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BRIDGING THE GAPS: A COMPARATIVE ANALYSIS OF UKRAINIAN AND EUROPEAN EXPERIENCES IN MUNICIPAL ENERGY DEVELOPMENT*

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Bridging the Gaps: A Comparative Analysis of Ukrainian and European Experiences in Municipal Energy Development

The full-scale war and the destruction of energy infrastructure have turned the development of local energy systems into a key prerequisite for the resilience of Ukrainian communities. At the same time, European integration requires aligning national decisions with the acquis communautaire in the energy sector, which highlights the need to define the regulatory and operational compliance of Ukraine's models of municipal energy development. The aim of the study is a comparative analysis of models of municipal energy development in the EU and Ukraine to identify points of functional alignment, key gaps, and priority areas for harmonization. The methodology is based on functional, comparative-legal, and systems analyses of EU and Ukrainian regulations, typology of models of municipal energy development, and the construction of a compliance matrix. The study systematized 12 European and 9 Ukrainian models of municipal energy development. Based on functional criteria, the models were identified as individual and collective participation, spatial integration, market coordination, and social distribution; by levels, the models were classified according to the legal status of the entity, network and organizational integration, and market monetization. A high correspondence was found between Ukrainian active consumer and aggregation models and the overall European ones; partial correspondence was seen in direct line models, small distribution systems, and flexible connection; low correspondence was found in the public energy association model. The main gaps are related to the lack of energy sharing, renewables acceleration areas, digital permitting processes, a municipal long-term contracting model, and proper protection of energy-poor consumers. The scientific novelty lies in the development of a functional typology and a correspondence matrix for models of municipal energy development. The practical value is in identifying priorities for the development of the municipal energy cycle — from spatial planning and connection to joint use, market energy sales, and social benefit distribution.

Keywords: *models of municipal energy development; territorial communities; energy sustainability; local energy systems; energy communities; energy sharing; European integration.*

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Хаустова В. Є., Губарєва І. О., Салашенко Т. І. Подолання розривів: порівняльний аналіз українського та європейського досвіду муніципального енергетичного розвитку

Повномасштабна війна та руйнування енергетичної інфраструктури перетворили розвиток локальних енергетичних систем на ключову передумову стійкості громад України. Водночас європейська інтеграція вимагає узгодження національних рішень із acquis communautaire у сфері енергетики, що актуалізує визначення нормативної та операційної відповідності моделей муніципального енергетичного розвитку України. Метою дослідження є порівняльний аналіз моделей муніципального енергетичного розвитку в ЄС та Україні для визначення точок функціональної відповідності, ключових розривів і пріоритетних напрямів гармонізації. Методичну основу становлять функціональний, порівняльно-правовий і системний аналіз нормативних актів ЄС та України, типологізація моделей муніципального енергетичного розвитку та побудова матриці їх

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відповідності. У дослідженні систематизовано 12 європейських та 9 українських моделей муніципального енергетичного розвитку. За функціональними критеріями виокремлено моделі індивідуальної та колективної участі, просторової інтеграції, ринкової координації та соціального розподілу; за рівнями моделі класифіковано за правовим статусом об'єкта, мережевою й організаційною інтеграцією та ринковою монетизацією. Встановлено високу відповідність українських моделей активного споживача та агрегації загальноєвропейським; часткову відповідність моделей прямої лінії, малої системи розподілу та гнучкого приєднання; низьку відповідність – моделі громадського енергетичного об'єднання. Основні розриви пов'язані з відсутністю енергетичного шерингу, зон прискореного розвитку відновлюваної енергетики, цифрового дозвільного провадження, муніципальної моделі довгострокового контрактування та належного захисту енергетично бідних споживачів. Наукова новизна полягає у розробленні функціональної типології та матриці відповідності моделей муніципального енергетичного розвитку. Практична цінність полягає у визначенні пріоритетів розвитку муніципального енергетичного циклу – від просторового планування і приєднання до спільного використання, ринкової реалізації енергії та соціального розподілу вигід.

Ключові слова: *муніципальний енергетичний розвиток; територіальні громади; енергетична стійкість; локальні енергетичні системи; енергетичні спільноти; енергетичний шеринг; європейська інтеграція.*

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Introduction. The full-scale war launched by russia against Ukraine has turned the decentralization of energy systems from a matter of market efficiency into a question of physical survival. Systematic attacks on generation and network facilities since October 2022 have repeatedly left millions of Ukrainians without electricity, heating, and water, forcing territorial communities to find energy resilience reserves where the national energy system could not guarantee uninterrupted supply. At the same time, Ukraine's postwar recovery is directly linked to integration into the EU energy space and, accordingly, to the gradual implementation of the *acquis communautaire* in the energy sector. This creates a double challenge for Ukraine and its territorial communities: on one side, they need to solve the urgent task of energy autonomy, and on the other, align those solutions with the European framework of market-based and collective energy resilience. So, the problem is that municipal energy development in Ukraine is happening along two tracks at the same time – wartime necessity and European integration – and the existing scientific and practical tools are not really suited to evaluating them in a coordinated way within a single framework.

