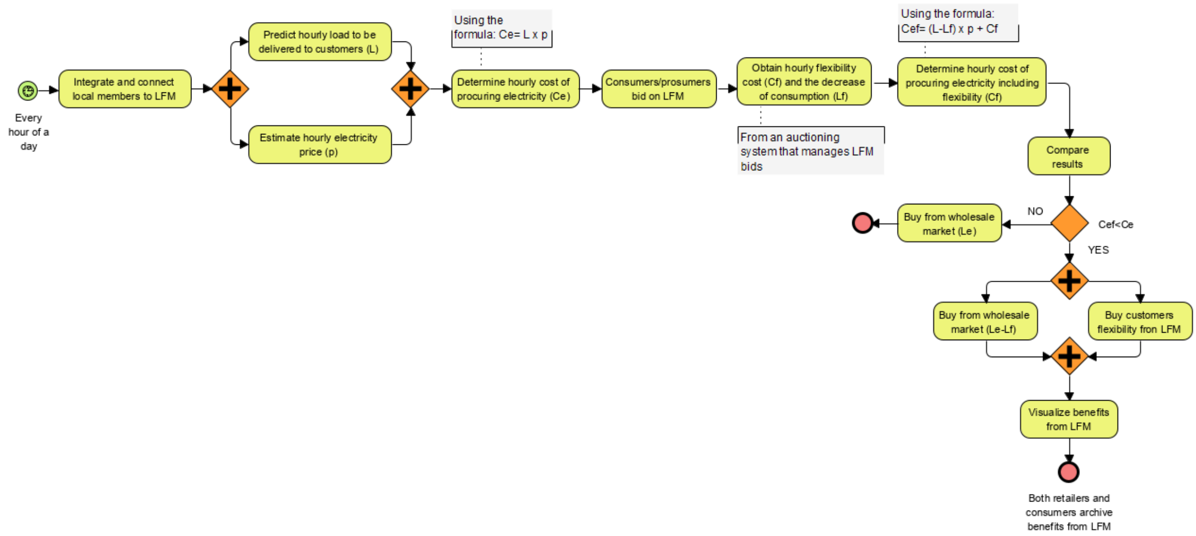

Fig. 7. Business process diagram for LFM

These two forecasts enable the calculation of the hourly cost of procuring electricity ($Cost_e$), determined by multiplying the predicted load with the estimated price, using the following formula:

$$Cost_e = Load_e \; x \; price$$

Once the electricity procurement cost is determined, local consumers and prosumers are encouraged to submit bids on the LFM platform, signaling their willingness to adjust consumption or supply in response to market incentives. The LFM's auction system manages and evaluates these bids, enabling the selection of available flexibility options.
After processing the bids, the workflow moves to determine the hourly flexibility cost ($Cost_{flex}$) and measure the reduction in consumption resulting from flexibility actions ($Load_{flex}$). This step is essential for calculating the adjusted hourly electricity procurement cost when flexibility is factored in. The updated procurement cost, incorporating flexibility ($Cost_{e+flex}$), is calculated using the formula:

$$Cost_{e+flex} = (Load_{flex} - Load_e) \; x \; price + Cost_{flex}$$

After determining both $Cost_e$ (the original procurement cost) and $Cost_{e+flex}$ (the procurement cost with flexibility), a comparison is made. If $Cost_{e+flex}$ is lower than $Cost_e$, it indicates that purchasing flexibility on the LFM is beneficial. In this case, the workflow shifts to acquiring flexibility from local members, thereby reducing the amount of energy needed from the wholesale market. The retailer then purchases only the adjusted quantity $Load_{flex}$ - $Load_e$ from the wholesale market, supplementing it with flexibility obtained from the LFM. Alternatively, if $Cost_{e+flex}$ is greater than or equal to $Cost_e$, then it is considered less cost-effective, leading the retailer to fulfill the entire energy requirement directly from the wholesale market without utilizing flexibility options.
In the final step of each hourly cycle, the benefits of participating in the LFM are visualized, offering insights into the advantages for both retailers and consumers. This overview highlights the financial impact of LFM engagement, showing how the flexibility market contributes to optimizing energy procurement costs.

5 Conclusions and future work

Proposed business process models provide a structured framework for analysing and optimizing operational workflow of varied EC members, capturing the intricate interactions and workflows of decentralized energy systems. The models offer a detailed view of tasks and decision points that shape each participant's role, revealing key interdependencies that are essential for effective resource management. By visually mapping critical processes such as energy forecasting, flexibility trading, and daily operations, BPMN helps stakeholders pinpoint bottlenecks and streamline workflows, enhancing both operational efficiency and economic outcomes.

Standardizing EC processes is crucial for creating a consistent framework adaptable to diverse participants. This standardization reduces redundancy, simplifies interactions between market participants, and ensures that each role aligns with the community's objectives. Moreover, the models support the seamless integration of essential market structures like LEM and LFM, which are involved in utilizing and trading community resource flexibility. BPMN's capability to illustrate these mechanisms in detail makes it an invaluable tool for both planning and improving processes in decentralized markets.

A key insight from the study is BPMN's role in enhancing decision-making by visualizing real-time interactions and dependencies. For instance, business process modeling of flexibility trading processes demonstrates how demand response and storage resources can be effectively mobilized during peak periods to ease grid stress and optimize costs. The decision-support function within BPMN aids day-to-day operations and establishes a foundation for strategic planning, enabling activities like optimizing resource allocation during high-demand periods or scheduling storage releases. As a result, proposed models offer guidance to community managers for aligning operations with both market demands and grid stability needs.

Finally, the comprehensive detail of BPMN models enables a clear understanding of the economic value that each EC member can achieve through structured participation in LEM and LFM. By identifying and visualizing value-adding processes, it is revealed how individual contributions—from energy production to storage management—drive collective economic gains. Understanding the interconnected economic contributions within ECs fosters the creation of financially sustainable frameworks, allowing participants to maximize the benefits of their roles.

Future research could explore further customization of business process models to accommodate variations in EC structures, such as those operating in regions with different regulatory requirements or in communities with unique energy needs and goals. Examining BPMN's capacity to model complex, evolving energy technologies could also be valuable, particularly for understanding interactions within communities that incorporate distributed energy resources (DERs) and advanced demand response capabilities. Moreover, future studies could explore more advanced BPMN elements, such as automated decision-making and machine learning integration, to improve real-time adaptability in energy processes.

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