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ANALYZING THE EFFECTS
OF THE NEW RENEWABLE ENERGY POLICY IN RUSSIA
ON INVESTMENTS INTO WIND, SOLAR AND SMALL HYDRO POWER

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ABSTRACT

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This thesis presents an analysis of recently enacted Russian renewable energy policy based on capacity mechanism. Considering its novelty and poor coverage by academic literature, the aim of the thesis is to analyze capacity mechanism influence on investors' decision-making process.

The current research introduces a number of approaches to investment analysis. Firstly, classical financial model was built with Microsoft Excel® and crisp efficiency indicators such as net present value were determined. Secondly, sensitivity analysis was performed to understand different factors influence on project profitability. Thirdly, Datar-Mathews method was applied that by means of Monte Carlo simulation realized with Matlab Simulink®, disclosed all possible outcomes of investment project and enabled real option thinking. Fourthly, previous analysis was duplicated by fuzzy pay-off method with Microsoft Excel®. Finally, decision-making process under capacity mechanism was illustrated with decision tree.

Capacity remuneration paid within 15 years is calculated individually for each RE project as variable annuity that guarantees a particular return on investment adjusted on changes in national interest rates. Analysis results indicate that capacity mechanism creates a real option to invest in renewable energy project by ensuring project profitability regardless of market

conditions if project-internal factors are managed properly. The latter includes keeping capital expenditures within set limits, production performance higher than 75% of target indicators, and fulfilling localization requirement, implying producing equipment and services within the country. Occurrence of real option shapes decision-making process in the following way. Initially, investor should define appropriate location for a planned power plant where high production performance can be achieved, and lock in this location in case of competition. After, investor should wait until capital cost limit and localization requirement can be met, after that decision to invest can be made without any risk to project profitability. With respect to technology kind, investment into solar PV power plant is more attractive than into wind or small hydro power, since it has higher weighted net present value and lower standard deviation. However, it does not change decision-making strategy that remains the same for each technology type.

Fuzzy pay-method proved its ability to disclose the same patterns of information as Monte Carlo simulation. Being effective in investment analysis under uncertainty and easy in use, it can be recommended as sufficient analytical tool to investors and researchers.

Apart from described results, this thesis contributes to the academic literature by detailed description of capacity price calculation for renewable energy that was not available in English before. With respect to methodology novelty, such advanced approaches as Datar-Mathews method and fuzzy pay-off method are applied on the top of investment profitability model that incorporates capacity remuneration calculation as well. Comparison of effects of two different RE supporting schemes, namely Russian capacity mechanism and feed-in premium, contributes to policy comparative studies and exhibits useful inferences for researchers and policymakers.

Limitations of this research are simplification of assumptions to country-average level that restricts our ability to analyze renewable energy investment region wise and existing limitation of the studying policy to the wholesale power market that leaves retail markets and remote areas without our attention, taking away medium and small investment into renewable energy from the research focus. Elimination of these limitations would allow creating the full picture of Russian renewable energy investment profile.

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Lappeenranta, March 2015

Mariia Kozlova

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LIST OF SYMBOLS AND ABBREVIATIONS

ATS	Trading System Administrator
CAPEX	Capital expenditures
CFO	Chief financial officer
CM	Capacity mechanism
DMM	Datar-Mathews method
DPM	Capacity supply contract (abbreviation from Russian)
DPP	Discounted payback period
EBIT	Earnings before interest and taxes
EBITDA	Earnings before interest, taxes, depreciation, and amortization
EU	European Union
FFCZ	Free Flow Capacity Zone
FiP	Feed-in premium
FiT	Feed-in tariff
FPOM	Fuzzy pay-off method
GIS	Geographic information system
IFC	International Finance Corporation
IRR	Internal rate of return
m	Meter
m/s	Meters per second
MW	Megawatt
NP	Non-profit Partnership
NPV	Net present value
OJSC	Open Joint Stock Company
OPEX	Operating expenditures
PI	Profitability index
PV	Photovoltaic
RE	Renewable energy
REN21	Renewable Energy Network 21
RO	Real option
SO	System Operator of the Unified Power System
TWh	Terawatt hour

UAE	United Arabic Emirates
UK	United Kingdom
UNEP	United Nations Environmental Program
US	United States
VBA	Visual basic for applications
WACC	Weighted average cost of capital

1. INTRODUCTION

Renewable energy policy design is a central issue in clean energy promotion. On the one hand, it should effectively trigger new investments; on the other hand, it should expose the whole energy system to minimum additional costs. Consequently, scientific community, as well as policymakers, have become increasingly interested in renewable energy (RE) policy design and its optimization in order to achieve a high pace of renewable energy adoption minimizing system cost. From the other perspective, RE policy provides a number of incentives for investors and analyzing them with conventional techniques might disturb the decision-making process. Renewable energy policy design and implementation have great importance for both policymakers and investors.

Recently Russia has introduced renewable energy policy based on capacity mechanism, which implies remuneration of renewable energy projects in terms of their installed capacity. Unique character of this mechanism as renewable energy support scheme is elucidated further in the background part, where it is presented in the light of existing RE supporting schemes worldwide. Additionally, scarcity of the academic research conducted on the Russian capacity mechanism is emphasized in the state-of-the-art literature part. Both insights allow formulating research problem, focus, detailed objectives, and methodology presented in the correspond sub-sections of the introduction. Finally, the introduction part ends with the structure of the whole study.

1.1. Background

1.1.1. Renewable energy policy worldwide

Renewable energy investment projects are known as capital intense, implying high initial capital costs relative to installed capacity, but benefiting from low and stable operating costs, where fixed expenditures comprises the biggest share. Despite low operating costs and high learning-by-doing effects of RE technologies, conventional energy in industrial scale appears to remain more investment-attractive in the absence of renewable energy supporting mechanism. Thus, RE policy turns up to be one of the main drivers for investment in clean energy. Global annual investment in renewable energy reached more than 500% of 2004th level in 2013 accounting for $214 billion with constantly increasing share of developing countries in the total mix (Frankfurt School UNEP Collaborating Centre and Bloomberg New Energy Finance 2014).

As of early 2014, 144 countries around the world have specified renewable energy targets, supporting them by implementing corresponding RE policies (REN21 2014). In accordance with Renewables Global Status Report (REN21 2014) the most widely spread policies are:

- Feed-in tariffs and premiums;
- Renewable portfolio standards or quota systems;
- Tendering or auctioning.

Feed-in tariffs scheme provide the minimum price (generally higher than average market price) for all electricity produced with renewable energy sources, usually for a limited time horizon counted from RE power plant commercialization. Some European Union countries adopted such scheme, for instance, Finland, Germany, France, and Spain. In addition, it has spread to some African countries like Egypt, Nigeria, Algeria, and Ghana (International Energy Agency and International Renewable Energy Agency 2014). Feed-in premium scheme is similar approach, but it implies fixed premium over the electricity price for electricity produced from renewable energy. Countries that implemented this scheme include Italy, Denmark, Luxemburg, and Thailand (International Energy Agency and International Renewable Energy Agency 2014).

Renewable portfolio standards, or quota systems, impose requirements to electricity suppliers to buy certain share of energy from renewable sources that is organized with tradable RE certificates. Each certificate represents certain amount of electricity produced from renewables. Trading them induces market forces of supply and demand that establishes fair price of green electricity. The United States, the United Kingdom, Romania, and Korea are examples of countries with similar scheme (International Energy Agency and International Renewable Energy Agency 2014).

Tendering or auctioning where fixed over the contract period electricity price for each project is a result of a bidding process, prevails in South America countries, such as Peru, Brazil, and Argentina (International Energy Agency and International Renewable Energy Agency 2014).

All described schemes provide remuneration in terms of electricity produced e.g. kWh, whereas newly introduced Russian capacity mechanism does in terms of installed capacity e.g. kW. This is not the only difference between it and other RE supporting schemes that requires careful consideration.

To describe Russian capacity mechanism to support RE, firstly, we present Russian power market system and then continue with introducing capacity mechanism itself.

1.1.2. Russian power market

Russia is the fourth country/region by electricity production volume after China, the US, and the EU (Central Intelligence Agency 2014). In 2012 total electricity production reached more than 1000 TWh that corresponds to 223 GW of installed electricity generation capacity. Constant since 2000 growth rate of electricity consumption of 2% is roughly an equivalent to 8 GW of new installed capacity each year (based on data from the World Bank World Development Indicators Database).

As for energy sources, thermal power stations dominate in electricity production with almost 70% of the total energy mix, where gas contributes to this figure approximately by two thirds and the rest for coal, followed by hydropower with 20% and nuclear power with around 10%. Renewable energy sources account for less than 1% of the total electricity production (Russian Ministry of Energy 2013). This structure varies for different zones of Russia, such as European part, Siberia, and Far East. As can be seen from Figure 1, gas based generation prevails in the European part, while in the rest of Russia coal is the main fuel for power generation.

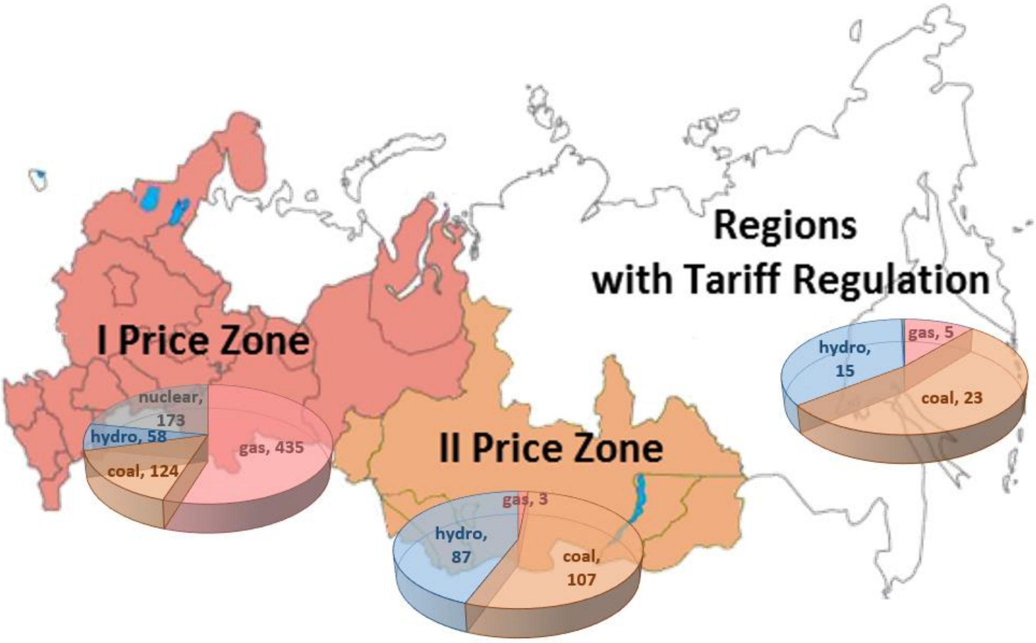

Figure 1. Power production in Russia by zone in 2011, TWh (based on (NP Market Council 2012a; Veselov 2013)).

Due to this fact, the whole territory of the country is divided into two price zones, the first one, where electricity prices follow changes in the gas price, and the second one, where coal price determines electricity prices. Marginal pricing mechanism as described below is realized in the power market within these two zones. In the rest of Russia electricity tariffs are regulated.

The whole power market consists of the wholesale market (95% of electricity production in the country) and retail markets. Participation in the wholesale market is obligatory for generators with installed capacity more than 25 MW. Power plants with capacity between 5 and 25 MW may choose whether participate in wholesale or retail market. Industrial electricity consumers and utility providers are other participants of the wholesale market. Retail markets are established to bring electricity traded in the wholesale market to end-users. Retail markets participants are consumers, utility providers, power providers, small generators, and distribution companies.

There are two commodities in the Russian power markets: electricity and capacity. ***Electricity*** is traded through bilateral contracts, in the day ahead market, and in the balancing market. Bilateral contracts allow parties to negotiate price, quantity, supply duration, and other contract specifications directly with each other independently from current market conditions. Day ahead market enables wholesale electricity trade a day before actual delivery. The trade is organized in two steps. Firstly, one week before delivery generators submit technical information to the system operator OJSC “System Operator of the Unified Power System” (SO), while it forecasts consumption and selects enough production units to cover it. Secondly, one day before the delivery, generators that were selected in the first step submit price offers (reflected their marginal cost to produce electricity) to the trading operator OJSC “Trading System Administrator” (ATS), and it selects offers based in the price ascending order or merit order, this refers to as marginal pricing mechanism. The clearing price that all generators receive for the electricity is defined as the most expensive price from selected offers. The whole actual imbalance, e.g. power excess or deficit, is covered through the balancing market, where generators selection is carried out by SO. A non-profit partnership (NP) Market Council is responsible for developing a regulatory framework and for controlling the compliance with market rules. (NP Market Council 2012b)

Capacity trade is set up through auctions, where price is determined by ATS based on generators bids and the total amount is set by SO based on each price zone peak demand plus 17% reserve margin. Similar to electricity market, generators submit their bids, and then ATS ranges them in a price-up order and defines the clearing price by the most expensive generator that completes total needed capacity defined by SO. These auctions select capacity for a year ahead. The procedure is different for new electricity production plants. Auctions are hold four years ahead and capacity price is defined separately for each contract involving a number of factors. All wholesale electricity buyers are obliged to buy capacity in accordance with the quantity defined by SO. Demand-side capacity price is calculated as weighted average of all supply-side capacity prices (NP Market Council 2012b). Capacity trade functions only in the two price zones of the wholesale market (see Figure 1). Due to transmission constraints price zones are divided into so called free flow capacity zones (FFCZ), with capacity price formation separately for each FFCZ (Veselov 2013). In 2014 there were 21 FFCZs, thereof 16 in the first price zone and five in the second (System Operator 2014).

1.1.3. Russian renewable energy support

Russian land embracing a number of geographical zones and climatic regions, offers an abundance of renewable energy sources. Significant area, mostly coastal territories in the North and East, has average wind speed higher than 6 m/s (Figure 2) that in terms of electricity output of wind turbine might be interpreted as more than 20% capacity factor (European Wind Energy Association 2009).

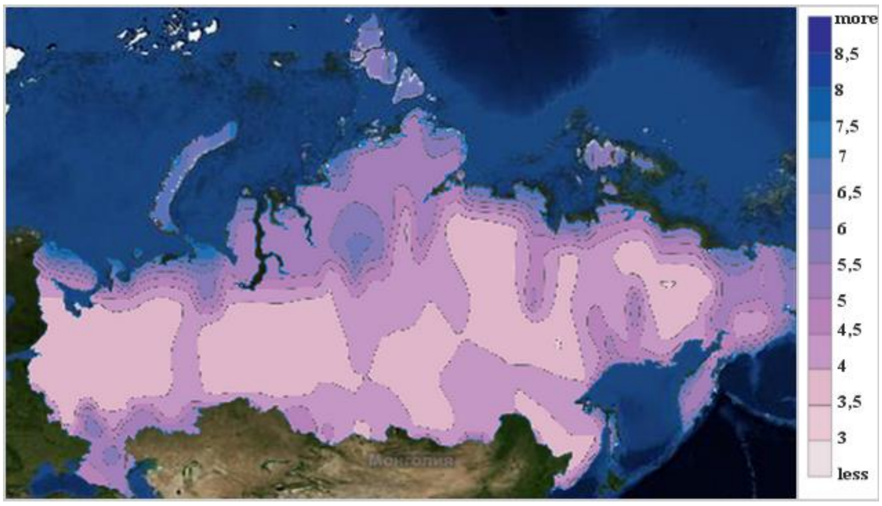

Figure 2. Average wind speeds at 50 m height, m/s (Moscow State University and Joint Institute for High Temperatures of the Russian Academy of Sciences 2015).

Almost half of Russian area has average solar irradiation more than 3,5 kWh/m2 per day (Figure 3) or more than 1278 kWh/m2 per year, which corresponds with higher than 11,7% capacity factor for an average solar PV power plant (ABB 2010).

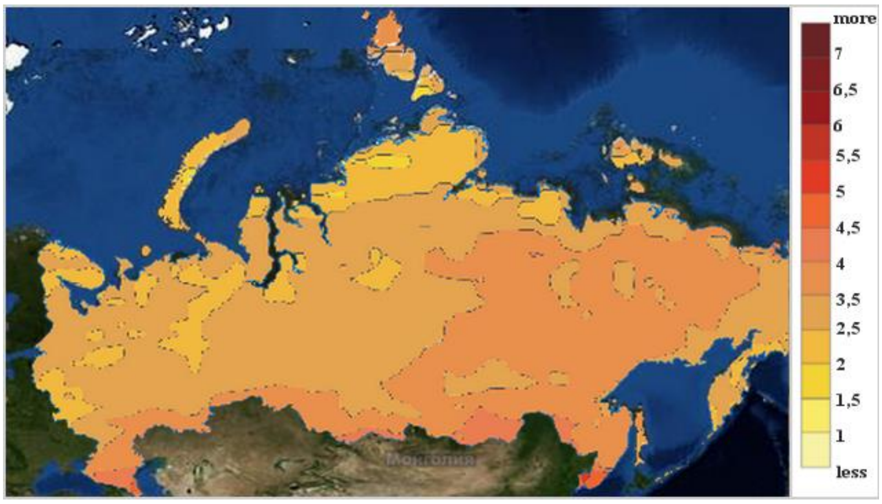

Figure 3. Annual average solar irradiation, kWh/m^2 per day (Moscow State University and Joint Institute for High Temperatures of the Russian Academy of Sciences 2015).

