

Analysis of pricing mechanisms efficiency for modernization of thermal generation ^a

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Abstract. The article deals with pricing and investment consequences of using alternative ways to stimulate investment in thermal power plants (TPP) modernization. Calculations made with the use of our simulation-based financial model show that “pure” market mechanisms (such as the spot market and capacity market with marginal pricing) are not efficient enough in terms of keeping balance between robust investment signals and electricity prices produced. In this light, a flexible regulation of capacity market “price cap” is recommended, which should be derived from the assessment of the necessary revenue for operation and investment activity of thermal generation.

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1 Introduction

One of the most important and actively discussed problems linked with the Russian electric power industry consists in an extremely high level of physical depreciation of the generating and grid equipment as well as their low economic efficiency. The solution of this problem demands deep modernization of the existing production equipment, often along with transition to new, more advanced technologies [1]. The problem discussed is especially acute in thermal generation due to its key role in the generation mix (almost 2/3 of the Russian total installed capacity is presented by thermal power plants) and high social importance in terms of providing centralized heat supply.

According to the current version of the General Scheme of Electric Power Industry Objects Accommodation (the main document in projecting future development of the Unified Power System of Russia), the installed capacity of the existing thermal power plants (TPPs), that will require various investment decisions (modernization or replacement by new installations), is amounted as 60 GW by 2025 and 75-120 GW by 2035 [2]. For approximately 60-65% of these capacities, the complex reconstruction with the replacement of the most worn-out equipment units is economically most effective decision. The remaining 30-35% of the capacity, that will reach the end of its life cycle by 2035, should be fully decommissioned with partial (giving the future energy balance conditions) replacement by new, more advanced generation technologies (such as TPPs based on combined cycle gas turbines, CCGT). Our previous study [3] shows that such “mixed” strategy of the Russian TPPs renewal is much

more efficient compared to both “extreme” strategies (only reconstruction of old TPPs or their total decommission along with new building of modern TPPs).

However, the implementation of any investment strategy is possible only with creating a system of price mechanisms that make it commercially attractive and financially feasible for private generating companies and, at the same time, not damaging for consumers’ welfare. Unfortunately, massive institutional reforms in the Russian power sector in 2000-2010s will not lead to formation of the effective price mechanisms able to stimulate the investment process in thermal generation. Despite the formally made liberalization of the electricity spot market, its price parameters are still insufficient for recouping investments in TPPs modernization, both because of the continuing regulation of domestic gas prices and because the strong regulation of the “price cap” on the capacity market. As a result, for the entire period from the moment of the formal start of the liberalization of the electricity market, the attraction of investments in thermal generation was almost entirely carried out through special tariff mechanisms with guaranteed rate of return on invested capital. This mechanism was legislated as so-called capacity supply agreements (CSA) under which power producers are taking obligations to build new generation units with defined technical parameters and wholesale consumers must pay the fixed tariff after the capacity is connected to the grid [4].

However, the experience of using CSA has exposed its fundamental disadvantages. The main ones are:

1) non-competitive nature of project selection, which leads to disproportion in the distribution of investment

projects between individual generating companies (in other words, CSA encourages companies to lobby their interests behind-the-scenes - especially for publicly owned companies).

2) the lack of adaptability of CSA to changes in the balance and macroeconomic conditions. After the shortfall of Russian economy in 2014 - 2015, this led to the appearance of a significant excess of power supply in the market, and consumers had to pay for it.

Giving this disadvantages of CSA, a new mechanism has been introduced to support the modernization of old TPPs [5]. It realizes the competitive principle of the investment projects selection with the criterion of minimal electricity price. However, it all overturns by strict administrative regulation of almost all parameters for calculating this price - the capacity factor, the average spot market price, unit operating costs, etc. Moreover, the regulator calculates the project price using retrospective (not future) values of these indicators, which is methodological mistake. Besides, the return on invested capital is strictly regulated, although, in our opinion, it would be more efficient to give producers ability to assess rate of return attractive for them. Such strict regulation of key selection parameters deprives the generation company of incentives to implement capital-intensive, but energy-efficient investment projects, thereby suppressing the competition of suppliers. This conclusion is confirmed by the results of the selection of TPPs modernization projects for 2022-2024, which took place in April 2019: the overwhelming part of the projects is the replacement of individual elements of turbine or boiler equipment, and only a few projects involve total replacement of steam turbines with the full absence of modern gas turbine installations. At the same time, there is a fierce backstage struggle of generating companies for getting into the quota of the government commission, which is an administrative tool for supporting modernization projects from among those that have not passed the competitive selection.

