DOI: 10.17747/2618-947X-2023-1-58-73
УДК 330.354

The concept of transformation of the retail electricity market in the context of digital transformation of the industry

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Abstract

The market model of the Russian power industry that currently exists is facing trends and challenges, such as rising electricity prices for end-consumers, rising tariffs for power transmission services and sales mark-ups, the complexity and high cost of technological connection to power grids and capacity expansion, as well as increase in cross-subsidisation.

At the same time, the energy industry is influenced by external factors caused by a number of technological changes that have matured in Russia and in the world, such as the transition from electric energy production at large power plants to the use of distributed generators (including those using renewable energy sources (RES), an increase in the final price on electricity due to growth in demand, as well as the transformation of the spread and reduction in the cost of generator techniques with the use of renewable energy sources, technologies for energy storage systems, as well as the development of smart metering systems.

In turn, cutting-edge technologies of the electric power industry not only lead to positive economic effects when implemented separately, they reveal the fullest range of effects and lead to the emergence of new models of interaction in the retail market if their interaction is coordinated by Industry 4.0 digital technologies. Thus, the combined influence of digital transition technologies in the electric power industry forms the prerequisites for the emergence of a new type of consumer of electric power – an active consumer.

The purpose of this study is to analyse the factors influencing the adoption of these technologies by retail market entities and the effectiveness of their implementation, as well as the formation of a target retail market concept that takes into account the introduction of active consumers and has the potential to create direct and indirect economic effects for energy industry entities.

Keywords: digital maturity, energy complex, digitalisation, retail market, active consumer.

For citation:

Kuzmin P.S. (2023). The concept of transformation of the retail electricity market in the context of digital transformation of the industry. *Strategic Decisions and Risk Management*, 14(1): 58-73. DOI: 10.17747/2618-947X-2023-1-58-73.

Концепция преобразования розничного рынка электроэнергии в условиях цифровой трансформации отрасли

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Аннотация

Рыночная модель электроэнергетики России, существующая в настоящее время, сталкивается с тенденциями и вызовами, такими как рост цен на электроэнергию для конечных потребителей, рост тарифов на услуги по передаче электроэнергии и сбытовых надбавок, сложность и дороговизна технологического присоединения к электросетям и увеличения мощности, а также увеличение объема перекрестного субсидирования.

При этом на энергетическую отрасль оказывают влияние внешние факторы, обусловленные рядом технологических изменений, назревших в России и в мире, таких как переход от выработки электроэнергии на крупных электростанциях к использованию распределенных генераторов (в том числе использующих возобновляемые источники электроэнергии), увеличение конечной цены на электроэнергию, обусловленное ростом спроса, а также распространение и удешевление технологий генерации с использованием возобновляемых источников энергии, технологий систем накопления электроэнергии, а также развитие систем интеллектуального учета.

В свою очередь, перспективные технологии электроэнергетической отрасли не только приводят к возникновению положительных экономических эффектов при реализации по отдельности, но и раскрывают наиболее полный спектр эффектов и приводят к появлению новых моделей взаимодействия на розничном рынке, если их взаимодействие координируется цифровыми технологиями индустрии 4.0. Таким образом, совместное влияние технологий цифрового перехода в электроэнергетике формирует предпосылки для появления нового типа потребителей электроэнергии – активного потребителя.

Целью настоящего исследования является анализ факторов, влияющих на принятие этих технологий субъектами розничного рынка и эффективность их внедрения, а также формирование целевой концепции розничного рынка, учитывающей внедрение активных потребителей и обладающей потенциалом к созданию прямых и косвенных экономических эффектов для субъектов энергетической отрасли.
Ключевые слова: цифровая зрелость, энергетический комплекс, цифровизация, розничный рынок, активный потребитель.

Для цитирования:

Кузьмин П.С. (2023). Концепция преобразования розничного рынка электроэнергии в условиях цифровой трансформации отрасли. *Стратегические решения и риск-менеджмент*, 14(1): 58–73. DOI: 10.17747/2618-947X-2023-1-58-73.

电力零售市场在行业数字化转型中转变的概念

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摘要

俄罗斯电力部门目前的市场模式面临着一些趋势和挑战，例如：终端用户的电价增加、电力传输服务费率与销售加价的增加、电网的技术连接和增容的复杂性和高成本、以及交叉补贴的增加。
能源部门还受到俄罗斯和全球出现的一些技术变革带来的外部因素的影响，如：从大型发电厂的发电过渡到使用分布式发电机组（包括那些使用可再生能源的企业）、由于需求增加而导致电价上升、以及可再生能源发电技术与储电系统技术的普及和减价化、智能电表系统的发展。
反过来，有前途的电力部门技术在分别实施时，如果通过工业4.0数字技术协调它们的互动，会带来积极的经济效应以及揭示最全面的效果，并导致零售市场的新互动模式。因此，电力部门的数字转型技术的综合影响构成了一种新型电力消费者—活跃消费者—出现的先决条件。
本研究的目的是分析影响零售市场参与者采用这些技术的因素以及这些技术的实施效果，以及形成一个零售市场目标概念，考虑到引入活跃消费者，并有可能为能源部门的参与者创造直接和间接的经济效应。

关键词： 数字化成熟度、能源部门、数字化、零售市场、活跃消费者。

供引用:

Kuzmin P.S.（2023）。 电力零售市场在行业数字化转型中转变的概念。战略决策和风险管理。14(1)： 58-73。 DOI： 10.17747/2618-947X-2023-1-58-73。

Introduction

The current market model of the Russian electric power industry is facing trends and challenges, such as an increase in electricity prices for end-consumers, caused by an increase in prices for both electricity and capacity in the wholesale electricity and capacity market (WEM), rising tariffs for power transmission services and sales mark-ups, the complexity and high costs of technological connection to power grids and capacity expansion, as well as increase in crosssubsidisation. [Khovalova, Zholnerchik, 2018].

At the same time, the energy industry is influenced by external factors caused by a number of technological changes that have matured in Russia and in the world, such as the transition from electric energy production at large power plants to the use of distributed generators (including those using renewable energy sources (RES), an increase in the final price on electricity due to growth in demand, as well as transformation of the behavioural model of consumers [Trachuk, Linder, 2018]. These factors determine the trend of transition from a centralised architecture of power supply to the decentralised one, which uses both small distributed generation and demand-side management [Frankel, Wagner, 2017].

These trends are enhanced by the spread and cheapening of generation technologies with the use of renewable energy sources [Digital transition.., 2017], technologies of energy storage systems [Application of energy.., 2019], as well as the development of smart metering [Kuzmin, 2021c]. The trend that allows the integration of innovative energy technologies, new energy sources and smart metering systems is the spread of Industry 4.0 digital technologies [Ivanov et al., 2018].

As it was shown earlier in the author's work [Kuzmin, 2021b], cutting-edge technologies of the electric power industry not only lead to positive economic effects when implemented separately, reveal the most complete range of effects and lead to the emergence of new interaction models in the retail market in case of their interaction coordinated by Industry 4.0 digital technologies. Thus, the cooperative effect of digital transition technologies in the electric power industry forms the prerequisites for the emergence of a new type of consumer of electric power - an active consumer.