Plenty of small rivers creates favourable conditions for small (less than 25 MW) hydropower plants. Average flow conditions can provide about 40% capacity factor (British Hydropower Association 2012).

Having an abundance of renewable energy sources Russia started to develop plans to harvest them already in 2009 by establishing renewable energy target as 4.5% of electricity produced from renewable energy sources by 2020 (Government of Russian Federation 2009). Since then elaboration of renewable energy supporting mechanism has started.

Initially, a feed-in premium scheme was considered, but it was abandoned due to several implementation barriers (International Finance Corporation 2013). Instead, existing mechanism for supporting new generation described in the previous subsection was extended to renewable energy with some adjustments and was entered into force in May 2013 (Government of Russian Federation 2013a; Government of Russian Federation 2013b). According to it, each year special auctions are hold that select investment project into wind, solar and small hydropower for several years ahead, ranking them by capital costs ascending order till target installed capacity for each year is selected. Winning bids are eligible for capacity delivery contracts that provide additional revenue to electricity sales for 15 years from power plant commissioning. Capacity price under this agreement is designed in a way to provide a certain return on investment taking into account changes in interest rates, inflation, expected revenues from electricity sales and amount of capital expenditures. Moreover, capacity price reflects electricity production of each power plant punishing for underperformance and imposes a localization requirement that forces investors to obtain equipment and services locally in Russia.

Overall, Russian capacity mechanism differs substantially from all existing renewable energy policies that together with complex capacity price formation reveals necessity and interest of its investigation.

1.2. State-of-the-art literature

Broad academic research covers almost each kind of policy from different perspectives. Comparing different policy types on the issue of its efficiency in RE promotion and cost-effectiveness is one of the main research directions in this field (Butler and Neuhoff 2008; Fais et al. 2014; Haas et al. 2011; Lund 2007). Empirical studies analyze factual policy effects on renewable energy deployment and electricity prices (Carley 2009; Ciarreta, Espinosa, Pizarro-Irizar 2014; Marques and Fuinhas 2012). Investment modelling, often incorporating real option analysis, under different support schemes allows researchers to investigate investors' behavior and approach the same efficiency questions from another perspective (Boomsma, Meade, Fleten 2012; Kim and Lee 2012; Scatasta and Mennel 2009; Yu et al. 2006).

However, less attention was paid to the Russian capacity mechanism due to its novelty. As of early 2015, only two relevant works are devoted to it (Table 1).

Table 1. Academic papers on Russian capacity mechanism.

Year	Authors	Topic
2012	Anatole Boute	Promoting renewable energy through capacity markets
2015	Evgeniia Vasileva, Satu Viljainen, Pekka Sulamaa and Dmitry Kuleshov	RES support in Russia: Impact on capacity and electricity market prices

Anatole Boute (2012) presented qualitative study describing mechanism drawbacks and strengths, analyzing its draft more than one year before its actual enactment. Vasileva et al. (2015) preformed market-oriented quantitative study exploring Russian RE capacity mechanism influence on the market capacity price suggesting minor effects in comparison with conventional energy effects.

Considering novelty and unicity of Russian capacity mechanism on the one hand, and lack of the academic literature on the topic on the other hand, this mechanism incentives require in-depth investigation in order to create the full picture of the new policy, provide investors with comprehensive analysis, and make useful inferences for policymakers.

1.3. Research problem, focus, and objectives

Russian capacity mechanism for supporting renewable energy appears to be different from all other existing RE supporting schemes. Amount of remuneration under RE capacity delivery contract is a function of different changing factors that makes it difficult to forecast and consequently to understand it influence on RE investments. State-of-the-art academic literature on the topic is limited to only two relevant papers that analyze capacity mechanism from different perspective. Apparently, this research gap should be covered in order to provide investors, policymakers, and further researchers with helpful insights on capacity mechanism effects.

Considering the research gap, the whole study is limited to the narrow research focus shown in Figure 4, effects of Russian capacity mechanism on renewable energy investments. This focus arises from taking research object ‘Russian RE support scheme based on capacity mechanism’ from investors’ perspective. The object by itself lies on the intersection of such areas as renewable energy support, Russia, and capacity trade.

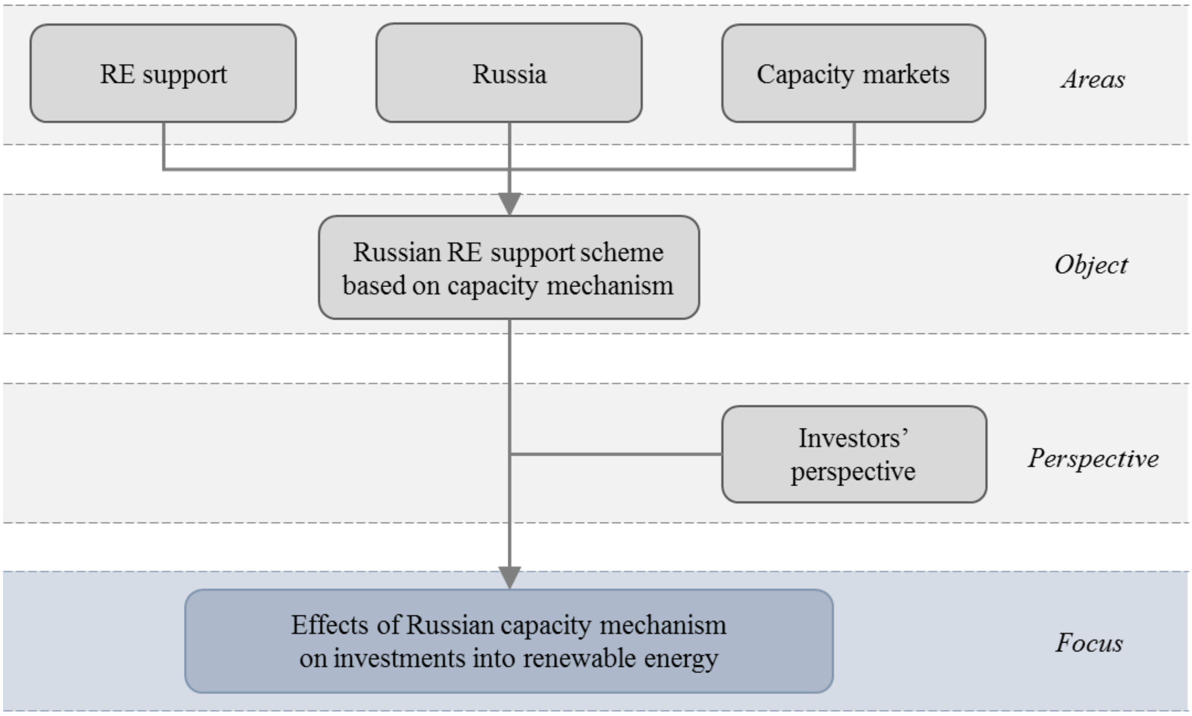

Figure 4. Research focus.

The main research question that would cover research gap is ***how new Russian renewable energy policy incentives affect investors' decision-making process***. Following sub-questions are set to provide the full answer to the main question.

Initially, the procedure of calculating financial aid under capacity mechanism or capacity price should be defined in details. Thus, the first sub-question is:

1. How is ***capacity price*** formed?

When the procedure is clear, investment analysis can be started, first step of which is calculating capacity price in accordance with the procedure and then defining investment project profitability under capacity mechanism.

2. What level of ***profitability*** does capacity mechanism provide to investments into wind, solar, and small hydropower?

To estimate what incentives the policy provides, factors that influence project profitability should be defined.

3. What are the main ***influential factors*** that shape project profitability under capacity mechanism?

After factors are defined, one can estimate how they influence economic viability of the investment project if they are uncertain.

4. How does ***uncertainty*** influence project profitability?

Incorporating uncertainty into analysis allows searching flexibility or real options of the project within uncertain environment. As real options can enhance value of investment project, the consequent question is following.

5. Does capacity mechanism enable ***real option thinking***?

Since real option analysis including modelling uncertain environment can be performed with different techniques, method comparison should be done to find out an appropriate approach.

6. ***What method*** is sufficient to address investment analysis under capacity mechanism and simultaneously easy to use for investors?

Finally, influence of policy incentives on decision-making process should be illustrated to accomplish an answer on the main research question.

7. How does ***decision-making process*** under capacity mechanism look like?

The interaction between research sub-questions is presented in Figure 5.

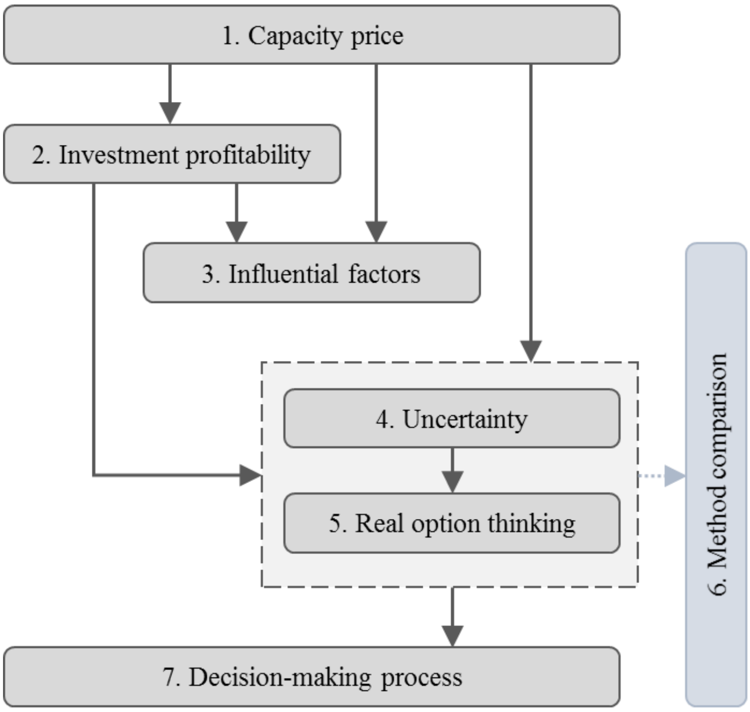

Figure 5. Interaction between research sub-questions.

An answer to the sub-question one ‘how is capacity price formed?’ allows investigating investment profitability (sub-question 2). Based on it, influential factors can be figured out (sub-question 3). How uncertainty shape investment profitability (sub-question 4) and whether capacity mechanism enables real option thinking (sub-question 5) can be revealed based on capacity price formation and project profitability analysis. Comparing all these analysis results would allow answering on the sub-question 6. Finally, decision-making process under capacity mechanism (sub-question 7) can be built based on real-option analysis that would automatically provide an answer to the main research question.

Next section links each sub-question with corresponding research methodology.

1.4. Methodology

Each sub-question is addressed with specific method that allows providing a sophisticated answer (Table **2**. Research methodology.Table 2). Initially, capacity price formation is analyzed by careful investigation of the Russian legislation. Investment profitability is calculated by conducting investment modelling analysis or applying conventional net present value (NPV) approach with Microsoft Excel®. On the top of this model, sensitivity analysis is built with macros written in VBA, to understand influence of various factors.

Incorporating uncertainty and real option thinking is addressed with two different approaches.

- Datar-Mathews method that implying random input variables, creates a probability distribution of an output by means of Monte Carlo simulation. In this study, it is performed with Matlab Simulink®;
- Fuzzy pay-off method treats uncertainty by evaluating most possible and extreme scenarios, creating possibilistic distribution of the outcome. Here it is built on the top of the constructed model in Microsoft Excel®.

These methods are compared based on their results and implementation process. Eventually, decision-making process is illustrated with decision tree that is built by means of Microsoft PowerPoint®. All methodology selection represents a logical choice driven by the research objectives.

Table 2. Research methodology.

Sub-question	Method	Tool
1. Capacity price	Legislation analysis	-
2. Investment profitability	Investment modelling / conventional NPV	Microsoft Excel®
3. Influential factors	Sensitivity analysis	VBA for Excel
4. Uncertainty, and 5. Real option thinking	Datar-Mathews method (based on Monte Carlo simulation)	Matlab Simulink®
	Fuzzy pay-off method	Microsoft Excel®
6. Method comparison	Comparative analysis based on results of each method	-
7. Decision-making process	Decision tree	Microsoft PowerPoint®

Next section concludes the Introduction with an overview of the whole study structure.

1.5. Study structure

The whole thesis is divided into six consequent parts, namely “Introduction”, “Literature review”, “Russian capacity mechanism”, “Modelling Russian capacity mechanism effects on RE investment profitability”, “Results”, and “Discussion and Conclusion”. They are illustrated in Figure 6 enriching analytical part that consists of “Modelling…” and “Results” with details.

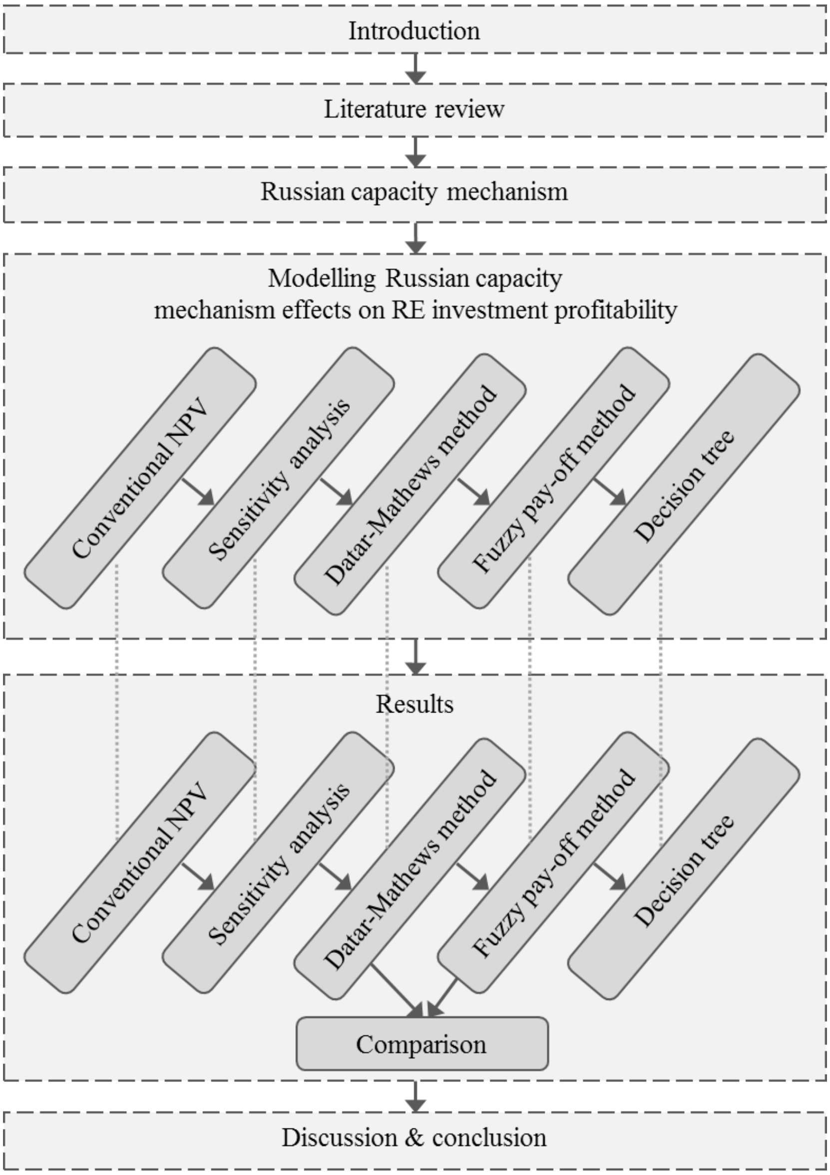

Figure 6. Study structure.

Following Introduction, Literature review presents state-of the-art academic literature on such topics as renewable energy policy research, real options approach in RE policy research, and finally Russian RE policy. The third part introduces detailed description of Russian capacity mechanism and capacity price formation. The next section represents model specification including method description, model overview, and assumptions. Next part delivers results of all analyses and compares two real options approaches. Eventually, the final part reviews main results, discusses contributions, draws conclusion of the whole thesis, and reveals limitations and ideas for further research.

2. LITERATURE REVIEW

Literature review presents state-of the-art academic literature on topics related to the research question and methodology (Figure 7).