In this regard, it is important to consider other mechanisms to support the modernization of thermal power plants, which should be realized on the market (not regulative) base.

2 Characteristics of alternative market mechanisms to stimulate the modernization of thermal power plants and a methodical approach to assessing their economic consequences

To quantify the effects of market incentives for investment, we have used our financial model which can assess the harmonized pricing and investment parameters in the power sector through the calculation of both required and market-based forecasted gross revenue (RGR and FGR) of the power industry as a whole, its

technological segments^b and individual energy companies (detailed description of the methodological approach and models is presented in [6, 7]). In this case, the analysis is carried out for thermal generation segment. In particular, our model allows to:

A) calculate the amount of the required gross revenue (RGR) of thermal generation, which is the minimal revenue necessary for the segment to fund its operation cost and capital investment taking into account its financing structure (ratio of equity capital and borrowings), interest payments on borrowed funds, tax payments and normal dividend ratio. The calculation of the thermal generation RGR allows to estimate the minimum market price parameters that made financially feasible to realize the considered strategy of technological renewal of TPPs. In doing so, we also take into account the macroeconomic consequences, the main of which is acceptable dynamics of growth in the price of electricity. The required revenue is determined on the basis of the forecast version of the production and investment programs and the cumulative financial plan of thermal energy, based on the maximum permissible parameters of the structure and return on capital, credit load, which ultimately leads to the lowest price growth rates for consumers.

B) calculate the dynamics of the forecast gross revenue (FGR) of thermal generation, which is the predicted revenue received from the market under different variants of the regulatory decisions in the electricity, capacity and heat markets. Thus, the calculation of the FGR allows to evaluate the influence of market conditions and regulatory policy in the industry through their impact on the generation sector revenue, and further - on its total funding and investment potential.

The joint solution these two modeling tasks for the given time horizon allows us to justify the desirability and rational scope of changes in the price parameters of the wholesale power market (with the possibility of detailing into its individual territorial and price segments) or the necessity of some non-market regulatory decisions that will provide thermal generation with sufficient financial flow for the technological upgrade program.

In our case, the calculation of RGR and FGR of Russian thermal generation sector is performed on the horizon until 2035 with production and investment parameters (installed capacity and output by type of technology, fuel consumption by type, input / reconstruction volume of capacity, etc.) corresponding to the low scenario from the General Scheme of Electric Power Industry Objects Accommodation to 2035.

The calculations show that already by 2025 the existing mechanisms for payment of electricity and power on the wholesale market will not fully provide the necessary gross revenue for thermal generation taking into account investments for the implementation of the capacity renewal program (Table 1). The revenue deficit

^b We use the term "technological segment" to describe different types of power plants (hydro, nuclear, thermal, renewable) and grid (transmission and distribution)

will dynamically increase and by 2035 will be about 11% of the total RGR of thermal generation sector.

Table 1 – Predicted deficit in thermal generation revenue under current pricing parameters in the wholesale electricity and capacity markets, billion rubles in 2016 prices

	2016	2020	2025	2030	2035
RGR of thermal generation	1139	1233	1423	1745	2168
FGR of thermal generation under current market conditions	1139	1233	1304	1567	1937
of which:					
- FGR in electricity market	730	792	959	1209	1467
- FGR in capacity market	408	441	345	358	470
Deficit of revenue	0	0	119	178	231
In % to RGR	-	-	8,3	10,2	10,7

Thus, for the implementation of massive technological renewal of thermal generation sector, a significant adjustment in the existing pricing mechanisms in the wholesale electricity and capacity market will be required. Below we will assess the consequences and discuss three different options for such an adjustment:

- increase in gas prices for TPPs, which rising spark-spread of the CCGT units in the spot market and leads to replacing old gas-fired TPPs instead of their life extension;
- withdrawal of the “price cap” in the capacity market (that means, transition to market-based long-term marginal pricing for capacity);
- regulation of the “price cap” in the capacity market taking into account the dynamics of the total RGR of Russian thermal generation sector; in this case, the “price cap” corresponds with average long-term cost of TPPs modernization defined on the basis of RGR calculations.