The author identifies 5 models of an active consumer in his study [Kuzmin, 2021b]:

1. The basic model of an active consumer. In the basic model a source of electric power or an energy storage system can be located on the consumer side before the electricity meter. A customer can consume electricity produced by a generator belonging to him and buy it from the grid if its own energy output is not enough to cover consumption. If there is no generation or accumulator system, the consumer has the opportunity to change the load profile taking into account hourly or zone electricity prices.

2. Active energy complex/microgrid. This model is based on end-users and retail generators (including generating capacities owned by active consumers and/or energy storage systems) connected to a low-voltage power grid on the territory of the microgrid owned by the microgrid operator. Electricity is

recorded at the border of the active energy complex as the balance of generated and consumed electricity.

3. Energy cell. The concept of an energy cell (or a local energy company) is not dissimilar to the concept of a microgrid, however, unlike a microgrid, the energy cell also includes local distributed generation connected to other consumers and microgrids through networks of territorial electricity transmitters.

4. P2P model / Internet of Energy. Peer-to-peer business models are based on eliminating the electricity supplier as an intermediary between active consumers. This model uses a third-party platform on which consumers trade electricity among themselves. If the generating capacities of active consumers are not enough for the balance of platform participants or, on the contrary, there is an excess, electricity can be purchased from the centralised electric power system or sold into it.

5. Load aggregator. This model implies the use of a subject, a Load aggregator, selling flexibility on the WEM and forming this flexibility (the ability of the electric power system to maintain a power balance in conditions of high volatility of consumption power and generation power) by means of demand management of many small consumers in the retail market.

The study [Kuzmin, 2021b] has shown that these models have the potential to create direct and indirect economic effects for energy industry members and consumers.

The purpose of the present study is a deeper analysis of the factors influencing the adoption of these technologies by the retail market participants and the effectiveness of their implementation, as well as the formation of a target retail market conception that takes into account the introduction of active consumers.

1. Research design

For a deeper analysis of the relationship between the investments of the retail electricity market participants in projects for the implementation of innovative models of interaction - active consumers using Industry 4.0 technologies in the energy sector, as well as the achievement of positive economic effects, it was decided to take as a basis the widely used structural model (CDM) proposed by B. Crépon, E. Duguet and J. Mairesse [Crépon et al., 1998].

This model has been successfully used for works analysing the relationship of investments in cutting-edge technologies with the increase of the effectiveness and productivity of companies and among other things, was tested in the study [Trachuk, Linder, 2020] and also in the research [Trachuk, Linder, 2017].

The initial CDM model describes three areas of relationships, linking the investments in development and research and the effectiveness and efficiency of these investments, expressed as the ratio of revenue to the full-equivalent employee number in enterprises. In the first part of the CDM model there are two equations characterising the propensity of companies to make investments and their "value". The second set of equations describes the relationship between different types of innovations and the amount of investments made in them. The third and the final part of the CDM model evaluates the relationship between the effectiveness of investment activity and the size of the created effects [Trachuk, Linder, 2017].

In order to analyse the efficiency of implementing active consumer models the CDM model was redesigned as follows.

1.1. Investments in projects for the implementation of active consumer models

The first group of model equations is designed to assess the probability of a company making a decision to invest in projects implementing active consumer models and in the case of an investment decision, to assess the relative value of investment (intensity) defined as the amount of expenses related to the number of employees of the company.

To specify the first part of the model it was decided to use the Heckman's censored regression equations. A feature of this model is the ability not only to estimate the probability of making a decision on investments in development projects, but also to calculate the relative value of these investments. The model consists of two ratios. The first equation is a binary choice model that evaluates the binary decision "to invest / not to invest" depending on a number of factors that will be determined later in the study. The second ratio is a linear model that determines the relative value of investments in projects for the implementation of active consumer models. It should be noted that the advantage of the Heckman's (censored regression) model is the ability to take into account not only companies that are already investing in projects for the implementation of active consumer models, but also those that only plan to make investments.

Thus, the specification of the first part of this mathematical model has the form expressed by equations (1)–(2):

The first equation has a hidden (unobservable) variable that describes the decision of the company (the electricity consumer) to invest in the implementation of the active consumer model:

$$D_i = \begin{cases} 1, if D_i^* = d_i x + \varepsilon_i > \vartheta \\ 0, if D_i^* = d_i x + \varepsilon_i \le \vartheta \end{cases}, \qquad (1)$$

where D_i is a manifest variable that takes the value 1 if the company has decided to invest in the implementation of the active consumer model and it takes 0 if the company has not made such decision; D_i^* is a hidden variable that describes the probability of a company to invest in the implementation of an active consumer model and is a conventional regression model that depends on a number of factors – independent variables; d_i are independent variables that are factors that influence the company's decision to invest in the implementation of the active consumer model;

Table 1
Factors influencing the adoption of active consumer models by companies

Perceptual factor	Explanation
d_1	Technical feasibility
d_2	Perceived advantages
d_3	Perceived risks
d_4	Expected costs
d_5	Complexity of assimilation
d_6	Influence of regulatory authorities
d_7	Influence of electric power companies
d_8	Pressure of market environment
d_9	Technological changes in the industry
d_{10}	Reliability

Source: compiled by the author.

x is a column vector of model parameters; ε_i is a column vector of remainder terms (random errors).

The list of d_i – independent variables that are factors influencing the company's decision to invest in the implementation of the active consumer model is defined in the study [Kuzmin, 2021c]. It is presented in table 1.

The Heckman's censored regression uses the assumption that random errors are described by a normal distribution.

Companies that consume electricity tend to invest in projects for the implementation of active consumer models if the manifest variable D_i is greater than a certain threshold value ϑ, which can be characterised as a decision criterion, for example, the projected amount of positive economic effects from the investment in active consumer models.

The second ratio in the Heckman's censored regression describes the relative value of investments when making a decision on investments in the first equation of the model, which is expressed as a value of investment in the project of the active consumer model implementation, calculated for one employee of the company:

$$Inv_i = \begin{cases} Inv_i^* = i_i y + e_i, \text{ если } D_i = 1 \\ 0, \text{ если } D_i = 0 \end{cases}, \quad (2)$$

where Inv_i is a manifest variable, which takes the value of the volume of investments in the project of implementing the active consumer model if the company has decided to invest and 0 – if the company has not made such decision; Inv_i^* is a hidden variable describing the amount of investment in the project for the implementation of the active consumer model; i_i are independent variables that are factors describing the relative amount of investment in the project for the implementation of the active consumer model; y is a column vector of model parameters; e_i is a column vector of remainder terms (random errors).

1.2. The results of investments in the elements of the project for the implementation of active consumer models

The second part of the model describes the dependence of investments in various elements of the project for the implementation of the active consumer model on the total intensity of investments in the project.

As it was shown in the work [Kuzmin, 2021b], the key equipment necessary for the implementation of active consumer models are: distributed generation, electrical energy storage systems, electricity smart metering systems, as well as Industry 4.0 digital technologies.