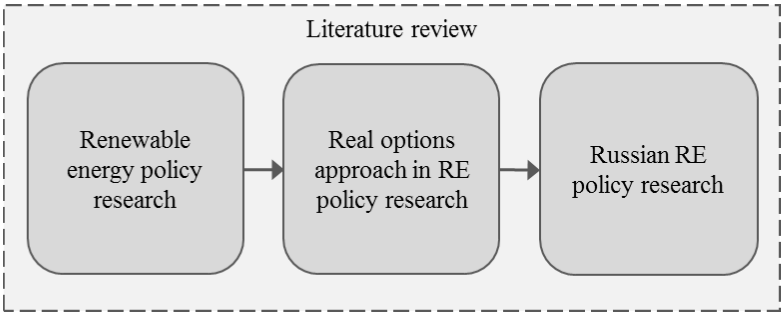

Figure 7. Structure of literature review.

Firstly, broad area on renewable energy policy is considered that includes all possible types of policies and different kinds of research perspectives, targets, and approaches. Thus, the general overview of the topic is presented. Secondly, we switch to the papers that apply real options technique to RE policy research that reveals main directions in real options reasoning application. Finally, rare articles on Russian renewable energy policy are examined.

2.1. Renewable energy policy research

Worldwide adoption of renewable energy policies has caused extensive research in the academic field. Scientific papers address a variety of issues from different perspectives. In this area, case studies are the most common that elucidate benefits and drawbacks of a particular policy implemented in a specific country or region. Some researches perform comparative analysis of different policies to find out useful features and instruments. Renewable energy policies are scrutinized at different angles, including speed of RE adoption on the one hand and policy cost-efficiency on the other hand. Both investor’s and policymaker’s perspectives engage researchers’ attention. Alongside with qualitative analysis authors use a range of numerical methods to assess different features of policy design or its effects. We further characterized these academic literature dimensions one by one, starting with case studies, followed by policy comparative analysis, and concluding with numerical approaches in policy research.

Case studies prevail in RE policy research. Some of them have descriptive nature aiming to analyze renewable energy policy development in a particular country. For instance, Ming et al. (2013) investigate evolution of feed-in tariffs (FiT) in China; Byrnes et al. (2013) bring to light Australian policy barriers that reduce its efficiency in renewable energy deployment; Singh and Sood (2011) review renewable energy support mechanisms in India. Some papers are related to a specific event, for example, accession into the European Union of Poland (Wohlgemuth and Wojtkowska-Łodej 2003) and Lithuania (Gaigalis et al. 2014), and study their compliance and consequences for the local renewable energy policy. Notwithstanding an object of many papers is a developed country, probably the most prominent research direction is an analysis of renewable energy policies in emerging economies, such as Brazil (Marreco and Carpio 2006), Malaysia (Mekhilef et al. 2014), Mongolia (Detert and Kotani 2013), Maldives (van Alphen, Kunz, Hekkert 2008), Cambodia (Sarraf et al. 2013), UAE (Choucri, Goldsmith, Mezher 2010), and the whole of Africa (Mandelli et al. 2014). Case studies create a strong basis for RE policy comparative analysis.

Comparing RE policies in different countries allows researchers to optimize policy design for various purposes from boosting renewable energy growth to finding least-cost approach of RE adoption, implying maximization of social benefit. Researches distinguish quantity based mechanisms, such as quota system or RE portfolio standards (RPS), and price based mechanisms, such as feed-in tariffs (FiT). Widely accepted notion implies that price-based system is a better driver to renewable energy promotion (Butler and Neuhoff 2008; Haas et al. 2011; Menanteau, Finon, Lamy 2003), whereas quantity based system provides more cost-efficient way of RE adoption (Fais et al. 2014; Lund 2007). Few opposite conclusions present FiT not only as the best policy for RE promotion, but as a least-cost approach as well (Butler and Neuhoff 2008; Haas et al. 2011). Another view on policy efficiency by Dinica (2006) highlights the importance of policy design: "feed-in tariffs may also bring about disappointing diffusion results when poorly designed while quota systems may be also conceived as attractive instruments for independent power producers." Mir-Artigues and del Río (2014) propose a combination of RE energy policies, such as tariffs, subsidies, and soft loans, to be a more effective instrument in terms of RE capacity growth and they also conclude that it does not deteriorate cost-effectiveness. Palmer and Burtraw (2005) argue that from the perspective of carbon emission reduction the most cost-efficient policy is not even renewable energy policy, but cap-and-trade market based approach e.g. emission trading scheme. Similar belief is introduced by Edenhofer (2013). Overall, comparative studies rise two main features of RE policy, its efficiency in renewable energy adoption and its cost-effectiveness.

Along with qualitative research, renewable energy policy studies often present numerical analysis designed to answer a number of different research questions. Financial models are built to analyze policy cost-effectiveness mentioned above and to investigate its influence on electricity prices for market participants as well as ultimate consumers (Muhammad-Sukki et al. 2014; Sensfuss, Ragwitz, Genoese 2008). Another direction in quantitative analysis of renewable energy policy is ex post empirical testing of policy implementation results. Some authors aim to verify whether RE policy leads to actual increase in renewable energy generation (Carley 2009; Marques and Fuinhas 2012). Ciarreta, Espinosa, and Pizarro-Irizar (2014) use econometric model to define the cost of RE policy adoption in Spain. Whereas Lean and Smyth (2013) using empirical tests conclude that RE policies with unlimited duration are more effective in RE promotion than ones with pre-specified time horizon. In recent years real options (RO) approach is applied in RE policy research in a more frequent basis. We would like to pay particular attention to this topic introducing it in a separate part.

2.2. Real options approach in RE policy research

Number of papers studying renewable energy policy with real options approach has been growing over the last years. Although as of early 2014 total number of academic articles on this topic exceeds forty, during 2002 – 2004 period there was one paper per annum published. Since 2010, on average seven articles were introduced to the scientific society each year. Despite of a strong research focus on developed countries, the number of papers devoted to RE policy in emerging economies has been increasing as well. It reflects the real situation, where implementation of renewable energy policy seems to “force” not only industry and investments, but also scientific research. For instance, Renewable Energy Law in Turkey was introduced in 2005 and first paper on Turkish renewable energy policy was published in 2008 (Kumbaroğlu, Madlener, Demirel 2008). In Brazil since 1976 mandatory portion of ethanol in fuel has been increased, last amendment was in 2007 and consequently in 2009 a research on ethanol production assessment (Bastian-Pinto, Brandão, Hahn 2009) was published and then on valuing flex fuel cars in 2010 (Bastian-Pinto, Brandão, Alves 2010). A paper by Yang et al. (2010) followed Chinese Renewable Energy Law enactment in 2006. Thus, new policy enactment is often followed by academic papers that initially bring to light new policy features and expected effects. Moreover, real option approach becomes more common in the academic literature. Considering the fact, that number of national and regional RE policies arises each year (REN21 2014), it is essentially to expect growing number of papers studying RE policy with real options approach in the future.

Considered papers concern both investors' and policymakers' perspectives, although sometimes it is not possible to distinguish between them. These views are highly related, for example, risk reduction due to policy support means higher RE project attractiveness for an investor as well as it implies higher pace of renewable energy diffusion for a policymaker.

Real option valuation is used to analyze a single policy as well as for comparing different policies. As an example, Kim and Lee (2012) compare different feed-in-tariffs and make proposals for their optimization. Scatasta and Mennel (2009) bring into comparison FiT and Renewable Obligation Certificates. Yu et al. (2006) compare new switchable tariff with old fixed one in Spain, arguing that switchable tariffs provide more flexibility increasing value of investment project. Boomsma et al. (2012) explore investors' behavior under FiT and renewable energy certificate trading scheme. Such research provides navigation for investors and inferences for upgrading existing policies and designing new support mechanism for emerging economies.

Researchers incorporate different types of uncertainties in their analysis. The most often they take into account uncertainty in future electricity and fossil fuel prices, and technology cost reduction represented by learning curves (Kumbaroğlu, Madlener, Demirel 2008; Siddiqui and Fleten 2010; Tolis, Rentizelas, Tatsiopoulos 2010). Some researchers consider also regulation uncertainty (Boomsma, Meade, Fleten 2012; Lee and Shih 2010; Reuter et al. 2012b; Venetsanos, Angelopoulou, Tsoutsos 2002; Vogstad and Kristoffersen 2010), uncertainty in carbon dioxide emission allowance prices (Fuss et al. 2009; Fuss et al. 2012; Tolis, Rentizelas, Tatsiopoulos 2010; Yang et al. 2010), and uncertain electricity production from renewable energy sources (Méndez, Goyanes, Lamothe 2009; Muñoz et al. 2011; Yu et al. 2006). Prevailing stochastic processes to model these uncertainties are binomial lattices, Geometric Brownian motion (GBM), and mean reverting model (MRM). Some papers combine several approaches to compare results (Bastian-Pinto, Brandão, Alves 2010; Detert and Kotani 2013). Overall, modelling different sources of uncertainty is an essential part of real options approach that provides the ground for flexibility value.

When sources of uncertainty are defined and modeled, real options types can be determined and evaluated. The majority of researchers recognize timing options, or the option to defer an investment. Some papers treat the whole investment project as a real option. In addition, almost all known variety of real options are represented in the renewable energy policy research, including option to abandon, to deploy, to grow, to stage, to stop/restart, and to switch inputs/outputs. As for the valuation method, most researchers prefer Monte Carlo simulation, followed by systems of partial differential equations concluding by binomial trees. Interestingly, on the top of these methods dynamic programming is applied in the almost half of all investigated papers that apply RO. This evidence confirms the relevance and popularity of dynamic programming approach adopted for real options valuation by Dixit and Pindyck (1994). Nonetheless, the most widely recognized real option is option to defer investment along with the mostly used valuation method, Monte Carlo simulation.

General inference provided by almost all considered papers used RO valuation is that propensity to invest in renewable energy increases with rising electricity prices and lowering capital costs. Researchers find real options approach more effective and better reflecting reality. There are different models proposed for renewable energy project valuation with respect to different types of technologies or their combination and uncertainties. In general, high rate of technology learning effects and high instability of markets creates value for the option to defer investment. Consequently, RE policy aims to encourage earlier investment by reducing price and/or guaranteeing buying of electricity from renewable energy source. (Boomsma, Meade, Fleten 2012; Fleten, Maribu, Wangensteen 2007; Kumbaroğlu, Madlener, Demirel 2008; Martínez Ceseña, Mutale, Rivas-Dávalos 2013; Martínez-Ceseña and Mutale 2011; Santos et al. 2014.)

Some specific implications for policymakers might be summarized as follows. Fuss et al. (2009) revealed interesting causality for climate policy that is consistent with Lean's and Smyth's (2013) results: stable over time policy is more effective than frequently changing one. Scatasta and Mennel (2009) found out that quantity based mechanism forces investors to innovate more than price based one. In addition, Boomsa et al. (2012) educed that the price based scheme favors earlier investment than quantity based, whereas the latter incentivizes larger projects. Some researchers constructed models in order to determine optimal features for the particular policies in different countries (Lee and Shih 2010; Lee 2011; Lin and Wesseh Jr 2013).

In conclusion, academic papers that apply real options approach in renewable energy policy studies, cover a variety of issues from elaborating a sophisticated tool for investment valuation to in-depth policy analysis with telling inferences for policymaking. Generally, they follow chronological order with a few years lag from particular policy enactment. Taking into account the fact that in Russia RE policy was introduced in 2013, the scarcity of its analysis in the academic literature is not surprising. The next part throws light on existing research of Russian renewable energy policy development.

2.3. Russian RE policy research

Abundance of renewable energy potential in Russia has been attracting business and academic attention for a long time, but a lot of barriers inhibited investments in Russian renewable energy sector (Martinot 1998). Long before Russian renewable energy supporting mechanism was introduced, Eric Martinot summarized main barriers to renewable energy deployment in Russia and depicted ways to overcome them. His suggestions included creating market intermediation institutions, developing information systems, and professional skills in economic analysis, finance and management, elaborating favorable legal environment, especially supporting instruments for independent power producers and energy service companies. (Martinot 1999; Martinot 1998.)

Later, in 2011 a group of Chinese researchers conducting a study on renewable energy policies in BRIC countries concluded that “Russian renewable policies are not working, reducing renewable energy consumption growth in the long-term.” (Zhang et al. 2011). To be precise, at that moment there was no renewable energy supporting mechanism in Russia, although Russian Federal Electricity Law already contained a basis for its creation.

To overpass existing obstacles International Finance Corporation (IFC) established Russian Renewable Energy Program in 2010, which aimed to attract investments to the sector by assisting in improvement of regulatory environment, building market capacity, expanding access to renewable energy financing, and eventually raising awareness about renewable energy issues. With introducing Russian renewable energy policy, IFC published its description to facilitate its understanding by investors (International Finance Corporation 2013).

Russian capacity trade-based mechanism was analyzed by Anatole Boute (2012), who was the member of IFC. He presented a qualitative study of the policy draft a year before its official enactment. Boute (2012) highlighted advantages of the capacity based scheme over the output-based supporting mechanisms, such as more predictable cash flows and elimination of an incentive to produce and supply electricity to the grid during low demand hours. However, he also emphasized the challenge to appropriately treat variable electricity output from renewable energy sources within capacity based scheme. (Boute 2012.)

Recently published investigation by Vasileva, Viljainen, and Kuleshov from Lappeenranta University of Technology Energy Department, and Sulamaa from Sulamaa Consulting Ltd., Finland (2015) studies Russian capacity mechanism possible influence on market capacity and electricity prices. Their findings suggest that a little additional burden will be imposed to industrial electricity users implying policy cost-effectiveness.

Renewable energy supporting mechanism based on capacity market is unprecedented and so far was not extensively studied in the academic literature. Capacity markets attracted researchers’ attention in relation to renewable energy, only as a solution to retain electricity market stability in the presence of considerable share of renewable energy with unstable electricity production (Cepeda and Finon 2013). An opposite idea of using capacity markets to support renewable energy has raised only with Russian case. Taking into consideration the fact, that Boute (2012) presented only qualitative analysis and Vasileva et al. (2015) analyzed it from the market perspective, we can conclude that there has been no attempt in the academic literature to examine Russian renewable energy policy quantitatively from the investors’ perspective.

3. RUSSIAN CAPACITY MECHANISM

In Russia, capacity mechanism arising during 2008-2010 was finally introduced in 2010 to trigger investment into new generation. Long-term capacity delivery contracts (DPM) ensure covering project investment costs creating favourable investment climate and security of electricity supply with timely available new generation capacity. DPM with 10-year duration are available for coal and gas power plants and 20-year tenancy for hydro and nuclear power plants. Recently this mechanism was extended to renewable energy, particularly wind, solar, and small hydro (less than 25 MW) with 15-year contract term (Government of Russian Federation 2013a; Government of Russian Federation 2013b). Project selection is carried out by annual competitive capacity auctions. (NP Market Council 2012a.)

Capacity mechanism originates from rate-of-return or cost-plus regulation, where beneficiary gets remuneration in amount sufficient to cover its costs plus defined return. It is widely used in industries that imply natural monopolies, namely network industries, for instance, telecommunication, water, railways, and, indeed, electricity (Jamison 2005; Nezlobin, Rajan, Reichelstein 2012).

Capacity price within DPM is defined in a way to provide a certain return on a power plant investment with a following computational logic. Initial investment costs are converted into regular payments by means of annuity. Its rate of return is defined by the regulator, and in order to adjust to market variability, it is corrected on a change in the yield of long-term government bonds (base rate). Thus, annuity with variable interest rate is used, that makes payment amount not fixed. Then, operating costs and tax expenses are added to the calculated amount. Finally, as capacity payments are not the only cash inflow of any power plant, capacity price is decreased by the expected revenue from electricity sales.

ATS computes capacity price on an annual basis. Following aspects are taken into account for capacity price calculation for conventional energy:

- Standard capital expenditures;
- Standard operating expenditures corrected on inflation;
- Rate of return is 14% and corrected by the change in the base rate;
- Only that part of expenses is compensated, that is not covered by anticipated revenues from electricity sales, that is realized by including into calculation fixed for each technology type share of expense to compensation;

- Contract tenor is 10 years, but payback period is assumed to be 15 years for coal and gas generations and 20 and 25 years correspondingly for hydro and nuclear power plants;

Renewable energy capacity pricing is based on the same logic, however, previously fixed inputs are variable here and some specific features are added:

- Planned project capital expenditures (with certain limit) instead of standard value;
- Capital expenditures are a subject to local content requirement of producing equipment within the country;
- Operating expenses are fixed as previously and corrected on inflation;
- Rate of return is set as 14% for projects that for auctioned before 1.1.2015 and 12% for the rest, corrected by the change in the base rate;
- Share of expenses to compensation now is a function of changing electricity prices;
- Capacity factor as production performance measure influences the final capacity payment amount;
- Contract tenor is 15 years with different assumptions of payback period for each type of technology.

The difference between capacity price calculation for conventional energy and renewable one is illustrated in Figure 8.