3 Assessment of stimulating TPPs modernization through the increase in gas prices

The first option to support the renewal of TPPs is possible only for gas-fired power plants, since coal prices are not regulated by the government.

The scale of the gas price gain necessary to stimulate the transition to the CCGT technology is defined through the equality of the cost of electricity from the existing gas TPP (taking into account the costs of extending the service life) and the new TPP based on the combined-cycle technology. We calculated the levelized cost of electricity cost of electricity (LCOE) for measuring the discounted operating and investment costs for the entire life cycle. The method of calculating LCOE is given in [8]. This indicator by its economic sense corresponds to the price of electricity, ensuring the break-even point of the project – that is, zero net present value (NPV) over the project life cycle.

We have calculated LCOE assuming fuel efficiency of the old TPP as 39% and the appropriate figure for new CCGT – as 55%. We have used 10% discount rate at the 15 years perspective. Our investigation shows that an increase in gas prices by about three times over the coming years is needed to equal LCOE for new CCGT and existing gas plants (Table 2). Accordingly, the economic consequences will be very noticeable through the influence of gas prices on the spot electricity prices, which are formed on the basis of short-term marginal costs - fuel costs of the least efficient power plants closing the electricity balance.

Table 2 – Comparison of LCOE of existing and new gas TPP, rubles / kWh (prices are discounted to 2016)

	Existing TPP	New TPP (based on CCGT)	At gas price increased by 3 times	
			Existing TPP	New TPP (based on CCGT)
At current gas price				
LCOE overall, including:	1,67	2,36	4,32	4,25
- fuel cost	1,32	95	3,97	2,84
- O&M cost	0,23	0,21	0,23	0,21
- investment return (including interest payments)	0,12	1,20	0,12	1,20

In general, a sophisticate node-based model (like PLEXOS, GE MAPS, GTMAX etc.) is required to imitate the dispatching schedule of generating units and, thereby, to assess the hourly prices based on the merit order. However, these models require very detailed information about the load profiles, operational technical parameters of generating units, their costs, and technical data on network facilities, grid modes and congestions, and so on.

To overcome this obstacle, we used a simplified approach to predict the overall long-term trend of the spot electricity price. In this approach, the of annual average price in the spot electricity market is forecasted by multiplying the actual value of annualized spot price by two basic figures affecting the changes in the supply curve profile: fuel price and thermal power plants’ efficiency cumulative growth rates (to year t):

$$DAP_t = DAP_0 \cdot FP_{gt} \cdot E_t \tag{1}$$

where DAP_0 – annual average day-ahead electricity price in the basic year 0 (exogenous input);

FP_{gt}, E_t – fuel g price and thermal plants’ efficiency cumulative growth rates.

In our case, for illustrative goals, we made an assumption about a one-time mighty increase in the gas price by 2020. In the case of a more gradual increase in the gas price — for example, with reaching the equality of LCOE for the steam-turbine TPP and CCGT by 2025, the effect of a sharp increase in the spot price will smoothly shift to 2025, followed by a decline after the introduction of new capacity.

As our calculations show, the rapid increase in gas prices will lead to an equally powerful increase in the

spot price of electricity (Fig. 1), which will provide incentives and financial resources to replace the old steam power units with new steam and gas capacities with higher fuel efficiency.

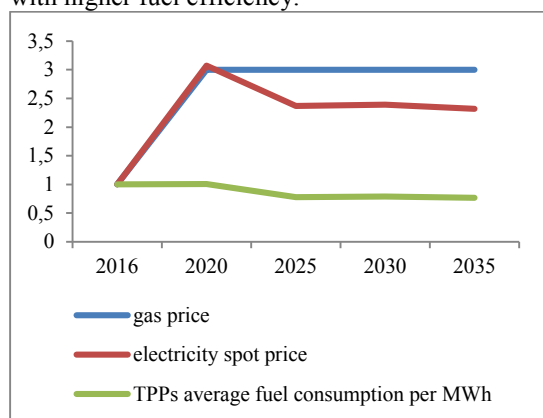


Fig. 1. Correlation between the real prices on gas and spot electricity (2016 = 1.0)