Thus, the specification of the second part is mathematically expressed by the ratio:

$$RGInv_i = \overline{Inv_i} z + k_i \alpha + \epsilon_i, \quad (3)$$

where $RGInv_i$ is the company's investment in the implementation of distributed generation;

$$SNEInv_i = \overline{Inv_i} z + k_i \alpha + \epsilon_i, \quad (4)$$

where $SNEInv_i$ is the company's investment in the implementation of electrical energy storage systems;

$$ISUInv_i = \overline{Inv_i} z + k_i \alpha + \epsilon_i, \quad (5)$$

where $ISUInv_i$ is the company's investment in the implementation of electricity smart metering systems;

$$CTIInv_i = \overline{Inv_i} z + k_i \alpha + \epsilon_i, \quad (6)$$

where $CTIInv_i$ is the company's investment in the implementation of Industry 4.0 digital technologies; $\overline{Inv_i}$ is the average amount of investment in the implementation of the active consumer model, calculated for one employee of the company; k_i are independent variables that are factors describing investments in the implementation of the active consumer model; α is a column vector of model parameters; ϵ_i is a column vector of remainder terms (random errors).

1.3. The achievement of positive economic effects for the active consumer model implementation

According to the research [Parag, Sovacool, 2016; Engel et al., 2018; Morley et al., 2018; Nalbandian, Zholnerchik, 2018; Brown et al., 2019; Brown et al., 2020; Architecture.., 2021; Harnessing artificial intelligence.., 2021], the following number of effects can be distinguished when distributing active consumer models. The economic effect for companies that have implemented active consumer models will be formed from a number of direct and indirect effects.

Direct effects:

- direct reduction of the final cost of electricity for the company with the use of distributed generation (Cost);
- creation of additional revenue for the company through the provision of system and ancillary services (participation in demand response programmes) (DR);
- creation of additional revenue for companies through the commercialisation of big data on energy consumption (Data);
- reduction of operating costs and reliability improvement of power supply due to predictive analytics of equipment (Expense).

Indirect effects:

- reduction of the equilibrium price of RSV by shifting and smoothing consumption peaks, as well as replacing expensive and inefficient capacities in the wholesale market with a flexible load (RSV);
- reduction of investment needs in new generating and power network capacities to cover peak consumption in the long term (Inv);
- reduction of technological and commercial losses in the power network complex (Loss);
- improvement of the effectiveness of participation in demand response programmes due to a deeper analysis of end-user behavioural patterns (BigData).

Thus, the total economic effect can be described by the ratio (7):

$$Eff_i = Cost + DR + Data + Expense + RSV + Inv + Loss + BigData. \quad (7)$$

In turn, the relationship between the relative value of investments in the elements of active consumer models and the achievement of positive economic effects is described by the equation (8):

$$Eff_i = \overline{Inv_i} + RGInv_i\beta + SNEInv_i\beta + ISUInv_i\beta + CTIInv_i\beta + \sigma_i, \quad (8)$$

where Eff_i is the economic effect of the implementation of active consumer models; α and β are the corresponding column vectors of the model parameters; σ_i is a column vector of remainder terms (random errors).

For a deeper analysis of the relationship between investments in projects for the implementation of active consumer models and the achievement of positive economic effects four main types of active consumer models will be considered in the analysis:

- active energy complex/microgrid;
- energy cell;

- P2P model / Internet of energy;
- load aggregator.

It was decided to abandon the consideration of the Basic model of an active consumer in the CDM model, as this model exists in theoretical studies and cannot be implemented in practice due to incommensurably high transaction costs relative to the potentially created positive economic effects.

2. Results of the CDM model study

To conduct the study the questionnaires were sent to 356 experts selected according to the criteria similar to the criteria of paragraph 2.1 among electricity consumer companies in the retail market. The response was sent by 203 experts, the response was 57%. The sample characteristic is presented in table 2.

Table 2
Sample characteristic (%)

Company characteristic	Number of companies
Electricity consumers	
Construction and investment company	4.1
Retail trade	27.0
Owner of commercial real estate	25.1
Housing and public utilities managing company	8.3
Production sector	16.2
Other SME	19.3

Source: compiled by the author.

The results of the analysis with the use of a two-stage Heckman's censored regression (the first group of equations) are presented in table 3. The decision of companies to invest in active consumer models is evaluated using a probit model, where the independent variables are the factors described in table 1.

In addition, the adoption of new technologies is influenced by factors characterising the company and the industry in which it operates, therefore the size of the company, calculated as the logarithm of the full-equivalent employee number, investments in current activities (the logarithm of investments in current assets) are used as control variables.

The relative value of investments is defined as the amount of investment in the implementation of active consumer models, calculated for one employee of the company.

The results obtained demonstrate that in the case of the implementation of an Active energy complex / microgrid the factors of technical feasibility, the influence of regulatory authorities and the influence of companies in the electric power industry have the strongest influence.

The strength of the impact of technical feasibility can be explained by the high level of requirements for the current infrastructure of companies, since in this model it is required to link heterogeneous hardware, from generators and storage devices to digital sensors and actuators.

Since many relations in the electric power industry are regulated by the authorities, especially in terms of consumers in the retail market, the corresponding factor was also scored high. The power of influence of electric power companies is explained by the fact that in the current structure of the laws and regulations of the industry they will be more entrusted with the role of operators of the active power complex and they can be the main suppliers of equipment for the deployment of the active consumer model and its further operation.

The factors of complexity of assimilation and expected costs scored slightly higher. This can be explained by the fact that for the successful deployment of the active consumer model the company should have a high level of competence not only in the field of energy and price setting in retail markets, but also possess significant digital competencies. The expected costs are significant since digital power equipment is quite expensive, and the benefits achieved during its implementation lead to a payback period of the implementation in the medium or long term.

The reliability and risk factors earned moderate scores. Companies are concerned about the reliability of energy supply, however, with a sufficient level of equipment quality, availability of its reserves and timely post order management, as well as the possibility of interaction with the UES retail consumers assess these risks as controllable.

The factors of technological changes in the company's operating industry and pressure from competitors have a weak influence on the decision to implement models of an active energy complex. Thus, it can be concluded that in terms of the introduction of energy technologies of Industry 4.0 retail consumers have a relatively small share of innovators.

The energy cell model has similar parameters, however, in this model the factor of electric power companies influence is more powerful, since this model assumes local retail generation owned by energy companies, and the success of the implementation of this model will mostly depend on the effectiveness of interaction with these local energy companies.

For the P2P model / Internet of Energy the factors of technical feasibility and expected costs are significantly highlighted as their power of influence is globally similar. The implementation of this model requires the most complex and expensive digital equipment both on the side of end consumers and energy companies, while the company's fixed assets must be compatible with this equipment. For the same reason the factor of complexity of assimilation has the strongest influence on the decision to implement this particular model relative to neighbouring models.

The power of influence of factors for the Load aggregator model differ the most from the previous models. This model does not require significant investments in expensive equipment and smart metering devices and a digital energy consumption monitoring platform are sufficient for its implementation. Thus, in this model the strongest influence is exerted by electric power companies and authorities, which are the main methodologists and operators demand response and load aggregation programmes. Technical feasibility, expected costs, the complexity of assimilation and perceived benefits have a moderate impact. The influence of other factors is relatively small.

Thus, the following conclusions can be drawn from the analysis of factors:

1) companies need to have plausible guesses concerning the level of their infrastructure readiness and digital maturity before deciding on the implementation of a particular model;

2) for the successful distribution of active consumer model's effective interaction of consumers with energy companies is necessary, it creates value for both end-consumers and electric power companies;

3) the low impact of technological progress and the pressure of competitors in the market indicates low innovation activity among end-consumers in terms of the introduction of electric power technologies.