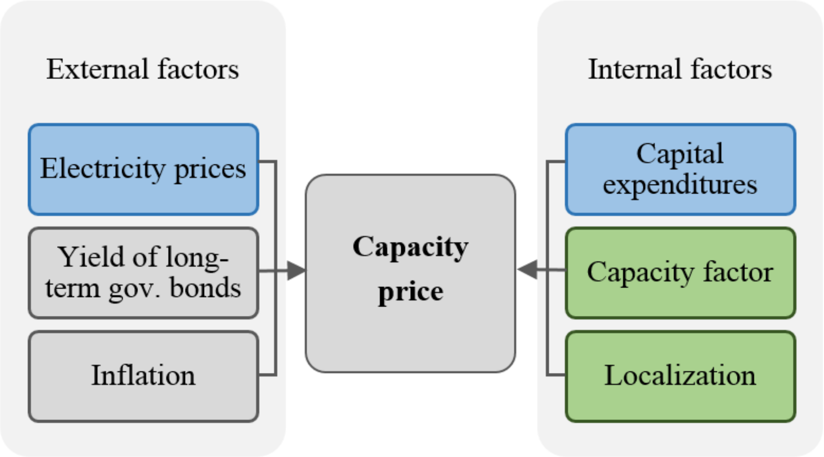

Figure 8. Factors contributing to the capacity price
(blue – variable for RE, green – totally new for RE)

The only variable factors in capacity price calculation for conventional energy are rate of return and inflation. Additionally, twice per contract duration capacity price is adjusted on a change in electricity prices. Apart from already mentioned, capacity price for renewables depends on annual electricity price changes, amount of planned capital expenditures, equipment and services origins (localization), and electricity production performance (capacity factor). Thus, capacity price for renewable energy projects differs not only among different years of the same contract, but also among contracts.

Detailed price formation procedure for both conventional and renewable energy is presented below.

3.1. Capacity price formation for conventional energy

Determining the capacity price for conventional energy DPM consists of the following steps:

1) A guaranteed rate of return is calculated, based on an initially set level of 14-15% (for different groups of participants) and corrected on changes in the base rate, namely yield of the Russian state long-term obligations or base rate (only notes with maturities from 8 to 10 years are appropriate for the calculation (The Ministry of Economic Development and Trade 2010). The following formula is used:

$$R_i = \frac{(1 + R_b) * (1 + Rf_1)}{(1 + Rf_b)} - 1 \approx R_b + \Delta Rf, \qquad (1)$$

where R_i is the guaranteed rate of return for i year of contract tenant;

R_b is base guaranteed rate of return;

Rf_b is base rate = 8.5%;

Rf_i is base rate for i year.

2) As an investment project has some revenues from electricity sales, a share of expenses to be covered (expense share) by capacity payments should be established. On the one hand, this share is based on the expected revenues from electricity market that is dependent on electricity production profile, on the other hand, it is a function from capital (CAPEX) and operating expenditures (OPEX). However, all these characteristics are well known for conventional energy technologies in Russian conditions, hence, all this calculation inputs are determined, more precisely CAPEX, OPEX, and expense share are fixed and specified by the rules (Government of the Russian Federation 2010). To avoid capacity price being out of date with regards to market conditions, OPEX is adjusted on inflation for each year of the

contract, expense share is adjusted on electricity price change twice per contract duration (for the 4th and 7th years of the contract).

3) So called capacity price component is calculated as follows. Firstly, adjusted to the first year of capacity contract CAPEX is defined:

$$CAPEX_{adj} = CAPEX * E * (1 + R_{-1})^{N_{st}} \tag{2}$$

where *CAPEX* is defined in (Government of the Russian Federation 2010) for each technology type and multiplied by a number of fixed coefficients;

E is expense share defined in step 2;

R_{-1} is *R* defined in (1) for $i=-1$;

N_{st} is a constant different for each technology type;

Then adjusted CAPEX is converted to the annuity payments with variable interest rate. Principal payment is defined as follows (principal implies adjusted CAPEX):

$$Pp_i = \frac{Rp_i * (k - 1)}{(k^{16-1} - 1)}, \tag{3}$$

where Pp_i is principal payment on investment;

k is equal 1.19 for the first price zone and 1.16 for the second one;

Rp_i is a remaining principle. For $i=1$ $Rp_1=CAPEXadj$, for other years it is calculated by the formula:

$$Rp_i = Rp_{i-1} - Pp_{i-1} + (R_{i-1} - R_{i-2}) * (1 + R_{i-1}) * Rp_{i-1}, \tag{4}$$

where R_i is a rate of return calculated in (1);

Eventually, capacity price component is defined as a sum of interest payment on before-tax principle, principle payment, and operating expenses:

$$CP_{comp} = Rp_i * \frac{R_{i-1}}{1 - r_{inc_{tax}}} + Pp_i + OPEX, \tag{5}$$

where CP_{comp} is capacity price component;

$rinc_{tax}$ is an income tax rate equal to 0.2;

OPEX is an inflation adjusted *OPEX* specified in (Government of the Russian Federation 2010) for each technology type multiplied by the expense share.

4) Finally capacity price is a corrected on a coefficient of energy for own needs sum of the capacity price component defined in step 3 and property tax expenses multiplied by expense share defined in step 2:

$$CP = (CP_{comp} + \frac{T_{pr}}{12} * E) * k_2, \tag{6}$$

where CP is capacity price;

CP_{comp} is defined in (5);

T_{pr} is average property tax;

E is expense share defined in step 2;

k_2 is a coefficient of energy for own needs fixed for each technology type.

3.2. Capacity price formation for renewable energy

The procedure for calculating capacity price for renewables consists of the same steps as for conventional energy.

1) Defining rate of return with the same formula (1) with the only difference, that basic return is set as 14% for projects that auctioned before 1.01.2015 and 12% for the rest.

2) The expense share is determined for the “average RE power generator” technology wise for each group of provisional supply points[1]. Expense share is calculated using the following formula:

$$S_i = \frac{Re_i}{12 * Rc_i}, \tag{7}$$

where S is preliminary share of expense;

Re is expected revenue from electricity sales;

Rc is expected revenue from capacity sales.

We would like to highlight that expected revenue from capacity sales Rc is determined in accordance with the next third step with following assumptions: expense share E equals to 1, capital expenditures $CAPEX$ are defined as weighted average of $CAPEX$ of bids submitted to the auction (technology wise). Hence, step 3 is repeated twice: first, for the ‘average

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[1] A group of provisional supply points is defined by SO and ATS in the Agreement for Accession to the Wholesale Market Trading System.

project' to calculate the expense share, and second, to calculate actual capacity price for a particular project.

Revenue from electricity sales is defined as follows:

$$Re_i = cf_i * hours * \left(\frac{P_i}{k} - C_{pr_i}\right), \tag{8}$$

where cf is a normative capacity factor (Table 6);

$hours$ is a quantity of hours in year i;

P is a day ahead electricity market price defined in (9);

k is a coefficient of power consumption for own needs that is 1.005 for all RE types;

Cpr is inflated cost of production initially defined for wind, solar, and hydro as 1, 1, and 10 rub/MWh correspondingly;

Day ahead electricity market price is forecasted for each group of provisional supply points as a weighted average prices through the whole previous year corrected on the growth rate using the following formula:

$$P_i = \frac{\sum_h \sum_q P_{q,h} * Prod_{q,h}}{\sum_h \sum_q Prod_{q,h}} * \prod_{Y=X}^{i} g_Y^C, \tag{9}$$

where h is an hour of previous year;

q is a group of provisional supply points;

$P_{q,h}$ is day ahead electricity price for a particular node hour;

$Prod_{q,h}$ is production volume for a particular node hour;

$g^C{}_Y$ is a forecasted growth rate of prices of gas (for the first price zone) or of coal (for the second price zone) for year Y;

To determine final expense share value for each year of the agreement, firstly, average of the same and next year preliminary expense share (7) is calculated, then, expense share for uneven years of contract duration equals to this average and for even years to the value of final expense share in the previous year.

3) Calculating capacity price component for renewables is logically similar to conventional energy calculation, but with some important differences.

Firstly, capital expenditures are not fixed, they are limited for each technology type and these limits decrease with growing commissioning year (Table 3) (Government of Russian Federation 2013a; Government of Russian Federation 2013b).

Table 3. CAPEX limit and OPEX normative.

Technology type	CAPEX limits, thous. rub./kW				OPEX norm, rub./kW pm
	2014	2015	2016	2017	
Wind	65.8	65.7	65.6	65.5	118
Solar	116.4	114.1	111.8	109.6	170
Hydro	146.0	146.0	146.0	146.0	100

Projects with CAPEX higher than these limits are not accepted to the bidding process. However, if planned CAPEX is lower, than this lower figure is taken into calculation of the capacity price. Hence, lower the CAPEX, less the capacity price that decreases incentives to reduce CAPEX. To keep this motivation among investors, CAPEX is set as an object of the bidding process. All projects are ranked in the order of increasing capital costs and only first projects with lower CAPEX that satisfy target selection volume become eligible for capacity agreements. Target installed capacity for each year is presented in the Table 4 (Government of Russian Federation 2013b).

Table 4. Target installed capacity, MW.

Technology type	2014	2015	2016	2017	Total 2014-2020
Wind	100	250	250	500	3,600
Solar	120	140	200	250	1,520
Hydro	18	26	124	124	751

There are two coefficients that are applied to planned CAPEX for the capacity price calculation. One of the most important coefficients is local content one that is based on achieving target localization requirement meaning acquiring services and equipment produced locally in Russia (Table 5) (Government of Russian Federation 2013a).

Table 5. Local content requirement.

Technology type	Target local content requirement				Coefficient	
	2014	2015	2016	2017	Target achieved	Target not achieved
Wind	35%	55%	65%	65%	1.00	0.45
Solar	50%	50%	70%	70%	1.00	0.35
Hydro	20%	20%	45%	45%	1.00	0.45

Similar to CAPEX limits, project will be rejected if planned localization is less than target. However, after the plant is built, there is a qualification procedure, that verifies achievement of the local content requirement. If it is not fulfilled, than the coefficient substantially decreases CAPEX in the calculation and consequently capacity price along the whole agreement duration.

The second coefficient applied to CAPEX is one reflecting profits from wholesale market after breakeven point and before service life end, which is fixed and equal to 0.90 for wind and hydro power, and 0.99 for solar.

Now adjusted CAPEX can be calculated similar to (2)

$$CAPEX_{adj} = CAPEX * E * (1 + R_{-1}) \tag{10}$$

where *CAPEX* is planned CAPEX multiplied by the two above mentioned coefficients;
E is expense share defined in step 2;
R_{-1} is *R* defined in (1) for $i=-1$.

Then adjusted CAPEX is converted to the annuity payments with variable interest rate. Principal payment and remaining principal are defined as follows (principal implies adjusted CAPEX):

$$Pp_i = \frac{Rp_i * R_{i-1}}{((R_{i-1} + 1)^{16-\mathrm{i}} - 1)}, \tag{11}$$

$$Rp_i = Rp_{i-1} - Pp_{i-1} + (R_{i-1} - R_{i-2}) * (1 + R_{i-1}) * Rp_{i-1}, \tag{12}$$

where Pp_i is principal payment;
Rp_i is a remaining principal, for $i=1$ $R_1=CAPEXadj$.

Capacity price component is defined as a sum of interest payment on before-tax principle and principle payment converted to monthly terms, and operating expenses adjusted on expense share:

$$CP_{comp} = \frac{Rp_i * \frac{R_{i-1}}{1 - r_{inc_{tax}}} + Pp_i}{12} + OPEX, \tag{13}$$

where *CPcomp* is capacity price component;

$rinc_{tax}$ is an income tax rate equal to 0.2;

OPEX is an inflation adjusted OPEX norm specified in Table 3 and multiplied by the expense share.

4) As for conventional energy, capacity price for renewables is defined as a sum of capacity price component calculated in step 3 and property tax expenses multiplied by the expense share defined in step 2, corrected on the fixed coefficient of energy for own needs:

$$CP = \left(CP_{comp} + \frac{T_{pr}}{12} * E\right) * k_2, \tag{14}$$

where *CP* is capacity price;

CP_{comp} is defined in (5);

T_{pr} is average property tax;

E is expense share defined in step 2;

k_2 is a coefficient of energy for own needs equal 1.005 for all types of RE.

Eventually there is last, but the most important load coefficient left. It is a final multiplier to capacity price for each year. Load coefficient heavily influences capacity price to ensure motivation to electricity production and prevent 'steel-in the ground' effect (Table 6) (Government of Russian Federation 2013a).

Table 6. Load coefficient formation.

Technology type	Normative capacity factor	Condition[2]	Load coefficient
Wind	27%	F <= 0.5N	0.0
Solar	14%	0.5N > F <=0.75N	0.8
Hydro	38%	F > 0.75N	1.0

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[2] F is factual average capacity factor achieved in the previous year and N is normative one.

If the capacity factor achieved in the previous year for e.g. a wind farm was less than 13.5% (=27%*0.5), capacity payments would turn to zero; if capacity factor was from 13.5% to 20.25% (=27%*0.75), capacity payments would be multiplied by 0.8; and only if capacity factor was higher than 20.25%, capacity payments would be paid in the full amount.

Thus, capacity price for renewables is defined in a more complex way than for conventional energy because of unfixed capacity costs, variable energy output and hence variable expense share for compensation, and finally due to two important coefficients: local content coefficient that reflects degree of using national equipment and services, and load coefficient that trigger electricity production.

Some other details of Russian capacity mechanism functioning might be found in IFC's work (International Finance Corporation 2013).

Next section presents modelling techniques applied to investment projects into wind, solar, and small hydropower to elucidate capacity mechanism effects on these investments.

4. MODELING RUSSIAN CAPACITY MECHANISM EFFECTS ON RE INVESTMENT PROFITABILITY

To address new policy effects from investors’ perspective it is essential to perform investment analysis. However, there is a number of ways to implement investment analysis, although all of them are more or less based on estimating cash flows generated by planning project. According to Graham’s and Harvey’s survey (2001) among US chief financial officers (CFO), more than 70% of respondents use net present value (NPV) and internal rate of return (IRR) as evaluation techniques. Both indicators can be calculated based on estimated project prospective cash flows and guide investors whether to invest, if NPV is positive and IRR is higher than minimum required return (e.g. cost of capital), or to reject it otherwise. In addition, based on the same cash flow estimation such indicators can be calculated as simple or discounted payback period and profitability index (PI) that appears to be less popular among CFOs (Graham and Harvey 2001). Importantly, all this indicators are derived from a single scenario project cash flows resulting from assuming future project environment to be certain, but it is not.

Various techniques can deal with uncertainty within investment analysis. Sensitivity analysis is recommended by specialists of the US National Renewable Energy Laboratory (NREL) (Short, Packey, Holt 2005) as a first step to address some kinds of uncertainty. It reveals project profitability (expressed in e.g. NPV) exposure to an investigating factor, for instance, prices or interest rates, therefore providing a perception of project efficiency variability. Presuming similar nature of all mentioned above efficiency indicators and counting them as one approach, sensitivity analysis is the second popular technique (Graham and Harvey 2001). Advanced approaches, such as simulation and real option analysis, were very rare among practitioners according to Graham and Harvey research (2001) and seem to remain unfamiliar to a lion share of business community. However, real option analysis receives more and more attention by academia, being developed and applied to numerous general as well as specific investment cases in different industries.

In this section, we demonstrate all mentioned techniques to address project profitability analysis under Russian capacity mechanism. Firstly, conventional NPV method is presented, where resulting crisp NPV along with IRR, PI and discounted payback period (DPP) are determinants of project profitability. Secondly, to enhance understanding of different factors influence on NPV we present sensitivity analysis. Both techniques are realized by means of

Microsoft Excel®. Thirdly, more comprehensive real option analysis is performed that allows incorporating uncertainty into the project valuation and recognizing managerial flexibility or real option within investment project that can enhance its value. Real option analysis is performed by using Datar-Mathews method based on Monte-Carlo simulation (Mathews, Datar, Johnson 2007) with Matlab Simulink®. Additionally, pay-off method based on fuzzy logic (Collan, Fullér, Mezei 2009) is demonstrated, that is realized with Microsoft Excel®. Finally, decision tree is presented that illustrates decision-making process.

To highlight specificity of capacity mechanism, all analyses are performed for two kinds of policies, first – capacity mechanism, and second – fixed feed-in premium. The latter is just a constant premium over the electricity price for all electricity produced by renewables. Comparing these supporting schemes let us emphasize important capacity mechanism features.

All calculation are done for three types of renewable energy technologies that supported by capacity mechanism, namely wind, solar, and small hydro (< 25 MW).

4.1. Conventional NPV approach

4.1.1. Method description

Rise of net present value method dates to times of Karl Marx (1894) and Irving Fisher (1907). More than a dozen years ago, almost every CFO relied on this method (Graham and Harvey 2001). Nowadays net present value (NPV) approach is an essential part of any corporate finance textbook and seems to be a common practice for valuation of any asset. It is widely used to value investment projects (Bas 2013; Gardiner and Stewart 2000), firms (Bao and Edmans 2011; Goldenberg et al. 2007), and can be applied to any asset valuation that generates some (incremental) cash flows or provides savings. Moreover, many investment analysis techniques, that are more sophisticated, are built on the top of discounted cash flow approach, for example, simulation, real options analysis or dynamic programming. Most modern investment analysis research cannot avoid using NPV approach as a basis for further analysis (Detert and Kotani 2013; Fuss and Szolgayová 2010; Martinez-Cesena, Azzopardi, Mutale 2013; Reuter et al. 2012a; Yu et al. 2006).