The calculations show that at the initial stage (2020 - 2025) with the multiple spot prices increase, the additional revenue of thermal generation will be enough to install about 32 GW of new capacity instead of 23 GW according to the General Scheme of Electric Power Industry Objects Accommodation. However, the emerging investment the effect will be not robust: a massive replacement of obsolete equipment with high-efficiency equipment will quickly change the supply curve profile, which will reduce the marginal short-term costs and the spot price of electricity. Accordingly, the financial possibilities for further replacement of capacities will decrease: in 2025-2035 the FGR of thermal generation will be 7-13% less than its RGR (Table 3). Calculations show that investment incentives to increase gas prices will continue for no more than four or five years, with the replacement of only 15–20% of the existing capacity of TPPs with new ones. In the future, giving the shortfall of the spot price, companies will have to drastically reduce the scale of renewal and switch to less capital-intensive projects for the reconstruction of existing thermal power plants with partial replacement of equipment.

Table 3 – Revenue by generation segments in case of increasing domestic gas price, bln rubles (discounted to 2016)

	2016	2020	2025	2030	2035
Forecasted gross revenue including:	2101	5239	4708	4904	4998
Thermal generation	1645	3962	3596	3763	3885
Nuclear generation	275	905	772	795	765
Hydro and renewables	181	372	340	347	348
Required gross revenue including:	2101	4330	4599	5109	5414
Thermal generation	1645	3646	3842	4249	4456
Nuclear generation	275	492	530	592	633
Hydro and renewables	181	192	227	269	325
Surplus (+)/deficit (-) of revenue, in % of RGR	0	21	2	-4	-8
Thermal generation	0	9	-6	-11	-13
Nuclear generation	0	84	46	34	21
Hydro and renewables	0	94	50	29	7

Another problem that arises from stimulating the TPPs renewal through the spot market incentives is the formation of excess revenues in nuclear and hydrogenation sectors. So that, special mechanisms should be implemented for removing such unfair profits of these sectors.

Taking into account all the above-mentioned negative consequences, it seems that such market-based mechanism for supporting investment in the TPPs renewal is not acceptable both for consumers who will face a “shock” increase in the price of electricity, and thermal generation sector itself, since the investment process will be unstable, uneven and will ensure the implementation of the planned strategy for the renewal of TPP capacities.

4 Evaluation of stimulating TPPs modernization through the transition to marginal pricing in the capacity market

The alternative option to stimulate the TPPs modernization concludes in raising the “price cap” of the capacity mechanism named KOM - the second largest segment of the Russian wholesale market. Nowadays this mechanism is functioning as a centralized auction for capacity delivery for 4 years ahead, while the auction price is limited by the upper and lower limits administrated by the government body. The value of these limits is quite adequate for funding the operational and maintenance costs of most power plants, but it is absolutely insufficient to finance the TPPs modernization.

Some experts [9] suggest to remove the upper limit (“price cap”) for KOM or set it at the level equal to the long-term marginal cost (adjusted to the profit margin from the spot electricity market). In this occasion, the capacity mechanism price will cover not only new and reconstructed generating units, but also the existing capacity of the old TPPs. It should be noted, that an idea to stimulate TPPs renewal through the capacity market incentives is becoming popular in Europe, too.

To estimate the new level of capacity market “price cap”, we calculated LCOE for the replacement of existing power units with new ones (CCGT in the European part of the country and new coal TPPs in Siberia) and adjusted the received values to the forecasted spot market price. Thus, the estimated price, expressed in rubles per kW-in-month, includes in its entirety the components of operational and investment costs reduced by the share of revenue received in the spot electricity market.

We have made above-mentioned calculations under a payback period of 15 years and a discount rate of 10%. The results are given in Table 4. Compared to the existing upper limit of the capacity mechanism price, the marginal price of the capacity in the European part of the country will increase six times by 2035. The marginal capacity price in Siberia is even higher due to the higher capital intensity of coal-fired power plants projects, and by 2035 will exceed eight times the current capacity price in Siberia.

As shown in Table 4, this variant of supporting TPPs renewal will lead to extremal rise in capacity market prices in 2022-2025 (until 2021 pricing limits for capacity market are determined by the government). At the new, higher price, all the power generating units included in the commercial balance will be paid for by the results of the bidding (including power plants, where modernization will not be carried out, and the cost of maintaining them will be significantly less than the price parameters listed in Table 4).