After analysing the factors influencing the company's decision to invest in the active consumer model, an analysis of investments in the implementation of such models was carried out, disaggregated by investment directions (the second part of the model). The calculation results are presented in table 4.

The calculated value of the relative amount of investments in projects for the implementation of active consumer models has a moderately strong impact for the first three models, while the greatest values are achieved in the case of investments in the development of distributed generation and energy storage systems. This variable has a significantly lower impact on the Load aggregator model, which can be explained by the significantly lower cost of the elements of this solution.

Participation in government programmes has a moderately strong impact on all directions of investment. In addition, at present it is the authorities that legislatively support the implementation of pilot programmes (including a pilot project on Load aggregators and Active energy complexes). Thus,

Table 3
Forces of influence of factors on companies' decisions to invest in active consumer models

Exogenous variables	Active energy complex/ microgrid		Energy cell		P2P model / Internet of Energy		Load aggregator	
	The decision to invest in active consumer models	Relative value of investments	The decision to invest in active consumer models	Relative value of investments	The decision to invest in active consumer models	Relative value of investments	The decision to invest in active consumer models	Relative value of investments
Analysis method	The first component of the model – the Heckman's censored regression							
	The first equation	The second equation	The first equation	The second equation	The first equation	The second equation	The first equation	The second equation
Technical feasibility (d_1)	0.506 (0.101)	0.621 (0.132)	0.493 (0.109)	0.564 (0.127)	0.635 (0.114)	0.664 (0.157)	0.356 (0.068)	0.370 (0.059)
Perceived advantages (d_2)	0.350 (0.092)	0.327 (0.062)	0.368 (0.099)	0.342 (0.072)	0.341 (0.091)	0.335 (0.075)	0.324 (0.074)	0.365 (0.082)
Perceived risks (d_3)	0.331 (0.071)	0.261 (0.052)	0.301 (0.079)	0.256 (0.063)	0.368 (0.088)	0.296 (0.083)	0.158 (0.032)	0.174 (0.044)
Expected costs (d_4)	0.498 (0.056)	0.321 (0.048)	0.502 (0.106)	0.425 (0.098)	0.601 (0.131)	0.561 (0.108)	0.249 (0.046)	0.266 (0.050)
Complexity of assimilation (d_5)	0.444 (0.051)	0.321 (0.069)	0.424 (0.074)	0.331 (0.065)	0.554 (0.097)	0.487 (0.069)	0.274 (0.052)	0.261 (0.044)
Influence of regulatory authorities (d_6)	0.506 (0.101)	0.621 (0.132)	0.511 (0.112)	0.638 (0.127)	0.498 (0.085)	0.467 (0.83)	0.598 (0.136)	0.600 (0.149)
Influence of electric power companies (d_7)	0.550 (0.092)	0.427 (0.062)	0.682 (0.108)	0.598 (0.098)	0.596 (0.091)	0.598 (0.093)	0.571 (0.105)	0.537 (0.097)
Pressure of market environment (d_8)	0.131 (0.071)	0.161 (0.052)	0.117 (0.048)	0.136 (0.050)	0.124 (0.066)	0.154 (0.061)	0.152 (0.064)	0.141 (0.055)
Technological changes in the industry (d_9)	0.098 (0.056)	0.121 (0.048)	0.103 (0.037)	0.112 (0.025)	0.128 (0.032)	0.135 (0.029)	0.100 (0.029)	0.118 (0.046)
Reliability (d_{10})	0.244 (0.051)	0.221 (0.069)	0.278 (0.066)	0.235 (0.053)	0.305 (0.074)	0.311 (0.059)	0.109 (0.019)	0.114 (0.033)
Size of the company (log average number)	0.224 (0.055)	0.321 (0.069)	0.254 (0.045)	0.329 (0.051)	0.217 (0.023)	0.264 (0.027)	0.199 (0.021)	0.184 (0.024)
Logarithm of the number of employees engaged in innovation activity	0.321 (0.069)	—	0.345 (0.083)	—	0.405 (0.106)	—	0.344 (0.071)	—
Investments in current activities (log of investments in current assets)	0.125 (0.048)	0.129 (0.043)	0.159 (0.043)	0.162 (0.056)	0.201 (0.069)	0.218 (0.058)	0.138 (0.058)	0.142 (0.054)
Number of observations	203		203		203		203	
Evaluation of the quality of the model – the Heckman's Lambda	0.225 (0.110)		0.193 (0.102)		0.207 (0.089)		0.211 (0.093)	
Wald test for Ho, rho = 0	5.64		21.18		11.42		17.39	
The likelihood function	1453.24		3201.37		2535.08		2022.10	

Notes: 1. The numbers presented have marginal effect values. 2. Statistical significance of coefficients: $p \leq 0.01$. 3. Robust standard errors are indicated in-between parenthesis.
Source: compiled by the author.

Table 4
Results of the analysis of investments in the implementation of active consumer models, disaggregated by investment directions

Exogenous variables	Active energy complex/microgrid				Energy cell				P2P model / Internet of Energy				Load aggregator			
	IDG	IESS	IESMS	IIDT	IDG	IESS	IESMS	IIDT	IDG	IESS	IESMS	IIDT	IDG	IESS	IESMS	IIDT
The estimated value of the relative amount of the investment	0.392 (0.073)	0.289 (0.045)	0.089 (0.015)	0.147 (0.026)	0.385 (0.078)	0.277 (0.055)	0.102 (0.017)	0.163 (0.021)	0.373 (0.099)	0.312 (0.084)	0.125 (0.024)	0.206 (0.039)	–	–	0.156 (0.035)	0.178 (0.047)
Participation in government programmes (1 – yes, 0 – no)	0.286 (0.052)	0.247 (0.042)	0.235 (0.037)	0.201 (0.34)	0.308 (0.074)	0.254 (0.059)	0.265 (0.041)	0.223 (0.062)	0.274 (0.034)	0.229 (0.048)	0.243 (0.050)	0.221 (0.029)	–	–	0.395 (0.081)	0.402 (0.093)
Interaction with representatives of consulting companies (1 – yes, 0 – no)	0.128 (0.017)	0.175 (0.021)	0.123 (0.206)	0.246 (0.063)	0.124 (0.024)	0.156 (0.028)	0.145 (0.019)	0.239 (0.075)	0.178 (0.030)	0.189 (0.025)	0.226 (0.035)	0.265 (0.046)	–	–	0.283 (0.072)	0.296 (0.065)
Interaction with energy companies (1 – yes, 0 – no)	0.386 (0.074)	0.428 (0.083)	0.351 (0.059)	0.258 (0.042)	0.425 (0.089)	0.446 (0.094)	0.378 (0.072)	0.267 (0.048)	0.356 (0.088)	0.411 (0.101)	0.334 (0.062)	0.249 (0.038)	–	–	0.494 (0.091)	0.567 (0.103)
Interaction with scientific organisations (1 – yes, 0 – no)	0.087 (0.011)	0.103 (0.016)	0.078 (0.013)	0.124 (0.025)	0.077 (0.015)	0.095 (0.025)	0.093 (0.016)	0.111 (0.019)	0.125 (0.015)	0.132 (0.022)	0.119 (0.026)	0.127 (0.017)	–	–	0.154 (0.022)	0.136 (0.036)
Size of the company (log average number)	0.224 (0.055)	0.236 (0.063)	0.089 (0.029)	0.125 (0.048)	0.234 (0.076)	0.249 (0.057)	0.097 (0.019)	0.120 (0.031)	0.226 (0.054)	0.244 (0.068)	0.104 (0.026)	0.178 (0.053)	–	–	0.084 (0.011)	0.078 (0.017)
Logarithm of the number of employees engaged in innovation activity	0.105 (0.038)	0.112 (0.040)	0.143 (0.052)	0.137 (0.027)	0.110 (0.018)	0.101 (0.028)	0.128 (0.043)	0.145 (0.034)	0.165 (0.045)	0.157 (0.043)	0.203 (0.059)	0.222 (0.038)	–	–	0.093 (0.023)	0.105 (0.018)
Investments in current activities (log of investments in current assets)	0.246 (0.059)	0.213 (0.061)	0.157 (0.046)	0.198 (0.054)	0.253 (0.051)	0.231 (0.046)	0.187 (0.038)	0.172 (0.045)	0.264 (0.074)	0.231 (0.066)	0.175 (0.038)	0.189 (0.036)	–	–	0.157 (0.024)	0.198 (0.015)
Numberof observations	203				203				203				203			
McFadden Rsquared	48.31%				54.12%				53.03%				49.34%			
LR-statistic	71.23				66.14				78.89				63.56			
Prob (LR-statistic)	0				0				0				0			