The idea behind NPV is simple and straightforward. First, one needs to estimate cash flows generated by e.g. investment project. Cash flows are defined in the following way based on projected revenues and expenses:

$$EBITDA = Revenue - OPEX, \tag{15}$$

where *EBITDA* is earnings before interest, taxes, depreciation, and amortization;
Revenue is a sum of project inflows from electricity sales and from the support scheme;
OPEX is operating expenditures.

$$EBIT = EBITDA - Depreciation, \tag{16}$$

where *EBIT* is earnings before interest and taxes;
EBITDA is a result of (15).

$$Net\ income = EBIT - taxes, \tag{17}$$

where *EBIT* is a result of (16);
taxes are tax expenses.

$$Cash\ flow = Net\ income - CAPEX + Depriciation, \tag{18}$$

where *Net income* is a result of (17);
CAPEX is capital expenditures.

After prospective cash flows are calculated, they are discounted back with required rate of return, often defined as weighted average cost of capital (WACC).

$$NPV = \sum_{i=1}^{T} \frac{Cash\ flow_i}{(1+r)^i} \tag{19}$$

where *NPV* is net present value;
Cash flow$_i$ is cash flow for year *i* calculated in (18);
r is discount rate;
T is project lifetime of an investment project.

Such logic lies behind the financial model built for the purposes of the current work.

4.1.2. Model specification and assumptions

Financial model is implemented in Microsoft Excel® and consists of three major blocks: capacity price calculation, cash flow calculation for an investment project under capacity mechanism and cash flow calculation for the same investment project but under feed-in premium scheme. Last two are different only by the source of revenues, under capacity mechanism there are electricity sales at the wholesale market price and capacity sales within DPM, whereas under feed-in premium there is only electricity sales but at the wholesale market price plus fixed feed-in premium. For the rest cash flow calculation for both schemes is the same and follows the logic described above with (15)-(19). In addition to NPV, we estimate internal rate of return (IRR), profitability index (PI) and discounted payback period (DPP).

Capacity payments are calculated in accordance with the legislation procedure (Government of Russian Federation 2013a; Government of Russian Federation 2013b) that is described in the part 33.2 with formulas (7)-(14). The only exception is defining electricity price, which is performed for each group of provisional supply points by formula (9), whereas we apply average day-ahead market electricity price forecasted as specified further.

Feed-in premiums are fixed for each technology type on a level that provides the same NPV as for capacity mechanism defined by using goal seek.

There are a number of assumptions made for project cash flow calculation. The project lifetime is 20 years plus 2 years of investment phase. Commissioning year is 2017 with electricity production start since the 1st of January. Capital expenditures are defined as weighted average of winning bids for commissioning year 2017 (Trading System Administrator 2014). For wind and solar it appears to be a little bit lower than the specified in Table 3 limit, 64909 and 108055 rub./kW correspondingly, and the same for small hydro, 146000 rub./kW. All CAPEX was divided into two phases: project development phase in 2015 accounted for 5% and construction phase in 2016 with rest 95% (UNEP and Aequero 2011). Taxes are calculated in accordance with Russian Tax Code, income tax rate is 20%, property tax rate is 2.2%, straight-line depreciation for the whole project lifetime is assumed. Operating expenses are defined as normative ones in accordance with Table 3. Similarly to capacity price calculation, OPEX is corrected on the change in consumer price index. Historical data on it are procured from Federal State Statistics Service (Federal State

Statistics Service 2014). Electricity prices used are average day-ahead market prices derived from Automated Information Data System on Electricity and Capacity Markets (NP Market Council 2014). Historical data on Russian 10-year bond yield or base rate is obtained from Investing.com database. All three variables, namely consumer price index, electricity price and base rate are projected till 2036 using linear regression (Table 7).

Table 7. Regression results.

Variable	Estimation period	Frequency	Alpha	Beta	R-squared
Electricity price	01.2009-04.2014	monthly	0.5953	0.0073	0.8231
Consumer price index	02.2002-04.2014	monthly	101.0663	-0.0037	0.0861
Base rate	03.2005-06.2014	monthly	7.2875	0.0092	0.0411

Although R-squared is high enough only for electricity price series, all results are accepted, since our goal is not a precise forecast, but estimation of project profitability. Variability of these parameters will be in some extend captured by sensitivity analysis and then by applying real option technique.

To demonstrate capacity mechanism impact on projects of all three technologies in equal conditions we set capacity factor as normative one (Table 6) that is achievable in accordance with resource maps (Figure 2 and Figure 3).

Balance sheet financing is assumed, so leverage effect is incorporated into cash flows by discounting them with WACC. Discount rate was defined based on data available in the Datastream for several biggest Russian energy generation companies, namely ‘Inter RAO’, ‘OGK 2’ owned by ‘Gazprom’, ‘E.ON’, ‘Enel’ and ‘RusHydro’, that together with state owned non-listed ‘RosAtom’ possess more than a half of all installed capacity in the country. Their weighted average cost of equity is estimated on the level of 15.7%, cost of debt is 9.5% and debt ratio is 40.5% resulting in total weighted average cost of capital equal to 12.4%. In general, Russian companies use single fixed discount rate for investment analysis. Moreover, fixed discount rate would allow catching the pure effect of changes in base rate that influence capacity price. Thus, fixed over time discount rate is an input into the calculation. As nominal cash flows are involved, discount rate is also nominal.

The next section describes sensitivity analysis method and its application to the build investment model.

4.2. Sensitivity analysis

4.2.1. Method description

Sensitivity analysis is applied to investigate influence of different factors on system performance indicators. It is widely used across different technical fields and it assimilated into investment analysis as well. Investors and project developers need sensitivity analysis results to reveal major risks and possible potential for project profitability.

Sensitivity analysis is a one of recommendations to address uncertainty linked to investment project profitability (Short, Packey, Holt 2005). In business, it is often used by CFOs to count for uncertain factors in investment analysis (Graham and Harvey 2001). It is also common in academia, including renewable energy analysis, to address e.g. efficiency variability of a solar PV power plant (Talavera, Nofuentes, Aguilera 2010) or a wind farm (Kaldellis and Gavras 2000).

The idea behind sensitivity analysis is simple: changing factors one by one and registering changes in the system performance indicator, in our case net present value.

4.2.2. Model specification and assumptions

Sensitivity analysis can be performed manually. However, with growing number of factors it becomes time consuming. For this reason, we have built macros to perform sensitivity analysis, which code is presented in Appendix 2. The macros changes each factor multiplier from 1.5 to 0.5 with step 0.1 (meaning changing each factor from 50% to 150% with 10% step), registering NPVs to a table in a Microsoft Excel® sheet after each change. Based on this table spider diagram is built.

For sensitivity analysis those factors are chosen that influence capacity price (Figure 8), in particular inflation, base rate, electricity price, CAPEX and capacity factor (localization coefficient may possess only values 1 or 2, thus it was excluded from sensitivity analysis). Additionally, sensitivity to OPEX is shown.

In the next section we switch to one of real options approaches, namely Datar-Mathews method.

4.3. Datar-Mathews method

4.3.1. Method description

Datar-Mathews method allows visualizing all probable project outputs that result from all possible combinations of changing input factors. It involves creation of a probability distribution of the project net present value by means of Monte Carlo simulation with randomized input variables. Further, managerial flexibility is captured and defined as real option to invest in a project. Since real option is a right but not an obligation, its value is recognized as probability weighted mean of the positive area of the distribution, multiplied by a ratio of positive to the whole area of the distribution.

Monte Carlo simulation itself is frequently used in academic papers to incorporate uncertainty into investment analysis and define real options within an investment project (Boomsma, Meade, Fleten 2012; Vogstad and Kristoffersen 2010; Yang et al. 2010; Yu et al. 2006). However, there is no consistence in research applied real option analysis, as each paper analyses different cases that represent specific real options requiring specific way to value them.

Scott Mathews form The Boeing Company, Vinay Datar from Seattle University, and Blake Johnson from Stanford University (2007) demonstrated relatively easy and intuitive approach to recognize real options in investment opportunities that was used by The Boeing Company. If project profitability distribution lies in both negative and positive sides (that is often the case), the negative part of the distribution implies losses and leads to a negative investment decision. However, if project can be managed in a way to get rid of the negative part of the distribution, or if external circumstances can possibly shift project profitability distribution entirely to the positive side, then there is a real option to invest. The value of such real option is defined as an expected mean of the positive area of the distribution weighted on a ratio of the positive area to the whole.

$$ROV = E_{+} * \frac{A_{+}}{A} \qquad (20)$$

where ROV is real option value;

E_{+} is expected mean of the positive side of the distribution;

A_+ is an area of the positive part of the distribution;
A is an area of the whole distribution.

It is important to mention that not each investment project, which has a part of profitability distribution in the positive area, has a real option. Real option is recognized only if it is possible to shift this distribution entirely to the positive side either by managing project internal factors or by waiting proper external circumstances.

The next section describes how the Datar-Mathews method is implemented for the current research.

4.3.2. Model specification and assumptions

Monte Carlo simulation is performed with Matlab Simulink® software. Figure 9 presents model overview. All input variables and their randomization are in the left hand side. We assume uniform distribution of random numbers within specified intervals. The assumptions are listed in Table 8. For simplicity, all variables are assumed equal through the time and independent from each other.

Table 8. Assumptions on fixed and random values of variables.

Variable	Fixed value	Interval of random values	
		Lower border	Higher border
Electricity price, rub/kWh	2	1	3
Consumer price index	1	1	1.7
Base rate	10%	8.5%	20%
CAPEX multiplier	1	0.8	1.5
Capacity factor multiplier	1	0.3	1.2
Localization	1	1 (fulfilled)	2 (not fulfilled)

Each input defined in Table 8 has manual switch from fixed value to random one. Feed-in premium is set on the level that provides the same NPV if all inputs are fixed.

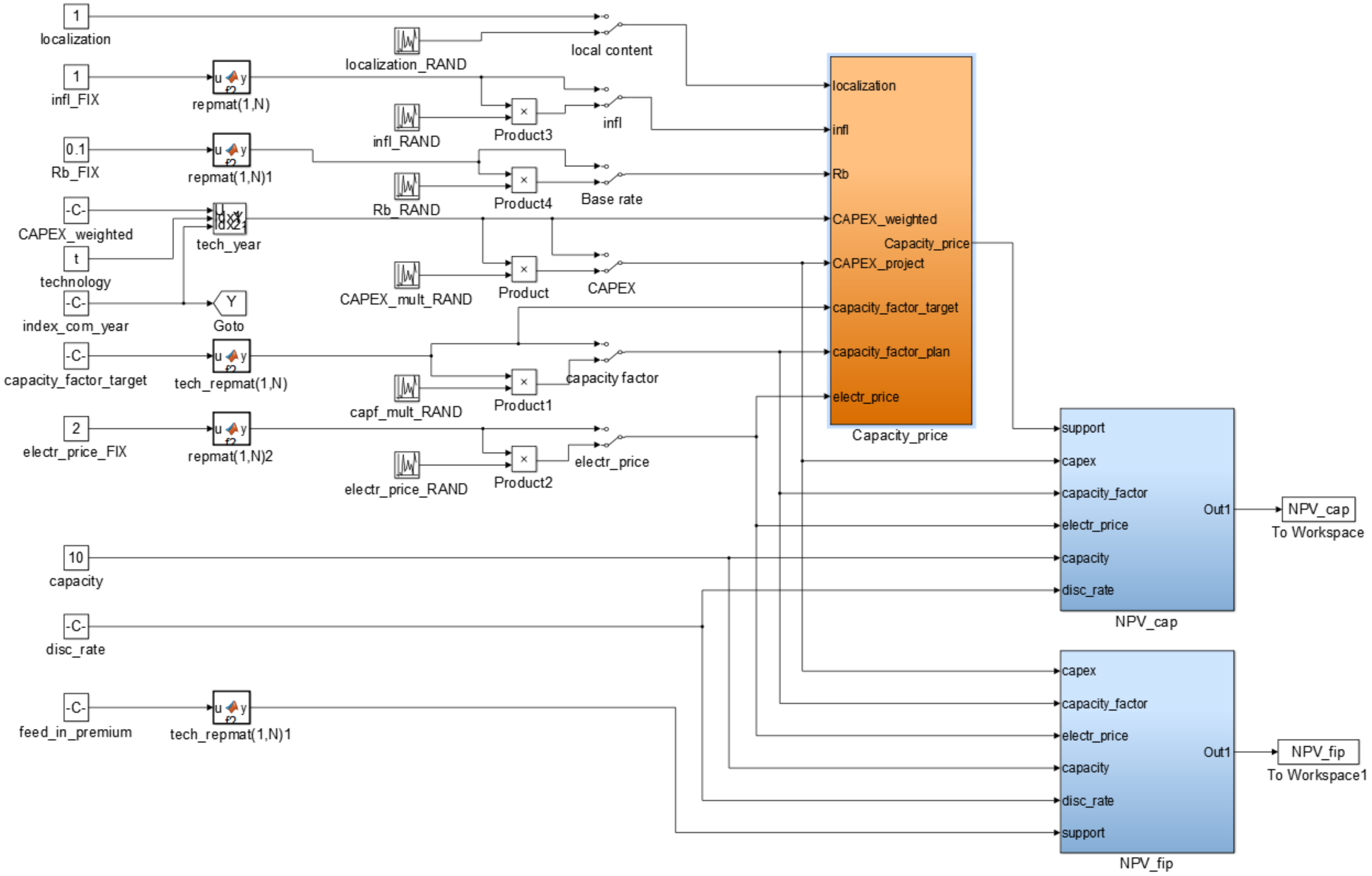

Figure 9. Model overview.

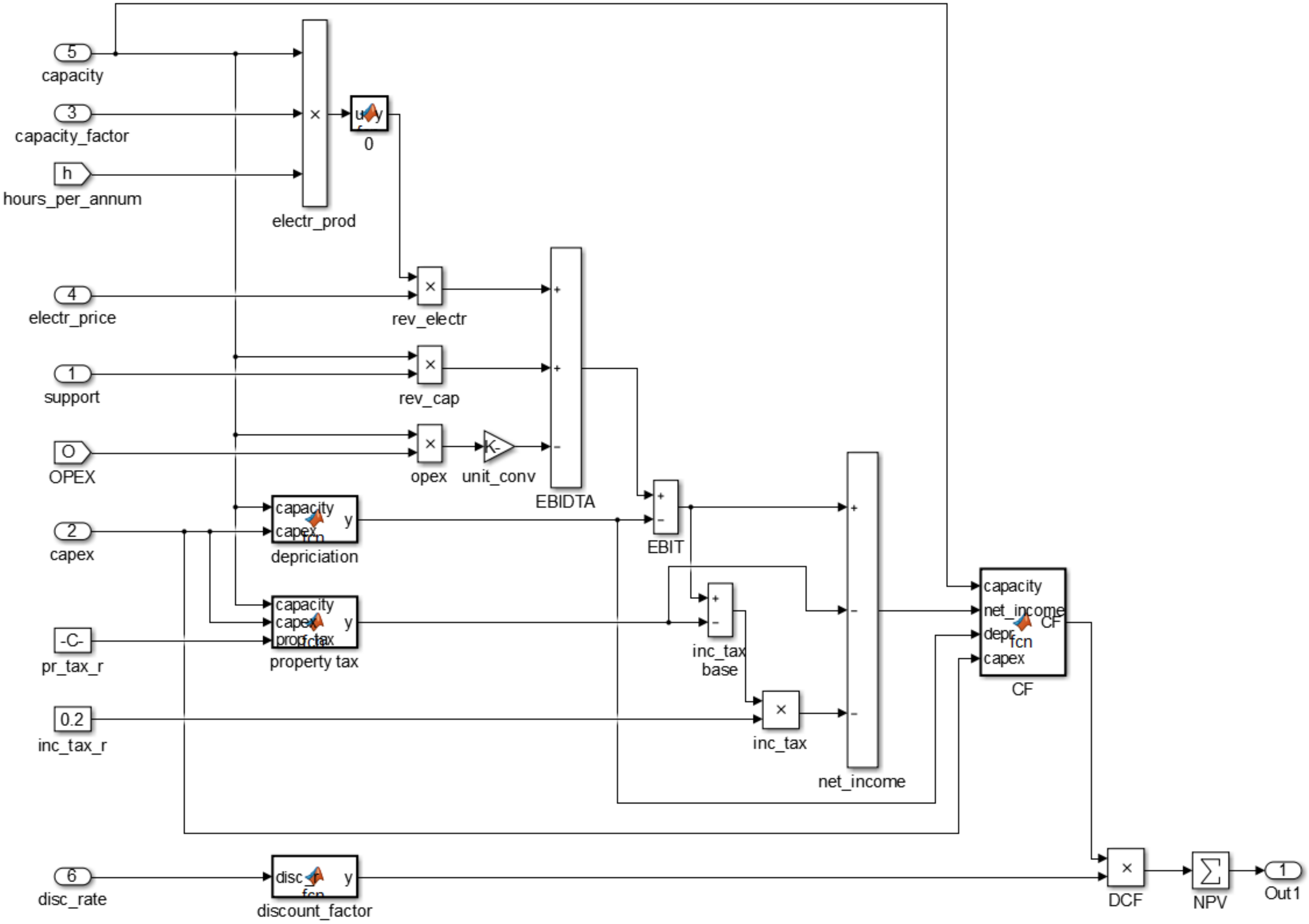

Figure 10. NPV block (for capacity mechanism).