European academic and institutional research receives steady attention to municipal energy development. The authors of study [1] conducted a systematic review of 140 articles from Scopus for 2018-2022 and noted a growing focus on renewable energy communities, mostly based on solar energy combined with storage and heat pumps, and also found that their development primarily depends on regulatory, financial, and managerial barriers. The authors of another study [2] mapped energy communities in Europe and confirmed that municipalities are driving forces behind their development: they can be members of energy communities and also initiate them on their own. A broader review of energy community modeling recorded a sharp increase in publication activity after 2019 under the influence of EU policies [3]. The authors of the study [4] found that it was the Renewable Energy Directive and the Internal Electricity Market Directive that significantly transformed the regulatory and operational framework of energy communities, although national differences still shape varying development paths. At the same time, technical and economic perspectives on the development of energy communities still dominate over social and institutional ones [5].

Ukrainian research, in turn, is mostly focused on areas closely linked to the war context. The first area is the development of organizational models for local renewable energy microgrids at the level of territorial communities. The authors of the study [6] looked into the prerequisites, options, and organizational forms for creating local microgrid cooperatives of renewable energy owners based on digital platforms and found a specific effect in the Ukrainian market of cross-subsidization between residential and non-residential active customers. This conception was further developed in the study [7], where a cooperative-local renewable energy microgrid is substantiated as a tool for inclusive development and support of Ukraine's energy security, and also in the study [8] regarding the impact of platformization on the development of the renewable energy market and the risks and prospects of small energy networks based on digital platforms. The second focus is on research into energy security and the resilience of the national economy during wartime, mostly at the macro level. The authors of study [9]

found that investments in solar energy within a decentralized energy system strengthen Ukraine's energy security during the wartime. The study [10] identified barriers and prospects for overcoming them to ensure the country's energy security during wartime. Both approaches rarely intersect with European research directions: the first looks at the macroeconomic assessment of the war's impact on the energy sector, while the second focuses on the organizational and economic design of a cooperative model at the level of an individual community.

What remains unresolved is the analytical framework capable of simultaneously: (1) classifying different models of municipal energy development according to unified functional criteria; (2) determining operational correspondence between them; and (3) pinpointing regulatory gaps that hinder the shift from specific solutions to a holistic municipal energy cycle.

The aim of the article is a comparative analysis of models for municipal energy development in the EU and Ukraine to identify points of functional correspondence, key gaps, and priority areas for harmonization.

To achieve this aim, the following objectives have been set:

- to systematize models of municipal energy development established in the EU and Ukraine according to functional criteria;
- to build a correspondence matrix between European and Ukrainian models and identify the key gaps that prevent territorial communities in Ukraine from transitioning from isolated models to a fully integrated municipal energy cycle.

Presentation of the main material. European law does not establish a separate special model for ensuring municipal energy development; it is formed as a derivative of the interaction of a set of regulatory acts: Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II) [11], Directive (EU) 2023/2413 (RED III) [12], Directive (EU) 2019/944 on common rules for the internal electricity market [13], Regulation (EU) 2019/943 on the internal electricity market [14], as well as the 2024 electricity market design reform acts – Directive (EU) 2024/1711 [15] and Regulation (EU) 2024/1747 [16].

Considering this, in the present study the term «municipal energy development» refers to the set of rights, procedures, and market instruments that a local government body (LGB), municipal utilities, or local business entities can use to develop local generation, storage, energy efficiency, and demand management.

A functional analysis of the mentioned acts makes it possible to identify 12 interconnected models of municipal energy development (Table 1), grouped into three functional blocks: models of individual and collective participation (models 1-4); models of spatial integration (models 5-9); and models of market coordination and social distribution (models 10-12). In the practice of European municipalities, these structures are often combined within a single project: with proper organizational and contractual arrangements, one facility can be a self-consumption asset, a form of energy community, the subject of an electric power purchase agreement (PPA), and a source of flexibility for the network operator.

Table 1

Typology of European models of municipal energy development

No.	Model	Legal basis	Status in EU legislation
1	2	3	4
1	Active customer / Renewable self-consumer	EU Directive 2019/944: Art. 2(8), 15 [13]; EU Directive 2018/2001: Art. 2(14), 21 [11]	An active customer is a consumer (or a group of them) who consumes, stores, or sells self-produced electricity, participates in flexibility/energy efficiency schemes, provided this is not their main commercial activity. A renewables self-consumer produces renewable electricity for their own use (on their own premises or, with State permission, in other buildings) and can store or sell any surplus
2	Citizen energy community (CEC)	EU Directive 2019/944: Art. 2(11), 16 [13]	A legal entity with open voluntary participation, controlled by individuals, LGBs, or MSMEs; the goal is environmental, economic, or social benefits rather than profit; can carry out production, distribution, supply, consumption, aggregation, storage, energy efficiency services, and electric vehicle charging
3	Renewable energy community (REC)	Directive (EU) 2018/2001: Art. 2(16), 22 [11]	A legal entity with open voluntary participation, autonomous, controlled by members (individuals, MSMEs, LGBs), located near their own RES projects; purpose – environmental, economic, or social benefits for the territories/members, without commercial profit
4	Energy sharing	Directive (EU) 2019/944: Art. 2(10a), 15a as amended by Directive (EU) 2024/1711, Art. 2(1)(b), 2(5) [13; 15]	Sharing renewable energy produced or transferred off-site of a participant (own, leased installation, or transfer by another active customer). Eligible participants – households, MSMEs, public authorities (and others if decided by the State), within a bidding zone or smaller area
5	Renewables acceleration areas and mapping of suitable areas	Directive (EU) 2018/2001: Art. 2(9a), 15b-15c as amended by Directive (EU) 2023/2413, Art. 1(1)(c), 1(6) [11; 12]	Areas designated by the State as particularly suitable for placing renewable energy installations. This process is preceded by coordinated mapping of renewable-energy potential, followed by the formal adoption of renewables acceleration areas and the associated infrastructure