Notes: 1. IDG – investments in the implementation of distributed generation. 2. IESS – investments in the implementation of energy storage system. 3. IESMS – investments in the implementation of electricity smart metering systems. 4. IIDT – investments in the implementation of Industry 4.0 digital technologies. 5. The numbers presented have marginal effect values. 6. Statistical significance of coefficients: $p \leq 0.01$. 7. Robust standard errors are indicated in-between parenthesis.
Source: compiled by the author.

participation in pilot projects and sending timely and objective feedback can increase the effectiveness of the implementation of these pilot projects. The authorities also responsible for the determination of costs of energy companies that can be included in tariff sources of financing.

Interaction with representatives of consulting companies most strongly influence the investments in smart metering systems and Industry 4.0 digital technologies for all types of active consumer models. At the same time, the greatest influence is exerted in the introduction of models of the Internet of Energy and the Load aggregator. This may be due to the fact that consulting companies have a great understanding of the functioning of Industry 4.0 digital technologies, including platform solutions, and also have extensive expertise in the implementation of digital solutions in enterprises, which allows them to provide effective assistance in the design of solutions and lead to more efficient deployment of digital components of models. The high effect for the Internet of Energy model is due to the highest requirements of this model for its IT component. In the case of a Load aggregator, an increased degree of influence may be due to the fact that the main component of this model also lies in the field of digital technologies.

Interaction with energy companies demonstrates the greatest power of influence, both in terms of the types of active consumer models and the components of the models themselves. First of all, this is due to the direct participation of energy companies in pilot projects for the implementation of active consumer models. Also, some energy companies participate in the development of equipment necessary for the implementation of such models and offers comprehensive solutions for the end-consumer.

Interaction with scientific organisations shows the least power of influence, which may be due to insufficient opportunities for commercialisation of developments by scientific organisations themselves. In addition, most of scientific organisations developing Industry 4.0 technologies in the energy sector are in the control loop of large energy companies, and it is energy companies that take responsibility for integrating developments into unified customer value propositions and subsequent commercialisation.

Thus, the results of the present calculation serve as an additional justification for the need for close interaction of consumers with energy companies when implementing projects for the introduction of active consumer models. Consulting companies with the necessary digital competencies and relevant experience, as well as participation in government programmes are also able to increase the efficiency of investments.

Concluding the present paragraph, the results of the calculation of the third part of the model, the impact of the relative amount of investment in the equipment of active consumer models on achieving positive economic effects are presented in table 5.

Table 5
The influence of the relative amount of investments in the equipment of active consumer models on the achievement of positive economic effects

Exogenous variables	**Equation of economic effects (dependent variable – the economic effect of the implementation of active consumer models)**			
The method of least squares	**Active energy complex/ microgrid**	**Energy cell**	**P2P model / Internet of Energy**	**Load aggregator**
Estimated value of the relative amount of investments in projects for the implementation of active consumer models	0.145 (0.037)	0.164 (0.041)	0.179 (0.035)	0.093 (0.017)
Intensity of the investments in the implementation of distributed generation	0.482 (0.095)	0.507 (0.093)	0.456 (0.072)	—
Intensity of the investments in the implementation of energy storage systems	0.534 (0.107)	0.514 (0.110)	0.505 (0.097)	—
Intensity of the investments in the implementation of electricity smart metering systems	0.335 (0.084)	0.327 (0.092)	0.339 (0.077)	0.539 (0.108)
Intensity of the investments in the implementation of the Industry 4.0 digital technologies	0.298 (0.076)	0.309 (0.080)	0.471 (0.083)	0.523 (0.096)
Size of the company (log average number)	0.154 (0.027)	0.143 (0.032)	0.212 (0.038)	0.099 (0.017)
Logarithm of the number of employees engaged in innovation activity	0.145 (0.035)	0.153 (0.031)	0.174 (0.068)	0.112 (0.028)
Investments in current activities (log of investments in current assets)	0.166 (0.053)	0.189 (0.043)	0.203 (0.061)	0.142 (0.039)
Number of observations	203	203	203	203
McFadden R-squared	47.41%	51.12%	49.55%	60.17%
LR-statistic	72.25	66.14	78.87	63.42
Prob (LR-statistic)	0	0	0	0

Notes: 1. The numbers presented have marginal effect values. 2. Statistical significance of coefficients: $p \leq 0.01$. 3. Robust standard errors are indicated in-between parenthesis.
Source: compiled by the author.

According to the results obtained, for each of the active consumer models the volume of investments in implementation projects is positively connected to the achieved positive economic effects, which is consistent with the theory.

At the same time, for the models of an Active energy complex and an Energy cell the strongest positive dependence is observed for investments in distributed generation and energy storage systems, since these two elements provide a direct reduction in costs per 1 kW*hr of energy. Also, the development of distributed generation and NEA leads to an increase in direct effects from the provision of system and ancillary services, as well as indirect effects from a decrease in the equilibrium price of RSV and a decrease in the need to investment in network and generating capacities in parts of the UES.

For these models the investments in smart metering systems and Industry 4.0 digital technologies demonstrate a moderate connection, since it is these elements that allow to link and optimise the operation of other equipment, thereby enhancing the effects of distributed generation and NEA and creating the own ones, such as optimising the operation of the enterprise equipment, predictive analytics of failures and breakdowns and also the possibility of commercialisation of the data collected at the enterprise.