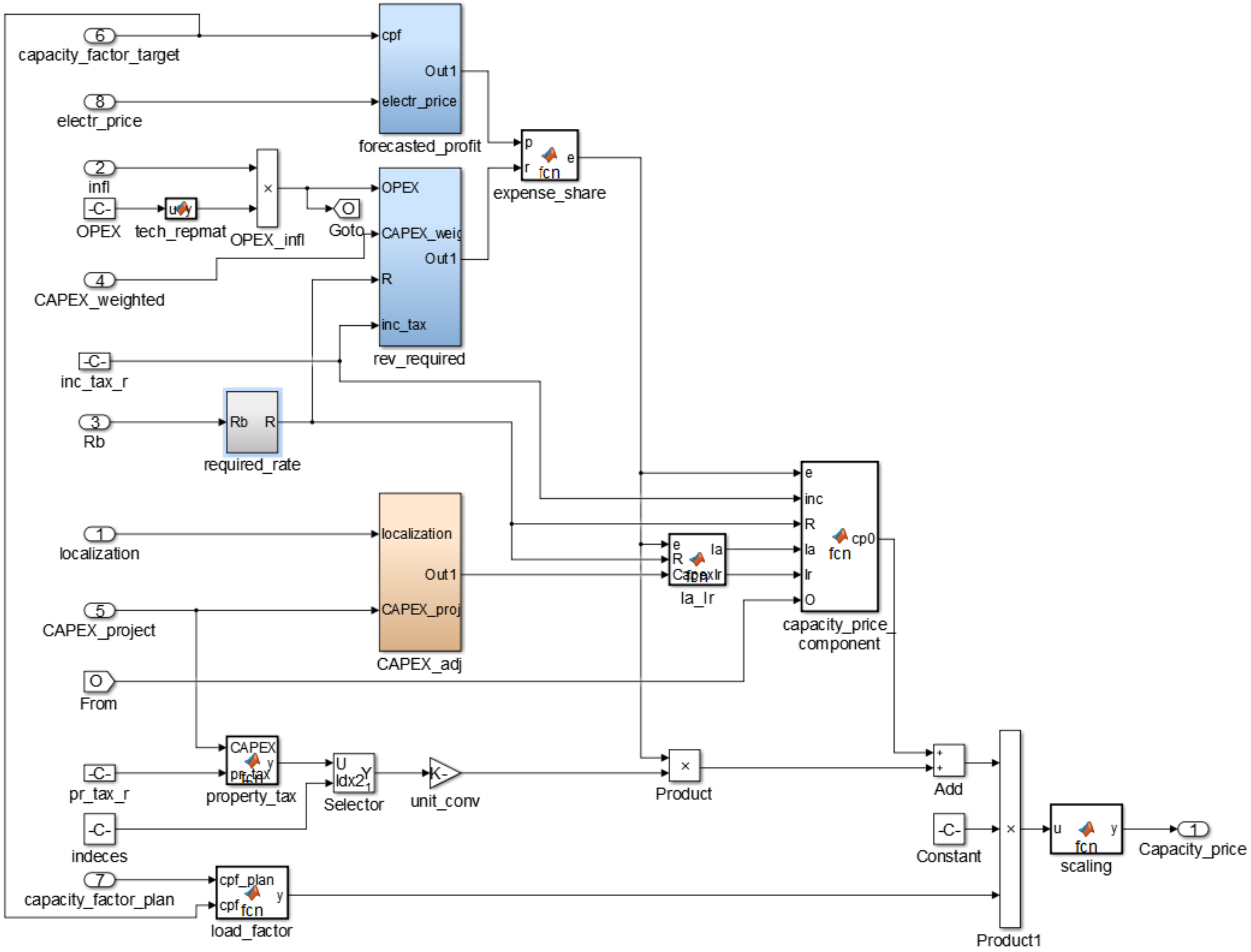

Figure 11. Capacity price block.

All calculations are performed in the three main blocks. Two blue blocks in Figure 9 are similar and calculate project NPV, one of them is presented in Figure 10. The only difference between them two is supporting mechanism. For feed-in premium scheme it is fixed feed-in premium, while for capacity mechanism it is capacity price calculated in the orange block, which is presented in Figure 11 in detail. Specifications for smaller blocks are provided in Appendix 4. The whole computational logic is the same as in previous Microsoft Excel® model. Capacity price is calculated in accordance with description provided in 3.2 and with formulas (7-14). Net present value calculation is described in 4.1.1 by equations (15-19). Simulink model computes NPV one hundred thousand times and exports two vectors with NPVs of a project under capacity mechanism and under feed-in premium to the Matlab workspace. There a function that builds frequency distribution is applied, which is specified at the end of Appendix 4. Real option value is defined in accordance with (20).

The next section presents another method of real options analysis.

4.4. Fuzzy pay-off method

4.4.1. Method description

Similar to the previous approach, pay-off method illustrates uncertain outcome as a distribution, but as opposed to Datar-Mathews method, this distribution is based on the fuzzy set theory (Collan, Fullér, Mezei 2009). Instead of running simulation 100,000 times to gain probability distribution, just three scenarios are often enough to build pay-off distribution: one realistic and two extreme scenarios – pessimistic (the minimum possible) and optimistic (the maximum possible). In this case, triangular distribution arises from assigning full possibility (membership degree = 1) to realistic NPV and zero possibility (membership degree = 0) to extreme NPVs (Figure 12). Thus, project net present value is not a single crisp number, but a fuzzy number. This appears to assist greatly any analysis on project valuation or their comparison, since two projects with the same crisp NPV (or realistic NPV) might possess distinct fuzzy pay-off distributions e.g. with different potential and risk.

Pay-off method was successfully applied to various problems such as pre-acquisition screening of target companies (Collan and Kinnunen 2011), patent analysis (Collan and Heikkilä 2011) and R&D selection (Hassanzadeh, Collan, Modarres 2012). Considering informativity on the one hand and simplicity in performance on the other, fuzzy pay-off method becomes an attractive analytical tool for our problem that can be used by any investor.

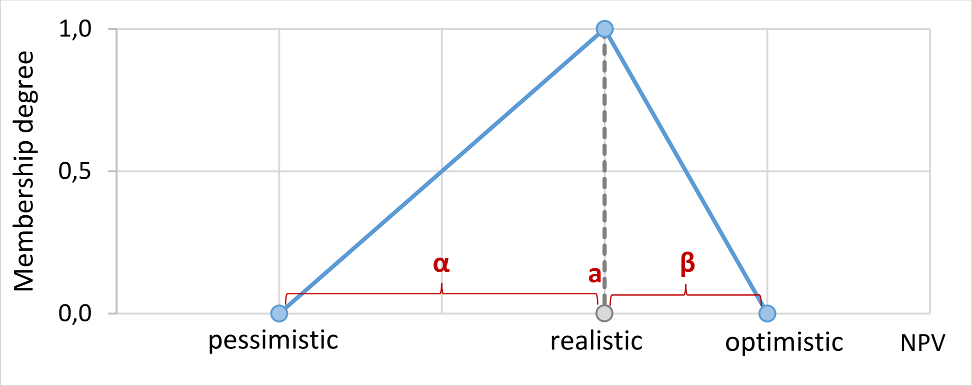

Figure 12. Classic triangular fuzzy pay-off distribution

Along with intuitively understandable visualization, fuzzy pay-off method offers some analytical values, such as:

- expected mean of the distribution that corresponds to weighted average NPV of probability distribution;
- standard deviation;
- success ratio, which is a ratio of positive area of the distribution to the whole;
- real option value, following the same logic, where real option value is an expected mean of the positive area weighted on success ratio.

These measures are calculated in a following way depending on the distribution position relative to zero:

- When the whole distribution is in the positive zone:

$$E(A) = E(A^{+}) = a + \frac{\beta - \alpha}{6}, \tag{21}$$

where *E(A)* is expected mean of the whole distribution;

$E(A^{+})$ is expected mean of the positive area of the distribution;

a is realistic NPV;

α is a distance between realistic and pessimistic NPV (Figure 12);

β is a distance between realistic and optimistic NPV (Figure 12).

$$A^{+} = A = \frac{(\alpha + \beta) * 1}{2}, \tag{22}$$

where A^{+} is positive area of the triangle;

A is the whole area of the triangle;

$\alpha+\beta$ is width of the triangle, and *1* is its height.

- If zero lies between pessimistic and realistic NPV:

$$E(A^{+}) = a + \frac{\beta - \alpha}{6} + \frac{(\alpha - a)^{3}}{6\alpha^{2}} \tag{23}$$

$$A^{+} = \frac{\alpha + \beta}{2} - 0.5 * |a - \alpha| * h_0, \tag{24}$$

where h_0 is membership degree of zero NPV:

$$h_0 = \frac{|a - \alpha|}{\alpha} \tag{25}$$

- If zero lies between realistic and optimistic NPV:

$$E(A^{+}) = \frac{(\alpha + \beta)^{3}}{6\beta^{2}} \tag{26}$$

$$A^{+} = 0.5 * (a + \beta) * h_0, \tag{27}$$

where

$$h_0 = \frac{\alpha + \beta}{\beta} \tag{28}$$

- If the whole distribution lies below zero:

$$E(A^{+}) = 0 \tag{29}$$

$$A^{+} = 0 \tag{30}$$

After positive area and its expected mean are calculated, we can compute real option value and other statistics:

$$ROV = E(A^{+}) * \frac{A^{+}}{A} \tag{31}$$

$$Success\ ratio = \frac{A^+}{A} \tag{32}$$

$$Standard\ deviation = \sqrt{\frac{(\alpha + \beta)^2}{24}} \tag{33}$$

Derivations and detailed explanations to presented equations might be found in papers by Collan et al. (2009) and by Carlsson and Fullér (2001).

4.4.2. Model specification and assumptions

All calculations are performed with Microsoft Excel® based on the already built model for initial project valuation that described in the section 4.1. Scenario manager is created on the one of model sheets, where one can assign different parameter values to each scenario, computing NPV for both supporting scheme and all three technologies. Based on those NPVs pay-off distributions are built and descriptive statistics are calculated.

Building pay-off distribution one should clearly understand influence of different factors in order to set parameter values for scenarios correctly. To be able to present all possible NPVs within a single triangular distribution, factors should influence NPV linearly. This is true for feed-in premium scheme, but appears not to held for capacity mechanism. Three factors shape NPV in discreet manner. First is localization requirement, that might be fulfilled or might be not. However, in this case we can assign failed localization target to pessimistic scenario and fulfilled one to realistic and optimistic. The same occurs with CAPEX that shapes NPV differently if it is higher than limit. This can be also represented by one distribution if we assign CAPEX multiplier to one for realistic scenario, higher than one to the pessimistic and lower than one to the optimistic. However, load coefficient that reflects production performance divides possible NPV distribution into three different levels with load coefficient equal to 0, 0.8 and 1 that is a final multiplier to capacity price (Table 6). Thus, a logical solution is to depict that as three pay-off distributions.

To keep the narration logic we first will present pay-off distributions when all factors are variable except the base rate. Then we will show influence of fulfilling localization requirement and keeping capital costs within limits. After production performance will be set to at least 75% of target one. Finally, influence of base rate change will be demonstrated. Parameter values for each scenario are shown in Table 9.

Table 9. Scenario specification for fuzzy pay-off method.

Parameter	Case 1. All factors variable except the base rate								
	Distribution 1			Distribution 2			Distribution 3		
	Pess.	Real.	Opt.	Pess.	Real.	Opt.	Pess.	Real.	Opt.
External factors									
Electricity price	1	2	3	1	2	3	1	2	3
Cons. price index	1.7	1.35	1	1.7	1.35	1	1.7	1.35	1
Base rate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Internal factors									
CAPEX multiplier	1.5	1	0.8	1.5	1	0.8	1.5	1	0.8
Localization	2	1	1	2	1	1	2	1	1
Capacity factor multiplier	0.300	0.400	0.500	0.501	0.625	0.750	0.751	0.975	1.200
	Case 2. All factors variable except the base rate CAPEX within limits, localization is fulfilled								
	Distribution 1			Distribution 2			Distribution 3		
	Pess.	Real.	Opt.	Pess.	Real.	Opt.	Pess.	Real.	Opt.
External factors									
Electricity price	1	2	3	1	2	3	1	2	3
Cons. price index	1.7	1.35	1	1.7	1.35	1	1.7	1.35	1
Base rate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Internal factors									
CAPEX multiplier	1	1	0.8	1	1	0.8	1	1	0.8
Localization	1	1	1	1	1	1	1	1	1
Capacity factor multiplier	0.300	0.400	0.500	0.501	0.625	0.750	0.751	0.975	1.200
	Case 3. Previous + capacity factor 75-120%			Case 4. Previous + base rate variable					
	Pess.	Real.	Opt.	Pess.	Real.	Opt.	-	-	-
External factors									
Electricity price	1	2	3	1	2	3	-	-	-
Cons. price index	1.7	1.35	1	1.7	1.35	1	-	-	-
Base rate	0.1	0.1	0.1	0.085	0.15	0.2	-	-	-
Internal factors									
CAPEX multiplier	1	1	0.8	1	1	0.8	-	-	-
Localization	1	1	1	1	1	1	-	-	-
Capacity factor multiplier	0.751	0.975	1.200	0.751	0.975	1.200	-	-	-

For all scenarios electricity price and consumer price index vary in the same way. Base rate is constant for all scenarios except the last one. CAPEX multiplier is from 1.5 to 0.8 for the first three distributions and from 1 to 0.8 for the rest. Localization requirement is not fulfilled (value 2) only for pessimistic scenarios of the first case. Capacity factor multiplier is set in accordance with load factor formation so that for each distribution will reflect a single value of this coefficient. For the feed-in premium scheme, all the same inputs are applied with the only exception, that there is no need to divide resulting distribution into three parts, so for the first and second cases scenarios are as follows: pessimistic is pessimistic from distribution 1, realistic is realistic from distribution 2 and optimistic is optimistic from distribution 3. All extreme values are chosen as limits of random number intervals for Monte Carlo simulation (Table 8) to provide compatibility of the methods.

The final subsection of the modelling part of this study presents the decision tree approach.

4.5. Decision tree

4.5.1. Method description

Decision tree is a common method to navigate investors illustrating decision-making process shaped by the most influential factors. Nodes of decision tree can represent either a managerial choice or states of external environment that shapes further decisions and project profitability. Thus, decision tree is an investment roadmap that illustrates main possible scenarios and their interconnections.

According to the research of Dutch companies (Verbeeten 2006), decision tree is often use as a complementary technique to investment analysis. In the academic literature decision tree is applied to various problems e.g. R&D projects (Sohn and Moon 2004), evaluation of energy efficiency measures (Mikučionienė, Martinaitis, Keras 2014), business-to-consumer control applications (Lee 2010), or capacity planning in automotive industry (De Reyck, Degraeve, Vandenborre 2008).

In the current thesis, decision tree is built in Microsoft PowerPoint® based on the results of previous analysis.

Next section presents the results of all described above methods applied to investment projects in wind, solar and small hydropower under Russian capacity mechanism in comparison with feed-in premium scheme.

5. RESULTS

5.1. Conventional NPV approach

Table 10 presents results of capacity price calculation for the year 2017. As we can see from the table wind power receives the least capacity payments, which is due to combination of relatively high comparing to solar capacity factor (line 1) and relatively low to both solar and hydro CAPEX per kW (line 2). Thus, wind power project has less investment costs to cover with supporting scheme and relatively high production performance to benefit from electricity sales. Comparing to wind power, solar has lower capacity factor that leads to lower profit from electricity sales (line 5), together with substantially higher CAPEX it needs higher revenues (line 6) resulting in very high share of expenses to compensation - 93% (line 7). Although hydro power has the highest capacity factor, it simultaneously has greatly higher CAPEX, consequently having the highest capacity price.

Table 10. Capacity price and interim parameters for the year 2017.

#	Parameter	Wind	Solar	Hydro
1	Normative capacity factor	27%	14%	38%
2	Total planned Capex, thous. rub./kW	64 909	108 055	146 000
3	Opex, rub./kW month	161	232	137
4	Property tax expenses, rub./kW year	1 392	2 318	3 132
5	Forecasting profit from electricity sales, rub./kW year	3 150	1 633	4 393
6	Required revenues, rub./kW year	14 820	24 239	30 626
7	Share of expenses to compensation	78%	93%	85%
8	Capacity price rub./kW month	977	2 053	2 203
9	Capacity price rub./kW year	**11 721**	**24 639**	**26 432**

Considering these results from a different angle, wind power requires less public support accounting for approximately 78% of capacity payments in revenue structure followed by small hydro power with 85%, but with the highest capacity price due to huge initial costs, and closing this list by solar power, which requires 93% of capacity revenue.