End tbl. 1

1	2	3	4
6	Accelerated and digital permitting procedures	Directive (EU) 2018/2001: Art. 16-16e as amended by Directive (EU) 2023/2413, Art. 1(7) [11; 12]	The permitting process should be carried out digitally and fully electronically; shortened timelines are set for certain types of projects
7	Flexible grid connection	Directive (EU) 2019/944: Art. 2(24c), 6a as amended by Directive (EU) 2024/1711, Art. 2(1)(d), 2(3) [13; 15]	Agreed conditions for connecting capacity to the grid, including restrictions and control of electricity delivery to the transmission or distribution system and its withdrawal from it
8	Direct line	Directive (EU) 2019/944: Art. 2(41), 7 [13]	An electric line that connects an isolated production facility with a consumer, or a line that connects a producer with an electricity supply company for the direct supply of its own premises, subsidiaries, and consumers
9	Closed distribution system	Directive (EU) 2019/944: Art. 38 [13]	An electricity distribution system within a geographically limited industrial, commercial, or shared service facility, usually without household consumers – provided there is technical/safety integration of user operations or predominant supply to the owner/associated enterprises
10	Power purchase agreement (PPA)	Directive (EU) 2018/2001: Art. 2(17), 15(8) [11]; Regulation (EU) 2019/943: Art. 2(77), 19a-19b as amended by Regulation (EU) 2024/1747 [15; 16]	A contract under which a person buys electricity from a producer on market terms; a separate definition – a contract to buy renewable electricity directly from the producer
11	Aggregation	Directive (EU) 2019/944: art. 2(18)-(19), 13, 17 [13]	The function of combining the load of multiple consumers or produced electricity for selling, buying, or submitting bids on the electricity market
12	Social inclusion	Directive (EU) 2018/2001: art. 21(6)(a), 22(4)(f) [11]; Directive (EU) 2019/944: art. 15a(7)-(8), 28a as amended by Directive (EU) 2024/1711 [13; 15]	A cross-cutting principle of accessibility: access for vulnerable and low-income consumers to self-consumption of RES and REC; for energy sharing – non-discriminatory access measures, benchmark of at least 10% for public authority projects; full protection against disconnection

Source: composed by the authors based on [11–16]

The basic model is an active customer / renewable self-consumer for their own needs. RED II establishes the right to produce renewable energy for personal use, store it, and sell the surplus, including through PPAs, suppliers, or peer-to-peer trading, without discriminatory procedures and fees; for energy stored on-site, double charging is prohibited, including network charges [11]. The Directive (EU) 2019/944 complements this setup with the status of an active customer, who can act directly or through aggregation, sell self-generated electricity, and participate in flexibility and energy efficiency schemes. At the same time, the network fee should separately account for electricity fed into and drawn from the grid, and the active customer must either take responsibility for imbalances or pass this responsibility on to another party. The owner of a storage facility can provide several services simultaneously if it is technically possible [13]. For a municipality, this opens up the possibility of moving from managing a single building to coordinated management of a portfolio of facilities.

The two models of energy communities have a similar organizational nature, but they differ in their scope of activity and control conditions. A citizen energy community (CEC) under the Directive (EU) 2019/944 covers all energy sources and can engage in production, distribution, supply, consumption, aggregation, energy storage, and provide energy efficiency and electric vehicle charging services. Municipalities are directly considered entities that can have actual control over a CEC. A Member State can also allow such a community to own, create, acquire, or lease distribution networks and manage them independently [13]. A renewable energy community (REC) operates specifically in the field of renewable energy, should be autonomous, and is effectively controlled by members or shareholders located near its renewable energy projects. Its members can include individuals, MSMEs, and LGBs. The main goal of both CECs and RECs is to provide environmental, economic, or social benefits to members or the area, rather than making a profit [11].

The 2024 reform of the European electricity market design established a separate right to energy sharing, separating it from the requirement to participate in an energy community. Households, MSMEs, and LGBs can share renewable energy based on a private agreement or through a legal entity within a single bidding zone or a smaller area defined by the Member State. The amount of joint electricity fed into the grid is subtracted from the total measured consumption of the participant over the interval, which does not exceed the imbalance settlement period, while keeping applicable taxes, fees, and substantiated network charges [13]. If a Member State allows other categories of end consumers, larger than MSMEs, to participate in the scheme, the capacity of the associated generating installation cannot exceed 6 MW, and the joint use must occur within a local or limited geographical area [13].

RED III raised the mandatory EU-wide target for the share of renewable energy to 42.5% of gross final energy consumption by 2030, while also setting a collective aspiration for Member States to reach 45% [11; 12]. The spatial dimension of the reform comprises two interlinked stages: coordinated mapping of renewable-energy potential together with the identification of renewables acceleration areas and associated network and storage infrastructure, and the subsequent approval of planning instruments for renewables acceleration areas. When defining these areas, priority is given, in particular, to building roofs and facades, transport infrastructure and nearby areas, parking lots, industrial sites, mines, artificial reservoirs, degraded lands, and so on [11; 12]. For the municipality, this allows coordinating land use, environmental restrictions, infrastructure accessibility, and local development plans before a specific investor appears.