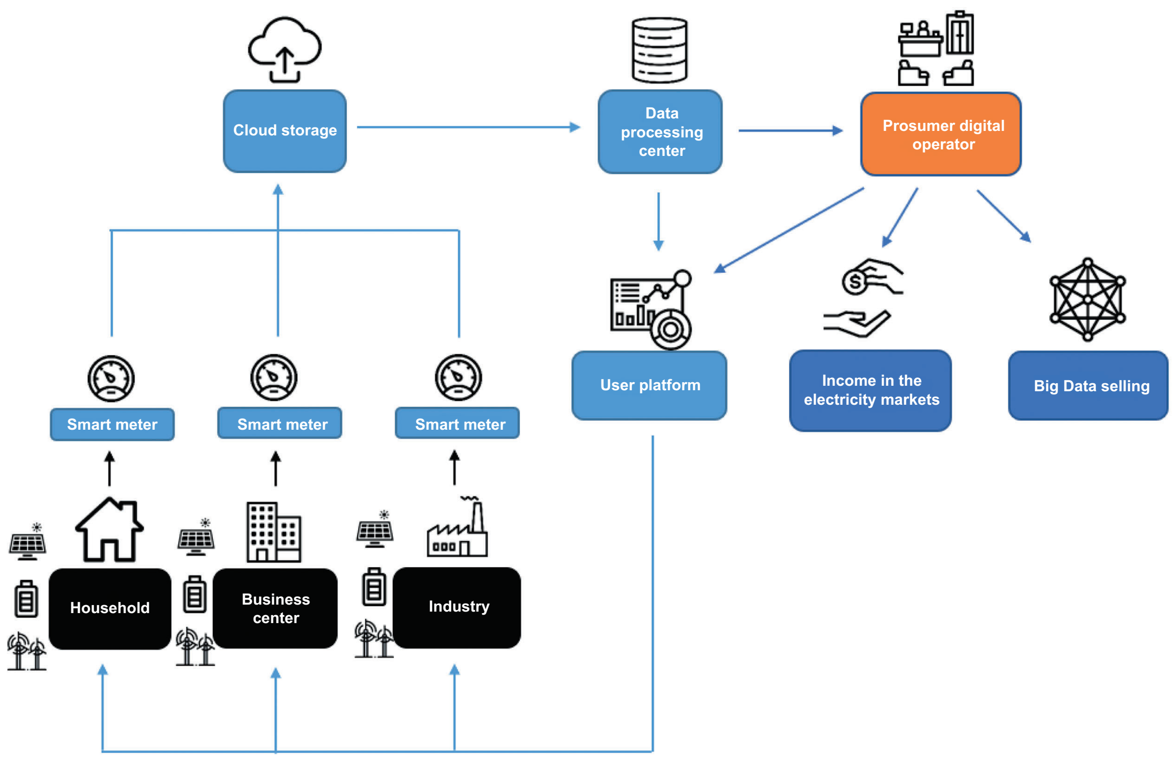
The P2P model / Internet of Energy has similar calculation results, however the role of investments in Industry 4.0 digital technologies is significantly increasing. Unlike the previous model, this one assumes the presence of a transactional platform for accounting of produced and consumed energy, system services provided, etc. in real time, as well as an industrial Internet of Things system for optimising the energy mode within the entire model as a whole, which significantly increases the effect of investments in the implementation of digital technologies within this model.

The Load aggregator model creates the greatest positive effects when investing in smart metering systems and digital technologies. This model creates direct economic effects due to the provision of one of the system services – demand response and commercialisation of big data collected from the consumer and also leads to an indirect effect of reducing the equilibrium price in the RSV in the short term and in the capacity market in the long term. On the side of retail consumers there is a significant potential for demand response and big data collection, which can be successfully implemented with the development of smart metering systems and digital technologies, which is confirmed by high elasticity coefficients.

3. The concept of transformation of retail electricity market

Having analysed the theoretical aspects of digital and Industry 4.0 electric power technologies, having formed a list of active consumer models and effects generated by them for retail market participants, having identified and evaluated qualitatively and quantitatively the factors influencing their adoption, it is necessary to form a concept of transformation of the retail electricity market, considering the implementation of active consumer models.

Fig. 1. Schematic diagram of interaction



Source: compiled by the author.

In this paragraph it was decided to demonstrate the value created by the implemented models of an active consumer for retail market participants, to describe the key principles of building an information exchange system and organisational interaction when implementing such models.

The construction of an active consumer model begins with the installation of digital and electric power equipment necessary for a particular type of model on the consumer side.

For each model it is necessary above all to establish information exchange with the energy company with the use of a smart metering system either based on traditional electricity meters supplemented with a GSM or WiFi module or with the use of NILM systems (fig. 1).

At the beginning, we will consider the simplest model of an active consumer – a load aggregator. In the case of households or small buildings, it is enough to install one ISU sensor at the entrance to the room and establish a stable Wi-Fi or GSM connection for further information exchange. When installing an SM system in factories or large commercial real estate objects, the number of electricity meters may increase depending on the purpose of their installation. For example, when distributing energy consumption by floors or rented rooms, the number of sensors will be equal to the number of floors or rooms, respectively.

After the connection is set up, the information collected by the SM in real time is sent to the cloud data storage, and then transmitted to the data processing center for subsequent analysis.

The processed data can arrive to the client in various ways. For individual users a custom application installed on a mobile phone will be enough. This method will allow the consumer to get the full range of advantages of the Load aggregator model, which only requires setting up smart metering and information exchange, avoiding the need to understand complex interfaces or interpret a large set of statistical data. For a commercial organisation using several sensors of the SM it is advisable to receive information through a personal account on a user platform, to which all sensors installed in the building will be linked. The possibility of implementing the software of the SM system using API-interfaces into digital solutions used by customers is not excluded.

At the same time, the end-consumer can supplement the system with additional sensors and actuators to automate the operation of their production or office equipment in order to obtain greater effects from the load aggregator model.

Having received the information, consumers increase their operational efficiency, reduce energy costs by adapting the energy consumption schedule to the existing tariff scale, analyse the load of power receivers, generate data and realise other advantages inherent in the load aggregator model.

In turn, data on the energy consumption of all users with SM are aggregated on the system server and the energy company acting as a load aggregator can use them to its advantage. The collected data can be used both inside the electric power company and in interaction with external concerned parties.

The internal use is expressed in improving the quality of consolidation of electricity balances, increasing the effectiveness of countering non-contractual and non-metered energy consumption and improving the quality of work with accounts receivable. Big data on load characteristics will make it possible to predict energy consumption more accurately, which will contribute to the growth of the performance of energy companies in the wholesale and retail markets.

Analytical data collected during piloting of load aggregators can become a powerful tool for the participation of energy companies in pilot programmes of new interaction models implemented in the Russian Federation. For example, the pilot project on demand response, regulated by the Resolution of the Government of the Russian Federation No.287 dated March 20, 2019, also includes the concept of a load aggregator.

And finally, big data can be commercialised beyond the electricity markets as well. In this case, the companies of the electric power industry act as sellers in the big data market and arrays of information about energy consumption act as a product. Potential buyers here are marketing companies, business consulting companies, manufacturers of household and industrial appliances, organizations in the field of remote healthcare and social monitoring.

Next, we will consider the models of the active energy complex / microgrid and the model of the Internet of Energy / P2P model. To implement these models the SM sensors, as well as digital sensors, communicators and actuators need to be supplemented with electricity generating equipment. First of all, these are distributed power sources, such as small generators using diesel fuel or gas, generators based on renewable energy sources, as well as energy storage systems.

In order to successfully integrate these devices into the enterprise network and in the unified energy system network, in addition to the SM meters, voltage source inverters, additional controllers and other grid equipment may be required.