The same results of capacity price should be anticipated neither for different years, nor for the same years of projects with different commissioning date, nor for the similar projects in different places, as ATS calculates forecasting profit from electricity sales differently for each group of provisional supply points of wholesale market individually for each project under the DPM.

RE project profitability analysis shows following results:

Table 11. Effectiveness measures of RE projects under capacity mechanism (CM) and feed-in premium (FiP).

	Wind		Solar		Hydro	
	CM	FiP	CM	FiP	CM	FiP
NPV, thous. rub.	34 081	34 081	104 303	104 303	63 322	63 322
IRR, %	13.4%	13.3%	14.4%	14.1%	13.3%	13.2%
PI	1.05	1.05	1.10	1.10	1.04	1.04
DPP, years	16	19	13	16	16	19

In general, results seem favourable, as NPVs are positive and IRRs are higher than discount rate (12.4%). However, profitability indexes are not much higher than one and payback periods are quite long, that might be affordable only for large institutional investors in the energy sector.

Importantly, capacity mechanism does not provide the exactly same returns for different technology type projects. Partly it is caused by different distribution of cash flows along the project lifetime, partly by setting different values for coefficients in the capacity price calculation.

Projects under capacity mechanism and feed-in premium have the same NPVs, as it was orienting point to set feed-in premium size. Oppositely, IRRs under FiP are lower and payback periods are longer. Capacity mechanism provides the whole support within 15 years of DPM tenor, whereas feed-in premium is assumed to be paid during 20 years. Hence, a project under capacity scheme is paid back sooner and has higher internal rate of return.

Nevertheless, these figures hardly can provide the full picture of the project profitability, since no inputs into the cash flow calculation are certain, and their change will lead to change in project effectiveness. Moreover, this analysis does not reveal any serious difference between two schemes. First step to deeper understanding of supporting scheme effects on the project profitability is sensitivity analysis.

The next section presents results of sensitivity analysis.

5.2. Sensitivity analysis

In terms of NPV sensitivity all three technologies represent almost the same picture. In the text wind power case is explained (Figure 13), while similar diagrams for solar and small hydro power might be found in the Appendix 3.

The left hand side of Figure 13 demonstrates NPV sensitivity to various factors under capacity mechanism, whereas its right hand side shows the same project under feed-in premium scheme. At a glance left diagram looks more compact, lines are lying closer to the center representing less potential (area above the base NPV 34.1 mln. rub.) and less risk (area below the base NPV). The ways all this factors influence project NPV through the capacity payments are summarized in Table 12.

Table 12. Capacity mechanism effects on project NPV in comparison with feed-in premium scheme.

Factor	Influence on project NPV
Electricity price	Compensation effect. NPV sensitivity almost flattens.
Inflation	Compensation effect. NPV sensitivity almost flattens.
Base rate	NPV becomes sensitive to the base rate due to capacity price formation, while discount rate is fixed.
CAPEX	CAPEX increase over the limit leads to the same severe NPV fall, but project potential with CAPEX shrinking is reduced.
Capacity factor	Risks of capacity factor decrease are partly softened, but in extreme cases NPV falls even lower. Possible potential due to capacity factor increase is reduced.
OPEX	Sensitivity to OPEX is minor and does not change.
Discount rate	High sensitivity to discount rate remains slightly changed.
Localization	Nonfulfillment of local content requirement makes investments irreversibly sunk.

Further we examine each factor one by one.

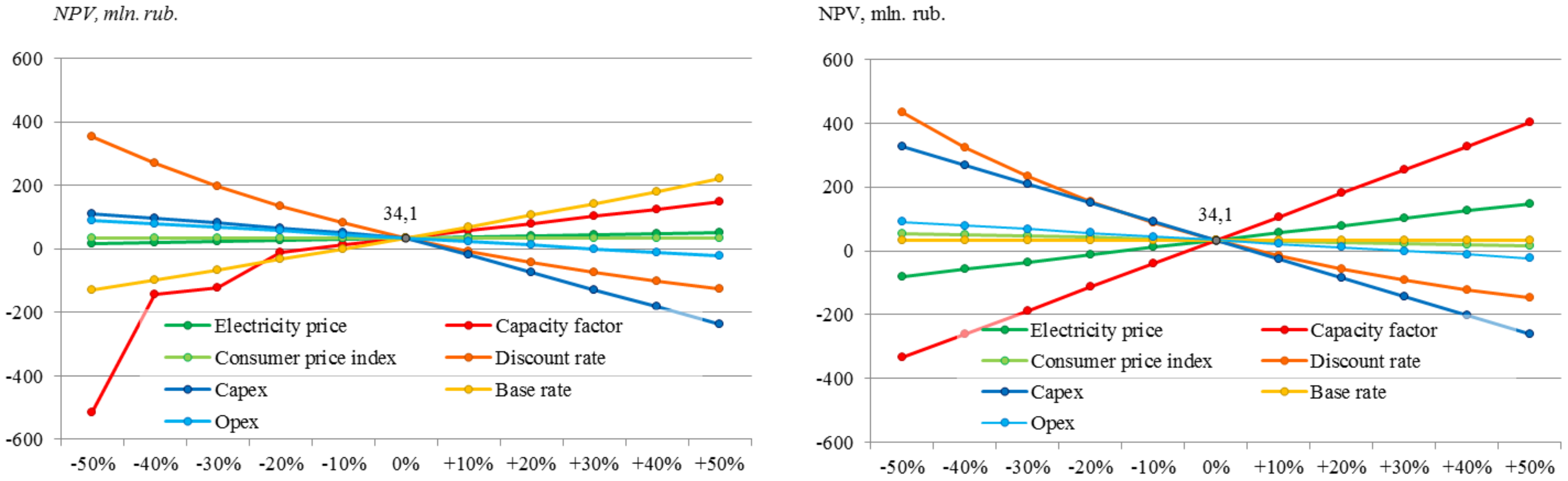

Figure 13. Project NPV sensitivity analysis under capacity mechanism (left diagram) and feed-in premium scheme (right diagram).

Electricity price directly affects revenue from electricity sales. For the project under feed-in premium scheme (FiP project) electricity price plays moderate role, since level of feed-in premium is fixed and independent from electricity price. In contrast, project under capacity mechanism (CM project) NPV sensitivity to electricity price is very low, its changes are almost fully offset by corresponding capacity payments. In case of electricity price increase, revenue from electricity sales grows, but capacity payment calculation reflects this change and decreases, balancing total income. As a result, project under capacity mechanism has considerably lower sensitivity to electricity price comparing with project under feed-in premium scheme.

The same occurs with ***inflation*** introduced by consumer price index, feeding project cash flows through operating expenses. Overall, it has minor effect on project NPV comparing to other factors for both projects. Nevertheless, NPV sensitivity to inflation is much lower in CM project, caused by capacity payment offsetting effect. In accordance with calculations, 50% increase in consumer price index leads to just 4% shrink in CM project NPV and 60% fall in FiP project NPV. It means that inflation should be considered as an important factor for project viability under feed-in premium scheme, but can be neglected under capacity mechanism.

Base rate has no influence on NPV of FiP project, because it simply does not feed calculations anyhow. However, it is a main input to capacity price formation (1). Base rate increase causes capacity payments growth and vice versa. As discount rate is fixed, it is the only effect that shapes NPV sensitivity. Base rate growth leads to capacity payments rise that boosts NPV of project under capacity mechanism, but remains NPV of project under feed-in premium scheme unchanged.

Initial ***capital costs*** are expected to be one of the most influential factors for capital intense renewable energy projects. And it is so for FiP project, where CAPEX weighting poses a great risk for project effectiveness and at the same time provides a large potential by cutting CAPEX. CM project NPV has the same sensitivity to CAPEX in case of its increase. However, CAPEX shrinking leads to the substantially less potential. CAPEX is a subject to capacity payment calculation with a cap (Table 3). Its increase over this limit does not affect capacity price imposing downward pressure on project NPV. But CAPEX decrease leads to capacity price lowering (10). Therefore CAPEX weighting over the limit set by capacity mechanism leads to the same amplitude of project NPV fall as for feed-in premium, but cost savings result in lower gain under capacity mechanism comparing with feed-in premium scheme.

Capacity factor as a production performance measure plays pivotal role in renewable energy project efficiency, because electricity production might fluctuate heavily following changes in resource availability. For FiP project it is the most crucial factor, which in case of halving capacity factor from 27% to 13.5% causes 370 mln. rub. loss and in case of 50% increase leads to the same amount of gain. Remarkably, CM project NPV sensitivity to capacity factor is presented by a broken line, three levels of which correspond with three possible values of load coefficient (Table 6) that leads to three different capacity price profile and thus three different NPV levels. The slope of each level arises from growing revenue from electricity sales with increasing capacity factor, while capacity price remains unchanged. In comparison, under feed-in premium scheme this slope is higher, as the whole cash inflow grows with increasing electricity production. As the result, capacity mechanism considerably reduces possible project potential with capacity factor increase comparing with feed-in premium scheme, but leaves penalizing effect to poor production performance.

Operating cost sensitivity line is precisely the same for both cases. Renewable energy projects have substantially lower OPEX comparing to conventional energy projects. This explains minor sensitivity to inflation that affects project cash flows only through OPEX. Capacity mechanism does not affect sensitivity to it enabling investors benefit from operating cost reduction.

Although both projects represent similar high sensitivity to ***discount rate***, there is a huge difference, since for CM project it is the only factor that reveals such a great potential in project profitability, while in FiP project one can gain the same potential by cutting CAPEX or by better plant allocation that would increase capacity factor. This makes project financing issues much more important under capacity mechanism.

Finally, there is one prominent factor left that is not presented in the sensitivity analysis since it cannot be measured in percent change terms. It is ***local content requirement*** presented in the Table 5. If there is not enough equipment and services produced locally, capacity price almost halves for the whole DPM tenor. CM project NPV falls to around -185 mln. rub. and almost whole ‘spider’ of sensitivity diagram lies below zero making project irreversibly sunk.

Overall, external factors such as electricity price and inflation are almost fully offset by capacity mechanism and do not impose any risk or potential to the project. Appearing sensitivity to base rate reveals opportunity to keep ability of a project to repay floating-rate debt at any levels of prime rate[3] and to provide shareholders with higher return in crisis time. Capacity mechanism differently treats internal factors that can be controlled by project management. They include capacity cost, capacity factor and localization. Capacity price ensures stable return on investment if those factors are managed properly, meaning CAPEX within limits (Table 3), average capacity factor more than 75% from target one (Table 6) and fulfilling local content requirement (Table 5). Otherwise, capacity price falls leaving

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[3] In Russia, prime rate (MOSPRIME) and base rate (yield of long-term government bonds) have correlation about 80% based on 02.2007-01.2014 period.

project unprofitable. As the result, capacity mechanism makes project profitability almost undependable from external factors and sensitive to internal ones.

Using sensitivity analysis one can get a good perception of different factors influence on project profitability, but each factor effect is considered separately. We cannot examine effect of combination of factors, thus there is no possibility to get the full picture of project profitability. Next section presents Datar-Mathews method, which incorporates Monte Carlo simulation of all probable project outputs and real option thinking.

In the next section, the results of real options analysis approached with Datar-Mathews method are presented.

5.3. Datar-Mathews method

Resulting pay-off distributions for the same projects under different support schemes, when all factors are random in accordance with Table 8 except base rate, are presented in Figure 14, where left graph corresponds to the project under capacity mechanism and right graph to the project under feed-in premium. In the text we elaborate only wind power plant case, while the same graphs for solar and small hydro are presented in Appendix 5.

Mean of the distributions is marked with red dashed line and real option value with green one. At a glance, we can see that bigger part of both distributions lies below zero that together with negative weighted mean indicates huge risk exposure of the projects, however, based on these graphs we cannot figure out what factors contribute to it. Anyway, both projects have some real option value and we can further analyze whether it is possible to exploit it.

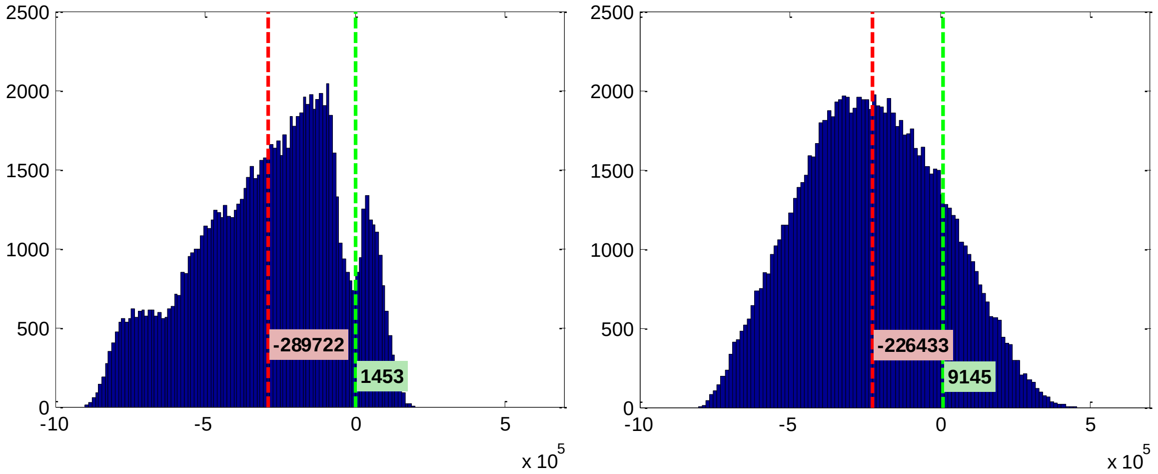

Figure 14. Pay-off distribution of projects under CM (left) and FiP (right), thous. rub. All factors random except base rate.

By switching off random factor one by one, we can obtain the full picture of different factors influence on the pay-off distribution. Since only internal factors are manageable, it makes sense to see how gaining control over them would shape pay-off distribution.

Firstly, we set localization requirement as certainly fulfilled (Figure 15).

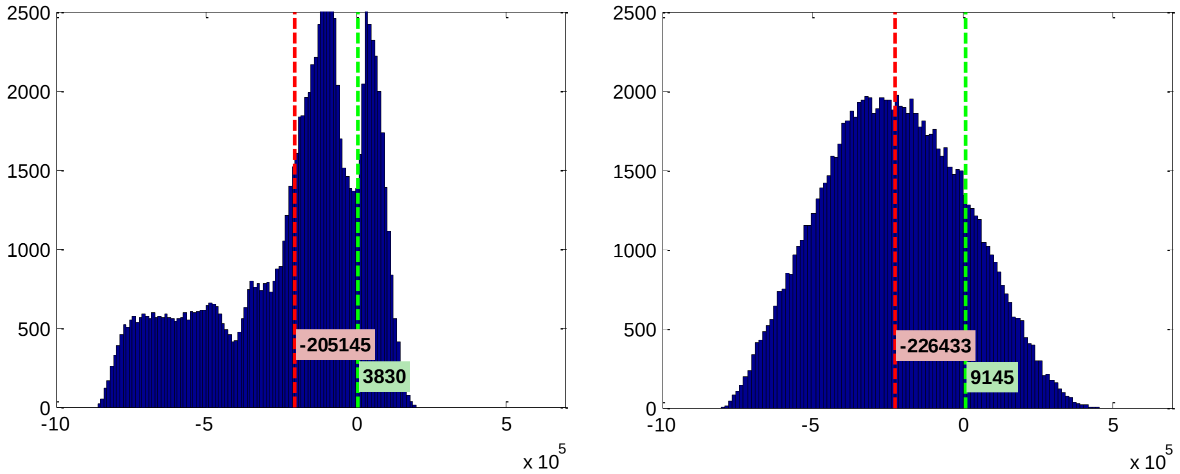

Figure 15. Pay-off distribution of projects under CM (left) and FiP (right), thous. rub. Localization is fulfilled.

It does not change project under feed-in premium scheme (FiP project) distribution as there is no such requirement assumed, but project under capacity mechanism (CM project) distribution becomes more ridged and concentrated closer to the positive side.