A separate part of the spatial model is the acceleration and digitization of permit procedures. For projects in renewables acceleration areas, the total time for obtaining permits should not exceed 12 months, whereas for projects outside these areas, the basic period is 2 years; for certain categories of installations, shorter periods are provided. In particular, the permit procedure for solar energy equipment with a capacity of up to 100 kW should not take more than 1 month. Documents must be accepted in digital form, and the permit procedures themselves should be carried out electronically [11; 12].

The network integration of local assets is primarily ensured through a flexible connection agreement. It can define maximum guaranteed volumes for intake and withdrawal, as well as additional flexible capacity, differentiated by time periods. Such agreements should be offered in areas with limited network capacity; as a general rule, they should not postpone necessary network upgrades, and after the network development, a transition to guaranteed connection should be ensured [13; 15].

Alongside this, the Directive (EU) 2019/944 provides for a direct line – a separate electric line between an isolated generation facility and an isolated consumer, or between a producer and an electricity supply company for the direct supply of their premises, subsidiaries, and consumers. Its construction is subject to an objective and non-discriminatory permitting procedure and does not override the general rules for system access [13].

A closed distribution system is a special setup for a geographically limited industrial, commercial, or shared service site. It can be used if the users' operations or production processes are integrated for specific technical or safety reasons, or if the system mainly distributes electricity to the owner or system operator and their associated companies [13]. Therefore, for municipal practice, this setup is most relevant not for a widespread city network of enterprises in general, but for compact industrial parks, campuses, hospital complexes, transport depots, or other territorially unified sites that meet the established criteria.

The long-term contracting model is based on power purchase agreements (PPAs). The Regulation (EU) 2019/943, as amended by the Regulation (EU) 2024/1747, requires Member States to promote the spread of PPAs, remove unsubstantiated barriers and discriminatory procedures and charges. States must ensure access to tools that reduce the risk of buyer non-payment for consumers who face entry barriers to the PPA market and are not in financial difficulty; such tools can include state or private guarantees and demand aggregation mechanisms [15; 16]. For a municipality, a PPA can combine price predictability with long-term demand for a new local renewable energy project.

Aggregation represents a standalone market model: a natural or legal person combines the loads of several consumers or the electricity produced for sale, purchase, or bidding on the market. The end consumer has the right to enter into an aggregation agreement without the consent of their supplier, and the independent aggregator is not organizationally linked to that consumer's supplier [13]. At the municipal level, aggregation allows combining controllable loads, distributed generation, and storage installations from various small sites to participate in demand management programs, electricity markets, and flexibility services.

Social inclusion in this typology is not a separate organizational-legal form but a cross-cutting principle of accessibility and protection. The self-consumption framework for RES should consider access for all end consumers, including low-income and vulnerable households, and participation in REC should be available to all consumers, including such households [11]. In the field of energy sharing, Member States should take appropriate and non-discriminatory measures to ensure access for vulnerable consumers and people experiencing energy poverty. Projects owned by local authorities should ensure that shared electricity is accessible to such people, and Member States should make every effort to ensure its average share amounts to at least 10% of all shared energy. There is also full protection for vulnerable consumers and those experiencing energy poverty from electricity disconnection [13]. This approach goes beyond purely compensatory support: a vulnerable consumer is also seen as a potential participant in the local energy model.

The provided typology of 12 models forms an analytical basis for further comparison with the Ukrainian legal framework. However, for such a comparison, it is essential to distinguish the legal nature of the sources: the EU Directives 2018/2001 and 2019/944 and the acts amending them require national transposition, whereas the EU Regulations 2019/943 and 2024/1747 are directly applicable. Therefore, the actual scope of authority of a specific municipality (territorial community) is determined not only by EU law but also by the legislation of the Member State, regulator decisions, system operator rules, and norms on local self-government and public procurement [11–16].

Ukrainian law includes 9 complementary models, but they do not form a single special regime for municipal energy. Their practical value depends on the proper combination of asset status, network configuration, organizational form, and market entry method. The relevant models are scattered across the Law of Ukraine «On the Electricity Market» [17], Law of Ukraine «On Alternative Energy Sources» [18], Distribution System Code [19], Transmission System Code [20], Retail Market Rules [21], Market Rules [22], and Commercial Accounting Code [23]. Key milestones were the 2023 reforms (Law No. 3220-IX [24], which introduced the self-production and aggregation mechanism) and 2026 reforms (Law No. 4834-IX

[25], which established new models – community energy association, microgrid, and flexible connection). For a territorial community, it is crucial that the LGB does not automatically acquire the status of a participant in the electricity market; specific rights are exercised by a designated market entity (municipal enterprise, budgetary institution, storage facility operator, producer, consumer, aggregator, or specially established legal entity). Accordingly, an LGB's decision to politically support the project must be translated into property, contractual, licensing, and accounting forms. In this context, 9 models of municipal energy development in Ukraine are further analyzed across four functional levels (Table 2): legal status of the object, network integration, organizational integration of participants, and market monetization.