Thus, all types of electricity producers will receive excess revenue relative to their RGR (Table 5). Therefore, similarly to the option of supporting the renewal of thermal power plants through rising gas prices and the spot price of electricity, this option will also require the formation of additional mechanisms for the withdrawal of unjustified nuclear and hydro generation revenues, or the return of nuclear power plants and hydropower plants to the tariff regulation mode.

A multiple increase in the capacity market price will lead to a sharp increase in the wholesale and retail price of electricity for consumers. As our calculations show, in 2025-2035 the wholesale price of electricity will be on average 28-33%, and the retail price – on 20-23% higher than the minimum required prices appropriate to RGR of the Russian thermal generation.

Thus, the relative advantage of this option of stimulating the renewal of thermal power plants compared to the first option (through the price of gas and the spot market) is that capacity mechanism produces sustainable investment incentives for the long-term horizon. On the other hand, the transition to LTMC pricing in the capacity market will lead to an even greater increase in the price burden on consumers as shown in Table 5.

Table 4 – Forecast of the capacity market “price cap” based on the long-term marginal costs of the new generation

	Long-term marginal cost (LTMC) of electricity, Rub./MWh		Forecast of the spot electricity price, Rub./MWh		Capacity market “price cap” based on LTMC, Rub./kW-in-month	
	2020	2035	2020	2035	2020	2035
New CCGT plant (European part of Russia)	2571	3226	1250	1870	690	735
New coal plant (Siberia)	3694	3654	985	1090	1558	1462

Table 5 - Revenue by generation segments in case of rising capacity market “price cap” to LTMC of new generation, bln rubles (prices discounted to 2016)

	2016	2020	2025	2030	2035
Forecasted gross revenue including:	2101	2424	3472	3879	4344
Thermal generation	1645	1745	2396	2731	3126
Nuclear generation	275	450	588	640	671
Hydro and renewables	181	230	488	508	548

Required gross revenue including:	2101	2233	2625	3122	3675
Thermal generation	1645	1715	1985	2367	2854
Nuclear generation	275	346	443	509	521
Hydro and renewables	181	172	197	246	300
Surplus (+)/deficit (-) of revenue, in % of RGR	0	9	32	24	18
Thermal generation	0	2	21	15	10
Nuclear generation	0	30	33	26	29
Hydro and renewables	0	34	148	107	82

5 Estimation of stimulating the TPPs modernization through the regulation of the capacity “price cap” based on calculation of thermal generation RGR

The third variant of price decisions to support the renewal of TPPs demonstrates more flexible regulation of the capacity “price cap”. We propose to link “price cap” to dynamics of thermal generation RGR calculated as described above. The principle of determining such “necessary” price of capacity market is illustrated in Figure 2.

First, we provide the forecast of operating and capital costs of thermal generation on the basis of indicators of electricity production, installed capacity and new commissions (all these indicators are corresponded to the optimal generation mix in the power system). The forecasted dynamics of operating and investment cost helps us to calculate RGR of thermal generation sector. On the other hand, we can forecast dynamics of changes in the fuel consumption at TPPs is calculated. In conjunction with the forecast of fuel price changes, this allows one to quantify the price dynamics in the spot market (for example, using formula (1)) and, accordingly, the dynamics of thermal generation FGR in the spot market.

Obviously, the FGR of thermal generation in the spot electricity market only partially covers the TPPs RGR. The rest of the required revenue should be obtained through capacity payments. At the same time, the forecast of revenue from capacity sales is carried out taking into account some differences between the mechanisms of the capacity market.

So that, various options for the distribution of their payment between competitive and regulated capacity mechanisms can be considered. Thus, for any variant of changing the rules for capacity payment, the required revenue of TPPs in a competitive sector of capacity market (KOM) can be calculated as the difference between the total RGR of thermal generation in the capacity market and the forecast revenue in other segments of the capacity market.