The advantages described earlier for the load aggregator model, in case of the implementation of the active energy complex model or the Internet of energy model, will be expanded by additional effects of the implementation of innovative electricity generating equipment.

Distributed generators and NEA can be used as uninterruptible power supplies, thereby increasing the company's resistance to accidents in external networks (which is especially important for industries with equipment sensitive to voltage and frequency jumps or enterprises of a continuous production cycle).

The use of distributed generation will directly reduce the cost of buying electricity. The price of electricity from the guaranteeing supplier consists of a uniform (common pot) tariff for the transmission of electricity through networks, as well as fees for the services of infrastructure organisations and the sales premium of the guaranteeing supplier, plus the price for the purchase of electricity and capacity at the WEM.

The price of electricity generated by a distributed generator consists of a uniform (common pot) tariff for the transmission of electricity through networks, as well as unit costs that ensure the return of capital and unit operating costs for the production of electricity on this generator.

Since a common pot tariff for electricity transmission will be the same in both cases, the effect of using electricity generated by distributed generation facilities will depend on the unit costs that ensure the return of invested capital in the construction of a distributed generation facility and the value of unit operating costs for electricity production.

Another direct effect of the installation of distributed generation is the reduction of costs for technological connection to networks.

In addition to direct effects, a number of indirect ones are possible for retail consumers, such as the reduction of the cost of building additional generating and power grid capacities at the level of the WEM in the long term, optimising the mode of operation of the UES. The models of the active energy complex and the Internet of Energy due to the fact, that distributed generators have an even greater margin of flexibility of energy consumption from a unified power system are relative to the load aggregator model.

The greatest efficiency of models of the active energy complex and the Internet of Energy is achieved when distributed generation is used together with energy storage systems.

Due to the ability of the NEA to quickly accumulate and issue electricity, the quality of participation of retail consumers in the market of system services, including primary and secondary frequency regulation services is significantly improved. Thus, on the side of the retail consumer electricity becomes cheaper, the reliability of power supply increases, it is possible to ensure the operation of critical equipment in case of power failure and create a reserve in case of accidents.

The NEA, as well as distributed generation, reduce the peak load on electric substations and the costs for upgrading the network infrastructure, improve the quality and reliability of energy supply to consumers and reduce the need for the construction of new capacities on the generation side.

Thus, in the current point of the study the value created by the implemented active consumer models for the participants of the retail market was shown. At the same time, in order to build such a concept and achieve the described effects, it is necessary to create a new functionality (digital operator of an active consumer) focused on organising the relationship of an active consumer with infrastructure and other electric power companies.

Active consumer models are solutions located at the intersection of digital and electric power technologies and thus include many components that organise a single system – generators, storages, SM sensors, network infrastructure, cloud or local servers, analytical platforms. As the analysis has shown, the successful achievement of economic effects from the implementation of these models requires retail electricity consumers to have a certain level of competence, as well as a certain level of maturity of the technologies and the infrastructure used, compliance with which forms the prerequisites for the successful implementation of active consumer models.

At the same time, the expediency and success of the implementation of the active consumer model directly depends on the technological process of the enterprise and/or the characteristics of the building where the implementation is carried out: continuous production, how sensitive it is to starts and stoppages? The effectiveness of implementation can be enhanced by a large share of climate equipment or lighting technology in the energy consumption of an enterprise or building.

Thus, at the end of the study the author proposes to develop a method that allows to assess the readiness of end-consumers of electricity in the retail market to implement active consumer models based on an assessment of their compliance with previously identified factors of the success of the implementation of these models.

4. Methodology for the digital readiness assessment of consumers to implement the active consumer model

To develop a methodology for the digital maturity assessment of consumers for the implementation of the active consumer model, it was decided to use the methodology developed in the study "Industrial digitalisation: an empirical assessment of the digital maturity of enterprises" [Kuzmin, 2021a].

The previously identified factors influencing the implementation of active consumer models were further analysed and structured into four main categories, which are proposed to be used in the concept as directions for the maturity assessment of the end-consumers in the retail market for the implementation of these models:

1) organisational readiness.
2) internal competencies of the organisation.
3) infrastructure and technological readiness.
4) the specifics of the production process.
5) financial capability.

The general structure of the model can be represented in the form of five directions with detailed breakdown of each direction on a number of aspects of the success related to implementing the active consumer model (fig. 2):

In order to assess the maturity of the retail market entities in each of the proposed directions the author has developed a standardised questionnaire. The questionnaire proposed by the author contains a list of closed questions, for each of which the respondent chooses one of the proposed options, which in the opinion of the respondent, most accurately and fully reflects the features and stages of development of individual directions of the company's activity. A five-point scale was used in the survey, where number 1 stands for "strongly disagree" and number 5 stands for "completely agree".

The questionnaire can be given to the organisation both in hard copy and with the use of various electronic means (sending by e-mail, using web resources for conducting the survey). The survey data are used as a basis for calculating the level of maturity of a retail market entity to implement an active consumer model in each of the directions under consideration.

At the same time, not all directions of maturity of the retail electricity market entity have the same influence on the success and effectiveness of the implementation of the active consumer model. In order to determine the degree of significance of each of the proposed directions for the successful implementation of projects a series of interviews with experts was conducted. Based on the interviews conducted, the average expert ratings were calculated for each of the aspects of the success of the implementation, as well as directions that were assembled into a single scale for the readiness to assess the organisation in various directions and are considered as a weight coefficient.

Thus, based on the assessments obtained as a result of filling out the questionnaire, the readiness assessment (RL_D) of the

Fig. 2. Elements of the model for the maturity assessment of the retail market entities for the active consumer model implementation

Aspects \ Directions	Organisational readiness	Internal competencies	Infrastructure readiness	The specifics of the production process	Financial capability
	Availability of a developed business case for the application of the active consumer model	Experience and level of expertise of the organisation's employees in the field of digital technologies	Infrastructure maturity level of the organisation	Ability to flexibly manage the production process	Availability of attracting financial resources
	Availability of the organisation's resources and management support	Experience of employees in the field of electric power industry and price setting in retail markets	The level of development of electric power and digital technologies	Availability of devices with high power consumption manoeuvrability	Competences in the field of implementation cost planning
	Maturity of process interaction with regulatory authorities	Experience in data management and data processing	The level of development of data protection and security technologies	Availability of inertial parameters of the production process	
	Maturity of process interaction with energy companies	Experience in data integration and data analysis			

Source: compiled by the author.

organisation is calculated as the sum of the weighted average values of the answers to questions within a certain factor, adjusted for the significance of this factor in terms of the impact on the success of the project implementation of the active consumer model and calculated using the following formula:

$$RL_D = \sum \frac{\sum_{i=1}^{n} S_{DFi}}{n} * W_{DF}, \qquad (9)$$

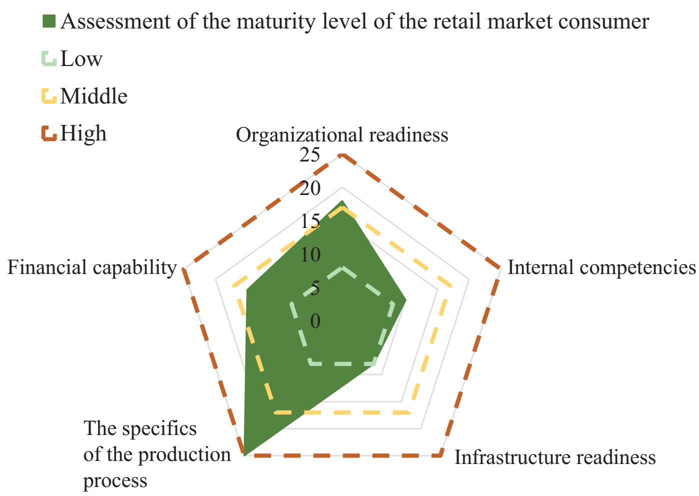
where D is the direction of the organisation's readiness assessment; F is the aspect of success under investigation; n is the number of questions within the factor under investigation; S is the value of the answer to the question on a five–point scale; W is the significance of the aspect of the success of the active consumer model implementation.