An active consumer is a consumer who not only takes electricity from the grid but also produces it for their own needs, can store it, and sell the excess. The basic rights of such an entity are defined in Articles 58 and 58[1] of the Law of Ukraine «On the Electricity Market» [17]. One commercial way to sell the excess is, in particular, the self-generation mechanism un-

Table 2

Ukrainian models of municipal energy development

No.	Mechanism	Legal basis	Level	Status in Ukrainian legislation
1	Active consumer	Law of Ukraine «On the Electricity Market» No. 2019-VIII, Art. 58, 58[1]; Law of Ukraine «On Alternative Energy Sources» No. 555-IV, Art. 9[6]; PDP, Ch. 11.5; CDMC [17; 18; 21; 23]	Legal status of the object	The legislatively defined status of a consumer who produces electricity for their own needs, can store it, and sell the surplus. The self-production mechanism provides for hourly value-based settlements (net billing). Simplifications regarding licensing apply within the limits set by law; connection, metering, contracts, and responsibility for imbalances remain
2	Distributed generation	Law of Ukraine «On the Electricity Market» No. 2019-VIII, Art. 1, 50, 50[1], 66; DSC; Law No. 3220-IX [17; 19; 24]	Legal status of the object	Recognized as a technical category of generating installations connected to the distribution system. Considered in DSO development plans, connection, dispatching, and market operations
3	Energy storage systems (BESS)	Law «On the Electricity Market» No. 2019-VIII, Art. 30[1], 58[1]; CDMC; Law No. 3220-IX [17; 23; 24]	Legal status of the object	Two modes are provided: an independent storage system operator as a market participant, and BESS as part of an active consumer. Possible uses include reserves, load shifting, balancing, and auxiliary services; separate accounting of charging and discharging is required
4	Direct line	Law «On the Electricity Market» No. 2019-VIII, Art. 25, Sections 1-4; DSC; PDP; CDMC [17; 19; 21; 23]	Grid integration	A separate line between the producer's generating object and the consumer's electrical installations, used exclusively by them. Requires regulatory approval, proper design, land use, accounting, and contractual arrangements
5	Small distribution system	Law of Ukraine «On the Electricity Market» No. 2019-VIII, Article 49; DSC [17; 19]	Grid integration	A licensed local distribution system in a geographically limited area. The law sets special qualification criteria, including at least two users, connected capacity of at least 1000 kW, and no household consumers
6	Microgrid / island mode	Law of Ukraine «On the Electricity Market» No. 2019-VIII, Article 1 as amended by the Law No. 4834-IX; DSC, clause 10.9 [17; 19; 25]	Grid integration	Legally, a microgrid is defined as a local system of interconnected loads and distributed generation with defined electrical boundaries, capable of operating in parallel with the UPS or in island mode. The DSC regulates the procedure for an organized energy island
7	Flexible connection	Law of Ukraine «On the Electricity Market» No. 2019-VIII, Art. 1, Art. 21, para. 10[1] as amended by the Law No. 4834-IX; DSC [17; 19; 25]	Grid integration	Connection to the transmission or distribution system with agreed limits on allowed output and/or intake power. Allows connecting a project to an overloaded section until the network is fully reinforced
8	Public energy association	Law of Ukraine «On the Electricity Market» No. 2019-VIII, Art. 58[2] as amended by the Law No. 4834-IX [17; 25]	Organizational integration	A new legal entity with open voluntary participation and mainly focused on environmental, economic, or social benefits for members or the territory. Can carry out various types of energy activities provided the relevant licensing and market requirements are met
9	Aggregation	Law of Ukraine «On the Electricity Market» No. 2019-VIII, Articles 30[2]-30[3]; TSC; DR; Law No. 3220-IX [17; 20; 22; 24]	Market monetization	Independent market activity that combines consumption, generation, and BESS into an aggregation unit. It regulates the status of the aggregator, market participation, balancing, dispatch instructions, and licensing conditions

Source: composed by the authors based on [17–25]

der Article 9[6] of the Law of Ukraine «On Alternative Energy Sources»: the cost of hourly feed-in to the grid is credited when calculating the cost of hourly consumption from the grid [18]. So, we are talking about a value-based settlement (net billing), not the physical transfer of kilowatt-hours between billing periods (net metering) [17; 18; 21]. For a community, this is the most direct way to set up their own generation at consumption sites: the main economic benefit comes from replacing purchased electricity, while selling the surplus plays a secondary role. This model is especially suitable for sites with predictable loads, as matching the production and consumption schedules reduces dependence on the price of selling the surplus. It is the most mature model of municipal energy, but it mostly stays «single-point»: electricity and settlements are tied to specific metering points, whereas portfolio management requires additional structures – aggregation, a community energy association, or some other contractual coordination.

Distributed generation refers to generating units connected to the distribution system and usually located close to where the electricity is consumed. The Law No. 2019-VIII defines this term and gives these units dispatch priority when buying and selling electricity [17]. The Distribution System Code requires taking into account distributed generation, storage facilities, demand management, and territorial development needs in the five-year plans of distribution system operators [19]. The strategy for distributed generation development until 2035 further emphasizes its importance for the resilience and recovery of the power system [26]. The regulatory maturity of the model is high at the level of technical planning, but the community's ability to influence the timing and configuration of network development is limited by the powers of the distribution system operator. Hence, distributed generation is a resource basis for municipal energy development, but it is not a complete model: its economic and social function only arises when combined with active consumption, storage, aggregation, a direct line, or a microgrid.