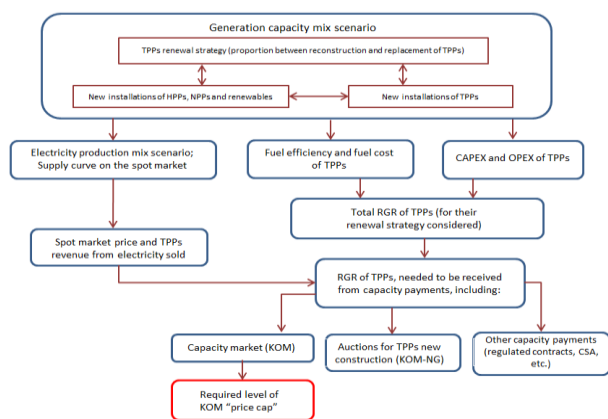


Fig. 2. Scheme of evaluation of necessary changes in capacity “price cap” parameters required for TPPs renewal

In Table 6 we present the modeling results regarding the required revenue of TPPs in the capacity market divided by its main segments (regulated tariffs, capacity supply agreement (CSA), KOM-NG, KOM). It is supposed to preserve the rules and parameters of payment for power supplied by generators at regulated tariffs for the population and already concluded CSA (within 10 years after commissioning). The main differences are related to the distribution of the required amount of capacity payment for projects of reconstruction, replacement and new construction of thermal power plants between two centralized competitive market mechanisms: the existing KOM (with a certain modification of its structure and parameters) and competitive selection of projects for the supply of new generating capacity (KOM-NG).

Table 6 – Distribution of TPPs RGR by different capacity mechanisms, billion rubles (prices discounted to 2016)

	2020	2025	2030	2035
RGR of TPPs	1176	1393	1714	2137
FGR of TPPs in spot market	792	959	1209	1467
RGR of TPPs from capacity sales, of which:	384	434	505	670
- supplied at regulated tariffs (mostly - for residential consumers)	43	43	43	43
- supplied under CSA	256	94	0	0
- KOM-NG (with the “price cap” set as LCOE of new CCGT)	-	31	117	218
- KOM (competitive capacity market with the “price cap”)	84	34	40	56
- KOM-M (sector for old TPPs reconstruction)	-	232	305	353
Average capacity price (for the whole market), rub./kW-in-month	214	253	276	341
Average price in KOM-NG, rub./kW-in-month	-	1330	1120	1100
“Price cap” in KOM, rub./kW-in-month	152	151	149	148
Average price in KOM-M, rub./kW-in-month.	-	285	330	400

The KOM-NG mechanism has been already realized in the existing market rules and it is planned for support of the new generation construction in energy-deficient areas. Its most important difference from CSA consists in competitive (not administrative) selection of projects

according to the criterion of the minimum price of new capacity declared by the entry. The physical volume of KOM-NG is determined by the balance conditions in the grid as a result of the growth of power consumption and peak loads. The marginal price parameters of this market segment are determined by the price of new capacity (see Table 4). At the same time, the actual amount of payment may be lower, since each project will be paid for at the declared price of capacity, which in the conditions of competition may turn out to be lower. This approach is very different from the previously considered option, where payment at a single price at the price level of new projects applies to all capacities, including the existing ones; in this embodiment, this high price will be applied only for a limited amount of capacity.

The main segment of capacity payment – KOM – will also require more flexible regulation of the “price ceiling” in order to form a residual amount of RGR for thermal generation, taking into account the revenue that will be received in other market segments (spot electricity market, KOM-NG segment, power supply for CSA, regulated contracts, etc.). Corresponding quantitative calculations allow a preliminary assessment of the levels of the new “price cap”. Taking into account the predicted shortage of financial resources at current prices of KOM (see Table 1), the new marginal price should be higher than the semi-fixed costs of existing power plants, but noticeably lower than the long-term marginal costs of new TPPs. Accumulation by generating companies of additional revenues from the sale of capacity of all TPPs will expand their lending opportunities and will provide additional financial resources for investments in projects of reconstruction or replacement of capacities.

However, a simple increase in the marginal price of KOM is not the optimal solution, since, as was shown in the part 3, it will lead to the excess revenue for nuclear power plants and hydropower plants. Excessive revenue will also be received by operating TPPs that have not reached the marginal service life. Accordingly, an increase in the price of a general KOM should be accompanied by a rather complicated system of rigid obligations of generating companies for the targeted use of this excess of their own funds for investments in the renewal of their capacities that have reached their maximum resource.