After the organisation fills out the questionnaire, the responses received are processed in accordance with the formula mentioned above. Based on the results obtained, a petal diagram is constructed, on the basis of which the organisation is assigned a certain level of maturity for each of the analysed directions.

The obtained estimates for each of the analysed directions can be further used to make a decision on the implementation of the active consumer model and, if necessary, the formation of measures aimed at the development of individual directions of the organization's activities in order to increase the level of readiness of the organization for the implementation. Also, additional questions were added to the survey list in order to determine the required level of maturity in each of the directions for different types of active consumer models and to select the recommended model depending on the level of maturity.

Figure 3 shows a sample of a petal diagram of the maturity level of the retail market entities in each of the analysed directions, which allows us to visualize the result of the analysis of readiness for the implementation of the active consumer model.

Fig. 3. Petal diagram of the level of maturity of the retail market entity for each of the analysed directions



Source: compiled by the author.

In order to determine the degree of significance of each of the proposed aspects within the directions of success of the active consumer models implementation, as well as to correlate the maturity levels in each of the directions with the recommended implementation of the active consumer model an additional expert survey was conducted.

As part of the survey, each of the experts assessed the significance of aspects on a scale from 1 (minimal influence on the success of the model implementation) to 5 (high degree of influence on the success of the model implementation). According to the results of the survey, the frequencies of assessing the degree of influence of the success aspects related to the active consumer model implementation were obtained.

With the purpose of further application of the results of the expert survey, the significance of aspects for each of the direction of assessing the maturity of the retail market entities for the active consumer model implementation was calculated using the ratio:

$$W_{DF} = \overline{A_{DF}} \cdot \frac{b}{\sum_{i=1}^{m} \overline{A_{DFi}}}, \quad (10)$$

where W is the significance of the success aspect of the active consumer model implementation; A is the average value of the significance of the success aspect of the active consumer model implementation; m is the number of aspects of the success of the active consumer model implementation in the direction of maturity assessment; b is the maximum score for the item of the questionnaire for assessing the maturity of the retail market entities.

The average scores calculated based on the results of expert surveys and the significance of the success aspects of the active consumer model implementation are presented in table 6.

Thus, based on the interviews conducted weight coefficients of the significance of success aspects of the active consumer model implementation were obtained for further use in the methodology for assessing the readiness of the retail market entities to implement the active consumer model.

Further, the experts were suggested to correlate the assessments of the level of readiness in the directions with the types of active consumer models and to determine what level of maturity in each of the assessment directions is required for a particular active consumer model. Based on the results of the survey, a table of the required maturity levels for the implementation of active consumer models was formed (table 7).

Thus, the methodology proposed by the author makes it possible to assess the level of maturity of the retail market entities for the implementation of the active consumer model based on the assessment of its maturity levels in five directions, as well as to correlate the estimates obtained with the recommended requirements for the successful implementation of various types of active consumer models: load aggregator, active energy complex / microgrid and P2P model / Internet of Energy.

Table 6
Results of expert surveys determining the degree of influence of digital transformation aspects

Success aspects of the active consumer model implementation	Average score	Significance
Organisational readiness		
Availability of a developed business case for the application of the active consumer model	2.06	0.75
Availability of the organisation's resources and management support	4.06	1.48
Maturity of process interaction with regulatory authorities	3.67	1.34
Maturity of process interaction with energy companies	3.94	1.44
Internal competencies of the organisation		
Experience and level of expertise of the organization's employees in the field of digital technologies	3.78	1.26
Experience of employees in the field of electric power industry and price setting in the retail markets	4.44	1.49
Experience in data management and data processing	3.28	1.10
Experience in data integration and data analysis	3.44	1.15
Infrastructure readiness of the organisation		
Infrastructure maturity level of the organisation	4.56	2.06
The level of electric power and digital technology development	4.22	1.91
The level of data protection and security technology development	2.28	1.03
The specifics of the production process		
Ability to flexibly manage the production process	4.44	1.69
Availability of devices with high power consumption manoeuvrability	4.56	1.74
Availability of inertial parameters of the production process	4.11	1.57
Financial capability		
Availability of attracting financial resources	4.22	2.90
Competences in the field of implementation cost planning	3.06	2.10

Source: compiled by the author.

Table 7
Required levels of maturity in the directions for the implementation of active consumer models

Direction of maturity assessment	Load aggregator	Active energy complex / microgrid / energy cell	P2P model / Internet of Energy
Organisational readiness	Middle	High	High
Internal competencies of the organisation	Low	Middle	High
Infrastructure readiness of the organisation	Middle	Middle	High
The specifics of the production process	High	Middle	Low
Financial capability	Low	High	High

Source: compiled by the author.

Conclusion

The study presents the results of the analysis of the key factors influencing the perception and willingness to implement active consumer models among end-consumers – participants of the retail market, as well as factors determining the effectiveness of the subsequent application of these models. It is proved that the decision to implement the active consumer model is most strongly influenced by the factors of readiness of the organisation's infrastructure and the level of its digital competencies. For the successful distribution of active consumer models, the effective interaction of consumers with energy companies as well as regulatory authorities is necessary.

Further, the author proposed the concept of transformation of the retail electricity market, concerning the implementation of active consumer models that meet the conditions of digital transformation of the electric power industry. A new schematic diagram of interaction with the energy company in the implementation of the active consumer model has been formed, implying the emergence of a new functionality (digital operator of the active consumer) focused on the organisation of relationships between the active consumer and infrastructure and other electric power companies, aimed at creating new value for both consumers and the companies of the electric power industry.

In the conclusion of the study, a transformation methodology was formed aimed at the successful implementation of active consumer models among the retail market entities. Taking into account the previously identified factors, the methodology allows us to assess the level of maturity of the retail market entities for the implementation of an active consumer model based on the assessment of the maturity level in five directions and correlate the estimates obtained with the recommended requirements for the successful implementation of various types of active consumer models.

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Статья поступила в редакцию 23.01.2023; после рецензирования 20.02.2023 принята к публикации 27.02.2023. Автор прочитал и одобрил окончательный вариант рукописи.
The article was submitted on 23.01.2023; revised on 20.02.2023 and accepted for publication on 27.02.2023. The author read and approved the final version of the manuscript.
文章于 23.01.2023 提交给编辑。文章于 20.02.2023 已审稿．之后于 27.02.2023 接受发表。作者已经阅读并批准了手稿的最终版本。