Energy storage systems (BESS). Legislation distinguishes the operator of an energy storage system as an independent market participant and the storage unit integrated into an active consumer model [17]. Commercial accounting for BESS should separately track electricity drawn for charging and released after storage, preventing the mixing of physical flows and market operations [23]. Thus, BESS serves three different functions: (1) backup – supports critical loads during external power outages; (2) optimization – shifts consumption or use of self-generation between hours; (3) system – can provide balancing and ancillary services, as well as flexibility services. For a community, the first two functions can be implemented at the level of an individual facility; the third usually requires market participation, either directly or through an aggregator. The legal structure of BESS is already operationally mature, but the greatest value of BESS comes as part of a community energy system, not as an isolated object. The storage unit should be designed together with critical loads, generation, the control algorithm, and according to the market model.

A direct line is a power line that connects the producer's generating facility to the consumer's electrical installations and is used exclusively by them. Parts 1-4 of Article 25 of Law № 2019-VIII define the right to its construction and operation, the need to coordinate with the energy regulator, and the rules of interaction between the producer and the consumer [17]. A direct physical route does not cancel requirements for safety, design, land use, metering, and the retail market [19; 21; 23]. A direct line is set up as a «one producer – one consumer» arrangement, not as a local public network. Expanding the circle of consumers may require classifying the infrastructure as a small distribution system. Having a direct line does not take away a consumer's right to have another supplier or network backup, but parallel modes need to be regulated both technically and commercially. Regulatory approval and the legal status of land plots can significantly affect the timeline of a direct line project, though the law provides a developed system of exceptions (renewable energy self-supply, cogeneration up to 20 MW for critical infrastructure), which basically takes typical community scenarios out of the burdensome classic direct line regime. The practical implementation of the direct line model is limited by martial law: the procedural approval mechanism is suspended, so the right under Article 25 of the Law No. 2019-VIII exists de jure, but is temporarily unfeasible de facto.

A small distribution system is a local system through which electricity is distributed to users in a geographically limited area. Article 49 of the Law No. 2019-VIII and the Distribution System Code establish the qualification criteria and specific requirements for its operator [17; 19]. Among the legal restrictions are: at least 2 users, a connected capacity of no less than 1000 kW, defined distribution volume indicators, no household consumers, a ban on transit and use of the network within the relevant facility; the operator's activity must be licensed. The model is best suited for a territorially integrated complex: an industrial park, a campus, a transport depot, a municipal hub, or another site where there are several legally separate users and a shared local network. The mechanism legally exists but has a narrow scope of application and high entry costs. The territorial dispersion of facilities, the presence of household consumers, or the transit of energy outside the site contradicts its special purpose.

Microgrid and organized energy island. According to the Law No. 4834-IX, a microgrid is defined as a group of interconnected loads and distributed generation with defined electrical boundaries, forming a local system at the distribution level, operating as a single controlled entity, and capable of working in parallel with the Ukrainian unified power system (UPS) or in island mode [17, p. 1; 25]. Separately, the Distribution System Code regulates the «organized energy island» – a part of the distribution system operator's network with connected installations for which a controlled autonomous mode is agreed upon [19; 27]. The value of this model lies in its ability to safely disconnect from the external grid, balance local power and energy, and synchronize with the OEI after the voltage is restored. In 2026, the model went through regulatory operationalization [27], but its architecture is still not fully integrated for complex municipal networks. The most realistic pilots are within a single site or a controlled section of the network in collaboration with the distribution system operator. In such projects, the list of critical loads and the duration of autonomy are determined first, and only then the generation capacity and BESS capacity.

The Law No. 4834-IX also introduced flexible connection – connecting an electrical installation to the transmission

or distribution system under conditions that limit the allowed supply and/or withdrawal capacity. Part 10^1 of Article 21 of the Law No. 2019-VIII now defines the basic contractual framework for such connections [17]. The economic logic is that a project can connect to an overloaded section without waiting for full network reinforcement by agreeing to managed time or situational restrictions. A municipal project can adopt limitations on power release during hours of local surplus if most of the energy is consumed on-site or stored. For consumption, on the other hand, the contract can include controlled draw restrictions provided that the critical portion is covered by self-generation or reserves. As of the analysis date, the legislative core of the model is in place, but full implementation depends on updating codes, standard contract documentation, transparent publication of available capacity, and digital management of limits.

Public Energy Association (PEA). The Law of Ukraine No. 4834-IX established a new model called the PEA in the Law «On the Electricity Market» as a voluntary association and a legal entity whose activities are primarily focused on environmental, economic, or social benefits for community members or the territory, rather than on maximizing profit. The Article 58^2 covers a wide range of activities: consumption, production, supply, distribution, aggregation, energy storage, and other energy services within the legally established frameworks [17; 25]. The model potentially allows LGB, communal enterprises, residents, condominium associations, SMEs, and investors to come together around a local asset. Unlike a single active consumer, a PEA creates an organizational framework: rules for joining and leaving, management bodies, benefit distribution, and procedures for financing and using assets. However, for full operation, coordinated rules for commercial accounting, interaction with suppliers and system operators, balancing, and the distribution of economic effects are needed. So, this is the closest Ukrainian equivalent to the EU's collective energy resilience, but as of the analysis date, it is still transitional: the legislative core of the model was formed in 2026, while the subordinate procedures still need systematic coordination. Therefore, it makes sense to build the pilot municipal PEA project as a combination of existing operational modes – active consumers, generation, BESS, and aggregation – along with an association charter that does not promise participants any rights for which there are still no procedural foundations.