These problems can be eliminated with the additional “splitting” of KOM into two segments:

- a separate competitive selection of capacities that require reconstruction (let's call it “KOM-modernization” - KOM-M) with guaranteed payment at a higher price for selected objects for the next 15-20 years;

- the usual KOM, in which all NPPs, hydroelectric power stations, operating TPPs that have not yet reached the marginal resource, as well as the facilities of PDM, KOM-NG and KOM-M after the expiry of the tariff payment period participate. At the same time, in the KOM sector, the existing conditions of payment for capacities at a single price are maintained, with regulation of the upper and lower limits of its limiting

values and preservation of the rules for their annual indexation.

It is important to note that such a structure allows the state to vary flexibly enough the intensity and technological depth of the renewal of TPPs, changing the proportions in the power traded on the other market segments, and also adjusting the minimum technical requirements (primarily for energy and environmental efficiency) to the projects of renewal of thermal power plants, as well as requirements for localization of the equipment used. Allocation of a separate segment for the selection of investment decisions on updating simplifies the task of the state in terms of forming obligations for the targeted use of funds - through the conditions for admission to the KOM-M segment.

In the KOM-M segment, as well as in the KOM-NG, it is planned to implement a competitive approach to the selection of TPP renewal projects. Each project that has passed competitive selection will be paid for in its actual price bid (but not higher than the normatively set "marginal costs"), and the one given in Table. 6 the price dynamics reflects the forecast of the weighted average of price bids for less capital-intensive projects of reconstruction and replacement of equipment of operating TPPs. Therefore, the average prices in this market segment are about three to four times lower than those of KOM-NG. The increase in the average price of KOM-M from 285 to 400 rubles per kW-in-month is explained by the gradual increase in the share of projects for the complete replacement of TPP equipment while reducing the proportion of less capital-intensive projects of partial reconstruction.

6 Conclusions

Comparison of all three support measures discussed above shows that the third one leads to the softest consequences for consumers in term of future price conditions (Figure 3).

So, in option 1, which suggests stimulating modernization by increasing gas prices, there is an explosive increase in the wholesale price of electricity by 2020, with a subsequent partial correction, but not in full. Option 2, where the incentive for TPPs modernization provides through increase of the capacity market "price cap" up to the level of long-term marginal costs of new generation, also leads to a significant increase in the wholesale price of electricity (by about 60% by 2035). In contrast, option 3 implies a mild increase in the wholesale price of electricity due to changes in the proportions and price limits set to KOM, KOM-M and KOM-NG sectors of the Russian capacity market, which ultimately will keep the growth of the wholesale price at 35% by 2035 or about one and a half percent a year. For retail consumers, the growth in the average selling price of electricity will be even lower due to the slower growth of the RGR of the electric grid complex and the possibility of reducing the network tariff in real terms and will amount to no more than one percent per year on average for the period up to 2035. These results show the possibility of To ensure a

balanced approach to the formation of a set of tariff and competitive pricing mechanisms for capacity, despite new investment challenges and a rise in gas prices, the maintenance of relatively low electricity prices for Russian consumers, which is important from the point of view of the sustainability of the national economic development.

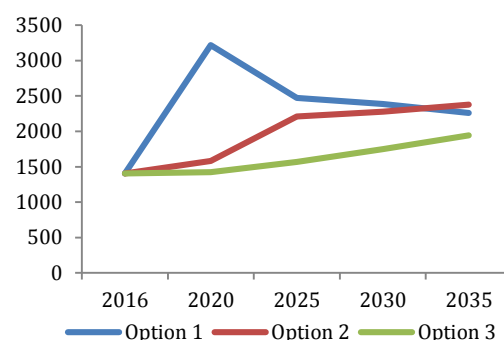


Fig. 3. Wholesale electricity price (incl. capacity payments) under different options of TPPs renewal support (in rub./MWh, prices discounted to 2016)

It should be noted that this variant of changes in the structure of the capacity market must be supported by a system of conditions that encourage companies to fulfill investment commitments. The simplest solution is to fix a specific object, technical solution, deadlines and fines for breach of obligations (as it is now in CSA). However, it seems more effective to focus on the use of economic incentives. Based on the experience of other countries, the introduction of such commitments is possible in the form of certificates for renewal volumes, which, according to the results of KOM-M, each generating company should provide with reconstructed facilities in the next one to two cycles (four to eight years). Failure (or incomplete fulfillment) of obligations to update the TPP will require the imposition of penalties against companies violators.

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