Aggregation allows you to combine the consumption, production, or storage of several participants into an aggregation unit and represent it on the market as a managed portfolio of assets. Section IV^2 and Articles 30^2-30^3 of the Law No. 2019-VIII define the status of the aggregator, the interaction with participants of the aggregation unit, and responsibility for imbalances and market operations [17; 24]. The details are provided by the Market Rules, the Transmission System Code, and the licensing conditions for aggregation activities [20; 22; 28]. So, aggregation turns dozens of small assets into a portfolio that can reach the technical minimum to participate in the wholesale electricity market or provide ancillary services. A community can create a licensed aggregator or sign contracts with an independent aggregator, setting allowed control modes, safety priorities, and revenue sharing. The aggregation model has licensing conditions and market rules, so it is legally operational. Its main barriers are mostly institutional and economic: an individual municipal asset rarely justifies transaction costs, and a portfolio requires unified accounting and centralized energy management. That is why aggregation is a final, not an initial stage: first, the community creates assets and sets up control mechanisms, then it monetizes them on the market.

Functionally, the 9 Ukrainian models of municipal energy development are not interchangeable: they sequentially define asset status, network configuration, collective entity, and market monetization. So a single solar power plant (SPP) with a BESS can combine several models, each addressing a separate legal issue. The regulatory architecture of Ukrainian models is asymmetric. So, having models does not yet mean ready-made «package» solutions for the community. The key institutional point for their implementation remains the distribution system operator, while the monetization of flexibility depends on the transmission system operator and market rules. The practical algorithm for implementing them at the community level should move from needs to legal form: determine critical load and autonomy, choose generation and BESS, set up metering and ownership boundaries, check network conditions, identify the operating entity, and only then decide on selling surplus or aggregation. So, Ukrainian legislation already provides basic tools for community energy resilience, but there is a lack of a single municipal pathway and a coordinated combination of energy, budget, property, and procurement regulations.

Based on the above, the regulatory convergence of Ukrainian law with the EU *acquis* in the field of municipal energy development is already significant, but operational convergence is considerably lower. The main gap has shifted from the absence of basic statuses to incomplete procedures, weak coordination, and the limited ability of communities to combine individual models into a holistic municipal energy cycle. Table 3 presents a comparative matrix of the alignment of models of municipal energy development in Ukraine and the EU.

The biggest convergence happened in individual models: the Ukrainian active consumer generally matches the self-consumer RES models under RED II and the active customer under the Directive (EU) 2019/944. At the same time, the Ukrainian model is tied to a single metering point and does not allow for hourly production distribution across multiple sites. Another important crossover point is aggregation, which both systems recognize as a separate market activity. Its main gap is the lack of practice in portfolio formation, telemetry, asset inventory, and revenue distribution. In the network segment, Ukraine has equivalents of the direct line and closed distribution system. However, the Ukrainian small distribution system is limited by narrow criteria and completely excludes household consumers, and the direct line remains regulatorily complex and small-scale [13; 17; 19]. The Law No. 4834-IX introduced new models – a public energy assosiation, a microgrid, and flexible connection [25]. However, these institutions still need to be operationalized in codes, standard contracts, commercial accounting, and DSO procedures.

European law distinguishes between CEC and REC: the former has a broad scope of activity, while the latter focuses on renewable energy, autonomy, local control, and local benefits [11; 13]. PEA in Ukraine combines elements of both models without replicating them separately [17; 25], creating an orga-

Table 3

Matrix of alignment of models for municipal energy development in Ukraine and the EU

Model	Intersection point	Key gap	Alignment
Active customer / Renewable self-consumer	Production for own needs, BESS, selling surplus, responsibility for imbalances	The Ukrainian model is mostly tied to the metering site; there is no full multi-point distribution within the municipal portfolio	High
Citizen energy community (CEC)	Voluntary legal entity, public benefit, local authority participation, wide range of energy activities	Subordinate procedures, license combinations, and rules for interaction with DSOs and suppliers do not yet form a complete model	Medium
Renewable energy community (REC)	Collective participation and directing benefits to members or the territory	Criteria related to proximity to RES projects, autonomy, and efficient local member control have not been separately established; REC are not clearly distinguished	Low
Energy sharing	Some elements are possible through active customers, associations, and aggregation	There is no right to distribute hourly generation between different metering points through private agreements or to subtract shares from participants' measured consumption	None
Renewables acceleration areas and mapping of suitable areas	Consideration of distributed generation, BESS, demand, and territorial development in distribution system operator development plans	No mandatory mapping of renewable energy potential, legal status of acceleration areas, or integrated combination of land use, ecology, and grid capacity	Low
Accelerated and digital permitting procedures	Some administrative services can be provided electronically	No end-to-end electronic processes or special deadlines for renewable energy projects	Low
Flexible grid connection	Connection with guaranteed and limited capacity components as an alternative to a standard network connection	The legislative core is new; detailed codes, model contracts, public data on available capacity, and rules for activating limitations are needed	Transitional
Direct line	Direct link between producer and consumer outside the usual distribution route	The Ukrainian procedure requires regulatory approval, is mostly structured as «one producer – one consumer», and has limited scalability	Medium
Closed distribution system	A local licensed network of a geographically limited industrial or service site	Narrow criteria, minimum capacity, a complete ban for household consumers, and significant regulatory costs limit use by communities	Medium
Power purchase agreement (PPA)	A long-term contract between the producer and the buyer is possible under general market rules	There is no special municipal PPA model, buyer risk guarantee tools, demand aggregation standards, or alignment with the budget cycle	Low
Aggregation	Combining load, generation, and BESS, licensing conditions, balancing, and market access	The local flexibility market for DSOs and municipal portfolio practices are still limited; high requirements for data, telemetry, and responsibility	High
Social inclusion	Recognition of vulnerability and the possibility of directing public benefits to the area	Protection is mainly compensatory; there is no guaranteed access for energy-poor consumers to shared assets or a share of collectively generated energy	Low

Source: authors' own development

nizational form, but for production, supply, distribution, aggregation, or storage, it still has to meet sectoral requirements. The main regulatory gap is the lack of energy sharing as an independent right: the Directive (EU) 2024/1711 allows hourly renewable energy output to be distributed among participants, while Ukrainian self-production and aggregation mechanisms do not provide that [15]. So, organizational integration at the municipal level in Ukraine is still at an early stage. Without rules for distributing output, data exchange, interaction with suppliers, network payments, and responsibility for imbalances, a PEA risks remaining a legal form without a key economic function – the shared use of local energy.

RED III has strengthened the territorial dimension of RES: the state has to map RES potential, networks, and storage, and determine renewables acceleration areas, taking environmental sensitivity into account. For a municipality, this reduces land, environmental, and network risks even before an investor shows up. In Ukraine, there is the Strategy for Distributed Generation Development until 2035, urban planning documentation, and DSO plans, but they do not form a single legal process. The community does not have a procedure that turns local potential and environmental constraints into renewables acceleration areas for project implementation. The related gap concerns permits: EU law provides for a single contact point,

electronic procedures, and time limits – 12 months for projects in renewables acceleration areas and one month for individual small solar installations [11; 12]. In Ukraine, the permitting route is scattered across different procedures, and the digital nature of some services does not create an end-to-end digital process.

In the EU, flexible connection is part of transparent management of network capacity deficits: operators publish data on available capacity, how it is calculated, and the status of applications, and contracts distinguish between guaranteed and flexible components [13; 15]. Ukraine has enshrined this institution in the Law No. 4834-IX [17; 25], but its efficiency depends on subordinate rules regarding contracts, restrictions, compensation, and the transition to guaranteed capacity. Without open network data, a customer cannot reasonably choose a point for flexible connection. Another gap is the lack of a stable municipal channel for selling local flexibility from DSO: in the EU, demand, aggregation, and pooling can replace or complement network expansion [14; 16], whereas in Ukraine aggregation is mainly focused on wholesale markets. Therefore, the network gap covers both access to capacity and monetization of local resources: without clear network demand and a flexibility contract, community BESS are mostly used for self-consumption.

In EU law, a PPA is not just a bilateral contract but also an investment policy tool: states are supposed to remove barriers, reduce buyer default risk, support demand aggregation, and promote voluntary contracts [14]. For the public sector, this combines predictable pricing with guaranteed demand for a new renewable energy project. PPAs are possible in Ukraine [17], but a special municipal PPA structure has not been set up: budgetary institutions and municipal enterprises have to align long-term commitments with budgetary, procurement, pricing, and market rules, and small buyers do not have risk guarantees or a mechanism to pool demand. So, Ukraine has the contractual possibility, but not a full institutional PPA market for communities.

The 2024 European reform integrates an inclusivity dimension into local energy: vulnerable and energy-poor consumers should have access to energy sharing, especially in public projects, as well as protection from disconnection [15]. Ukrainian law recognizes vulnerable consumers, subsidies, special obligations, and the public purpose of PEA [17; 25], but it does not link social support to participation in local energy assets. So, vulnerable households mostly remain aid recipients rather than co-participants in the energy produced or in the economic benefits. Moving toward participation requires rules regarding recipient criteria, share funding, hourly energy allocation, network payments, taxation, personal data, and interaction with subsidies.

The comparison reveals not only gaps: Ukrainian legislation separately establishes microgrids and organized energy islands as the basis for community autonomy [17; 19; 27]. Also specific is the cogeneration model up to 20 MW to supply critical infrastructure through internal networks without regular supply [17; 24]. This meets the national need for uninterrupted power, so it is about a Ukrainian adaptive innovation with an implementation gap, rather than the absence of an EU equivalent.

Conclusions. So, in 2023–2026, there has been a noticeable formal convergence of Ukrainian law with the EU acquis in the field of municipal energy development. The highest functional match is seen with active consumers and aggregation; medium – PEA, direct line, small distribution system, and flexible connection, although new institutions are still mainly legislative rather than procedural. The main regulatory gaps are focused on municipal coordination: energy sharing, fast-track renewables acceleration areas, a unified digital permitting procedure, municipal PPAs, and the participation of energy-poor consumers in local assets.

The main implementation gap is the lack of new structures for the full operational cycle of municipal energy development. The key municipal gap is the absence of a single legal path for projects, which communities currently have to navigate on their own through energy, land, construction, environmental, budgetary, property, procurement, and social procedures.

The strategic objective is to move from transposing individual terms to operationalizing the municipal energy cycle: planning the territory, obtaining permits, connecting an asset, operating it in normal and autonomous modes, sharing or selling energy, and ensuring the social distribution of benefits. This logic forms the basis for further development of local energy systems in territorial communities.

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28. Про затвердження Ліцензійних умов провадження господарської діяльності з агрегації на ринку електричної енергії та внесення змін до деяких постанов НКРЕКП : постанова НКРЕКП від 18.10.2023 № 1909 // База даних «Законодавство України» / Верховна Рада України. URL: https://zakon.rada.gov.ua/go/v1909874-23

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