Next, capital costs can be controlled not to exceed limit. Keeping localization requirement fulfilled and letting CAPEX vary only to the decreasing side from 100% to 80% (instead of 150% - 80%) we obtain the following picture (Figure 16). Left side of the FiP project

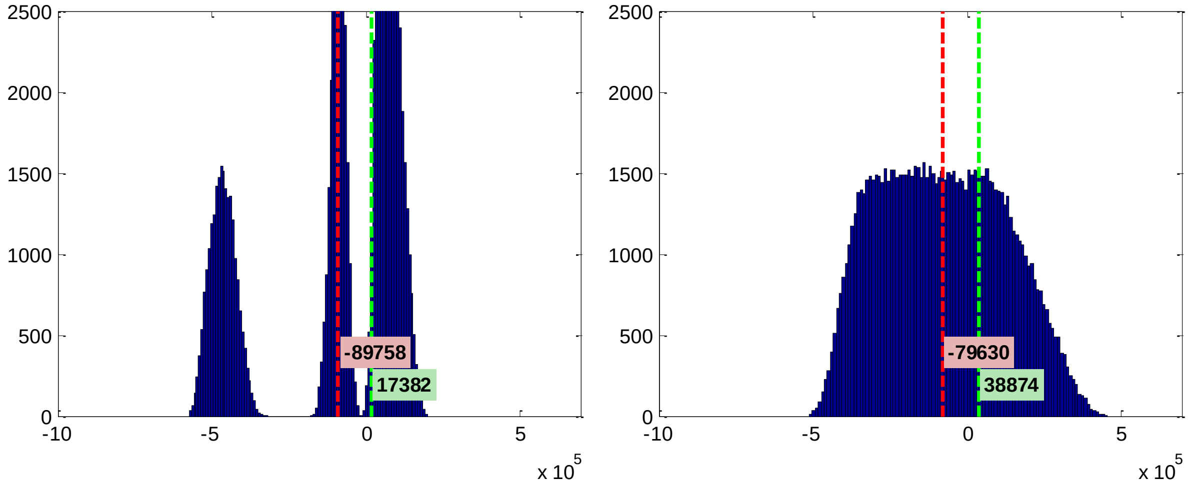

Figure 16. Pay-off distribution of projects under CM (left) and FiP (right), thous. rub. Localization is fulfilled, CAPEX 80-100%.

distribution predictably shifts to the right. However, CM project distribution now is divided into three separate parts, reflecting three levels of load coefficient that represents production efficiency. These three intervals of capacity factor, particularly 8-13%, 14-20% and 21-32%, reflect locations with different climate conditions, roughly an equivalent of average wind speed 4-5 m/s, 5-6 m/s, 6-7.5 m/s.

Obviously, in case of project under capacity mechanism we can easily get rid of two negative peaks of distribution by locking in good location for a wind farm. By keeping all previous preferences and changing capacity factor random multiplier from 30-120% to 75.1-120% we acquire following distributions (Figure 17). Now CM project pay-off distribution is represented by only a narrow peak almost fully positioned in the positive area. It happens because of capacity price that offset changes in external factors. It means that by managing project internal factors investor can limit all possible outputs within positive zone, implying no risk at all even considering unmanageable and unpredictable external factors. He or she needs to lock in an appropriate location and wait until local content requirement might be achieved and all equipment might be bought within CAPEX limit. This strategy would guarantee positive net present value of the project. However, it is not the case for the project under feed-in premium, where even after pushing all internal factors into optimal zone, there is still a large share of the pay-off distribution in the negative area. Thus, we cannot apply real option logic to this case, since there is no proper circumstances to exercise the option, there will be always a lot of risk coming from external factors that shape project profitability along the whole project lifetime.

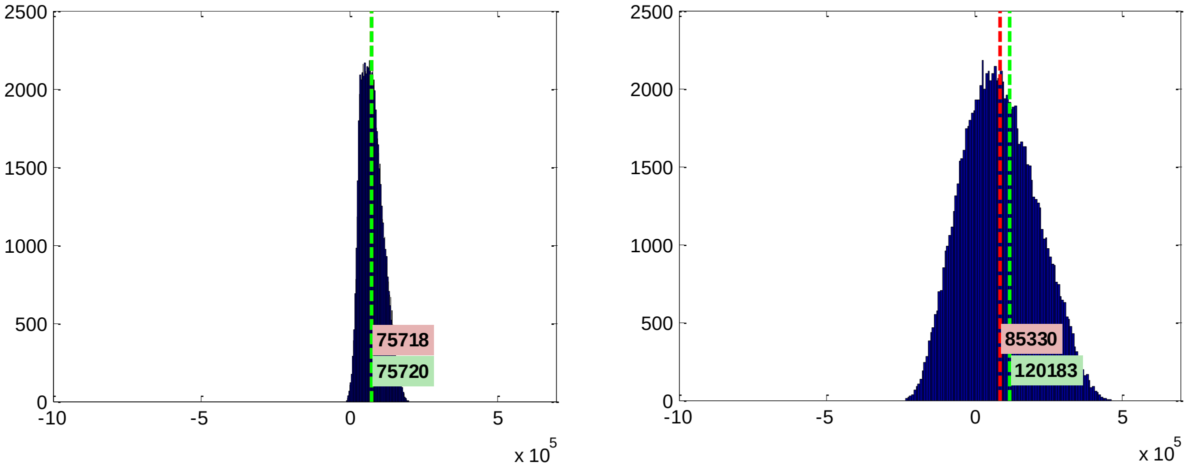

Figure 17. Pay-off distribution of projects under CM (left) and FiP (right), thous. rub. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target.

Eventually, we can observe influence of base rate that has no effect on FiP project, but appears to be an input to capacity price calculation (Figure 18).

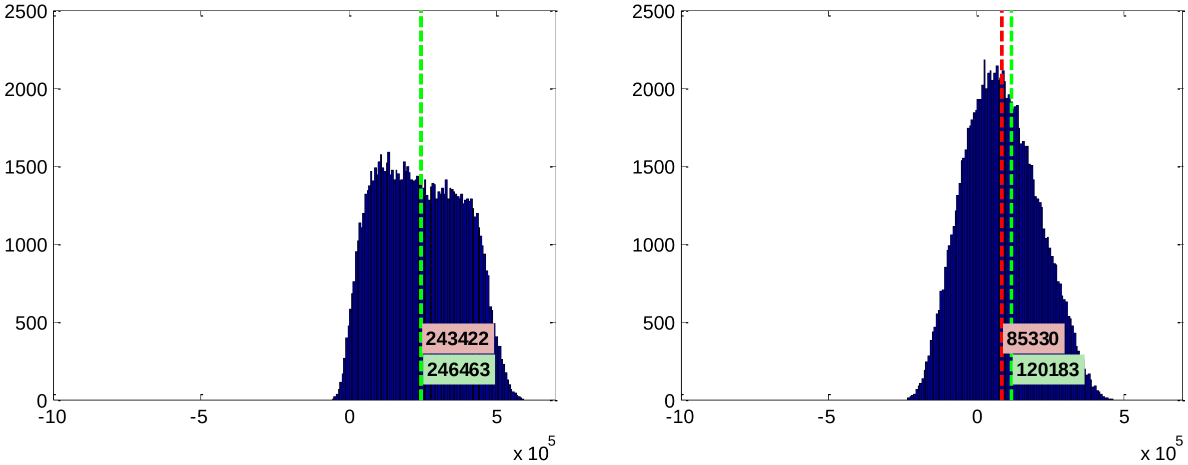

Figure 18. Pay-off distribution of projects under CM (left) and FiP (right), thous. rub. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target, base rate 8.5-20%.

Changing base rate from fixed value at 10% to random between 8.5-20% results in expanding CM project pay-off distribution mostly to the right side. Importantly, it does not mean that one can expect so broad distribution of outcomes with uncertain base rate, but it does mean that increase in base rate directly leads to increase in project NPV. It makes repaying floating debt possible in crisis circumstances. To illustrate relevance of this policy feature, average first half of 2014 base rate was 8.5%, afterwards it has soared reaching more than 15% in January 2015. All committed RE projects after capacity auctions in 2013 and 2014 are still able to meet their obligations and reach expected financial indicators in spite of the crisis.

Project under feed-in premium output does not go along with base rate, leaving project profitability to a chance.

Table 13 provides comparison of Datar-Mahews method results for different technologies. Apart from real option value and weighted mean of the whole distribution it contains also two risk measures: standard deviation (the bigger, the worse) and success ratio or ratio of positive area to the whole area of the distribution (the closer to 100%, the better).

Table 13. Comparing Datar-Mathews method results for different technologies, mln. rub.

		All factors random except base rate (Figure 14 for wind)		Internal factors are managed (Figure 17 for wind)	
		CM *(1)*	FiP *(2)*	CM *(3)*	FiP *(4)*
wind	Real option value	1	9	76	120
	Weighted mean	-290	-226	**76**	85
	Standard deviation	236	231	36	123
	Success ratio	**2%**	**8%**	**100%**	**86%**
solar	Real option value	4	22	163	243
	Weighted mean	-525	-322	**163**	207
	Standard deviation	441	384	18	178
	Success ratio	**3%**	**10%**	**100%**	**96%**
hydro	Real option value	3	21	153	273
	Weighted mean	-654	-456	**153**	219
	Standard deviation	507	485	51	234
	Success ratio	**2%**	**8%**	**100%**	**92%**

Firstly, we can see that when internal factors are properly managed, projects of all three RE technologies have only positive outcomes under capacity mechanism (column three green values of success ratio). However, there are some differences between them. Weighted mean of the distribution or in other words weighted average NPV under capacity mechanism when internal factors are managed (column 3) is twice higher for solar and small hydro comparing with wind project. In addition, solar technology has the smallest standard deviation that is twice smaller comparing to wind and three times smaller than for hydro. Although these three projects are equal in terms of installed capacity, they are different in terms of initial investment. Therefore, comparing relative values of e.g. profitability index (PI) is preferable than absolute NPVs. PI of wind, solar and small hydro investment project for column three case is 2.16, 2.49 and 2.045 respectively. Standard deviation divided by CAPEX (CAPEX limit) is 0.55, 0.17 and 0.35 respectively. Thus, if we rank three technologies by investment attractiveness, first one would be solar with the highest PI and the smallest risk (of decreasing NPV, but not below zero), the second place is shared by wind with second higher PI but the greatest risk and small hydro with the lowest PI.

Overall, results of Datar-Mathews method show us that capacity mechanism creates a real option to invest in RE project by ensuring positive NPV if internal factors are managed properly. If localization requirement is met, CAPEX is within limits and average capacity factor is more than 75% from the target one, project outcome under capacity scheme will be positive regardless of external factors.

The next section provides results of similar real options analysis, but performed with fuzzy pay-off method.

5.4. Pay-off method

Fuzzy pay-off distributions for projects under capacity scheme (on the left) and feed-in premium (on the right) for the first case when all factors are variable except base rate are presented in Figure 19. All following graphs in this section represent wind power plant case, whereas similar figures for other technologies are presented in Appendix 6.

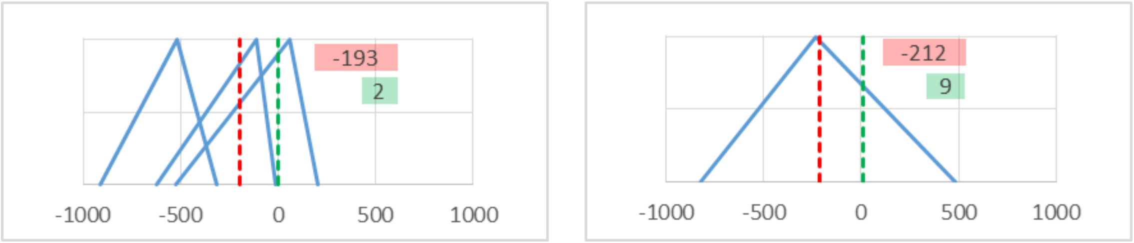

Figure 19. Fuzzy pay-off distribution of projects under CM (left) and FiP (right), mln. rub. All factors random except base rate.

As previously, red dashed line represents expected mean of the whole distribution specified by a number with red shadowing and green dashed line with corresponding number with green shadowing reflects real option value. On the left chart three distributions have quite substantial common areas, but further analysis will reveal the difference between them.

Figure 20 illustrates the second case, when capital expenses are within limits and localization criterion is fulfilled.

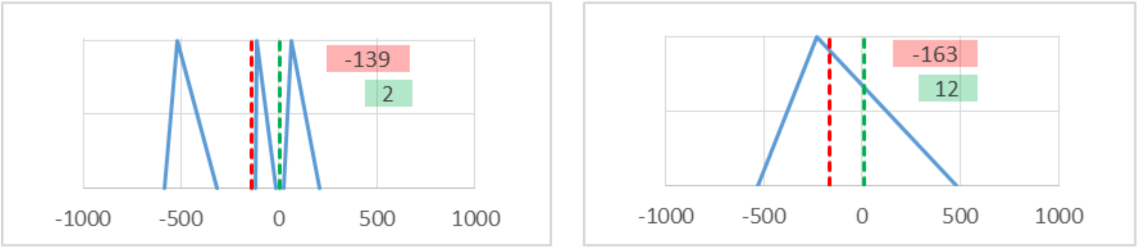

Figure 20. Fuzzy pay-off distribution of projects under CM (left) and FiP (right), mln. rub. Localization is fulfilled, CAPEX 80-100%.

Now we can clearly see three separate zones of profitability that can be gained with different production performance under capacity mechanism that reveals importance of proper location of power plant suggesting the only third option (with capacity factor higher than 75% of target) has sense to pursue. While for feed-in premium scheme, just pessimistic scenario becomes less severe, other remains the same.

Figure 21 represents the third case with capacity factor 75.1% from target for pessimistic scenario, 100% for realistic and 120% for optimistic.

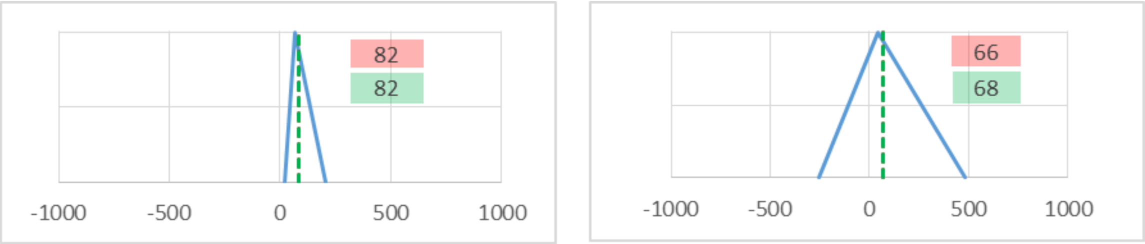

Figure 21. Fuzzy pay-off distribution of projects under CM (left) and FiP (right), mln. rub. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target.

We can see that pay-off distribution under capacity scheme is entirely in the positive zone meaning no risk of negative outcome if internal factors are managed properly even under conditions of variable external factors. Feed-in premium scheme leaves risks that project will not be profitable due to external factors.

Finally, to represent influence of the base rate to project profitability under both schemes we set base rate at 8.5% for the pessimistic scenario, 15% for the realistic one, and 20% for the optimistic. Resulting distributions are shown in Figure 22.

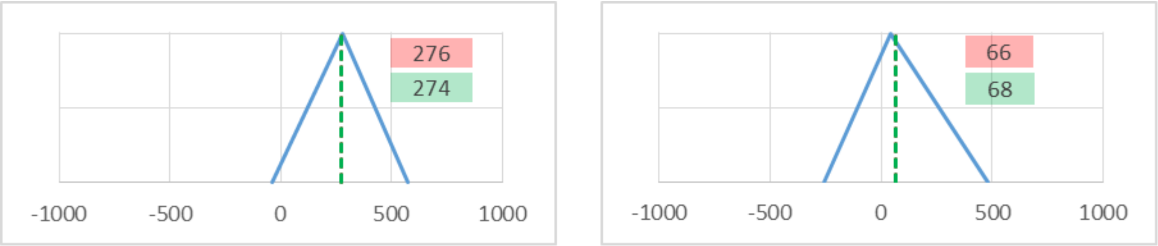

Figure 22. Fuzzy pay-off distribution of projects under CM (left) and FiP (right), mln. rub. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target, base rate 8.5-20%.

The pay-off distribution of project under feed-in premium has not changed; whereas one under capacity scheme has become wider, that reflects influence of the base rate on capacity price. With base rate growth, investors are assumed to have higher required rate of return to adjust to growing floating debt payments and satisfy shareholders interest. Thus, capacity price increases to cover these expectations.

The felicitous representation can be performed with fuzzy pay-off method results by turning at 90 degrees all the graphs and putting them in line. This allows easily comparing all the cases and follow the distribution change without difficulties. Figure 23 illustrates this approach. Upper line shows project under capacity scheme and lower one under feed-in premium. Distributions are ordered in accordance with previous narration from case 1 to 4 from left to right. We can see smooth changes of pay-off distribution under feed-in premium. While capacity scheme project represents more complex development due to complicated formation of capacity price as described above.

Descriptive statistics for cases 1 and 3 shown in Figure 19 and Figure 21 are presented in Table 14 with comparison of other technologies. For the cases with three distributions, statistics were calculated as for one.

Table 14. Comparing fuzzy pay-off method results for different technologies, mln. rub.

		All factors random except base rate (Figure 19**Error! Reference source not found.** for wind)		Internal factors are managed (Figure 21 for wind)	
		CM *(1)*	FiP *(2)*	CM *(3)*	FiP *(4)*
wind	Real option value	2	9	82	68
	Expected mean	-193	-212	**82**	66
	Standard deviation	229	267	37	150
	Success ratio	**0%**	**0%**	**100%**	**70%**
solar	Real option value	2	13	175	151
	Expected mean	-272	-322	**175**	165
	Standard deviation	358	406	13	196
	Success ratio	**0%**	**0%**	**100%**	**82%**
hydro	Real option value	2	16	163	158
	Expected mean	-396	-429	**163**	166
	Standard deviation	461	532	51	272
	Success ratio	**0%**	**0%**	**100%**	**76%**

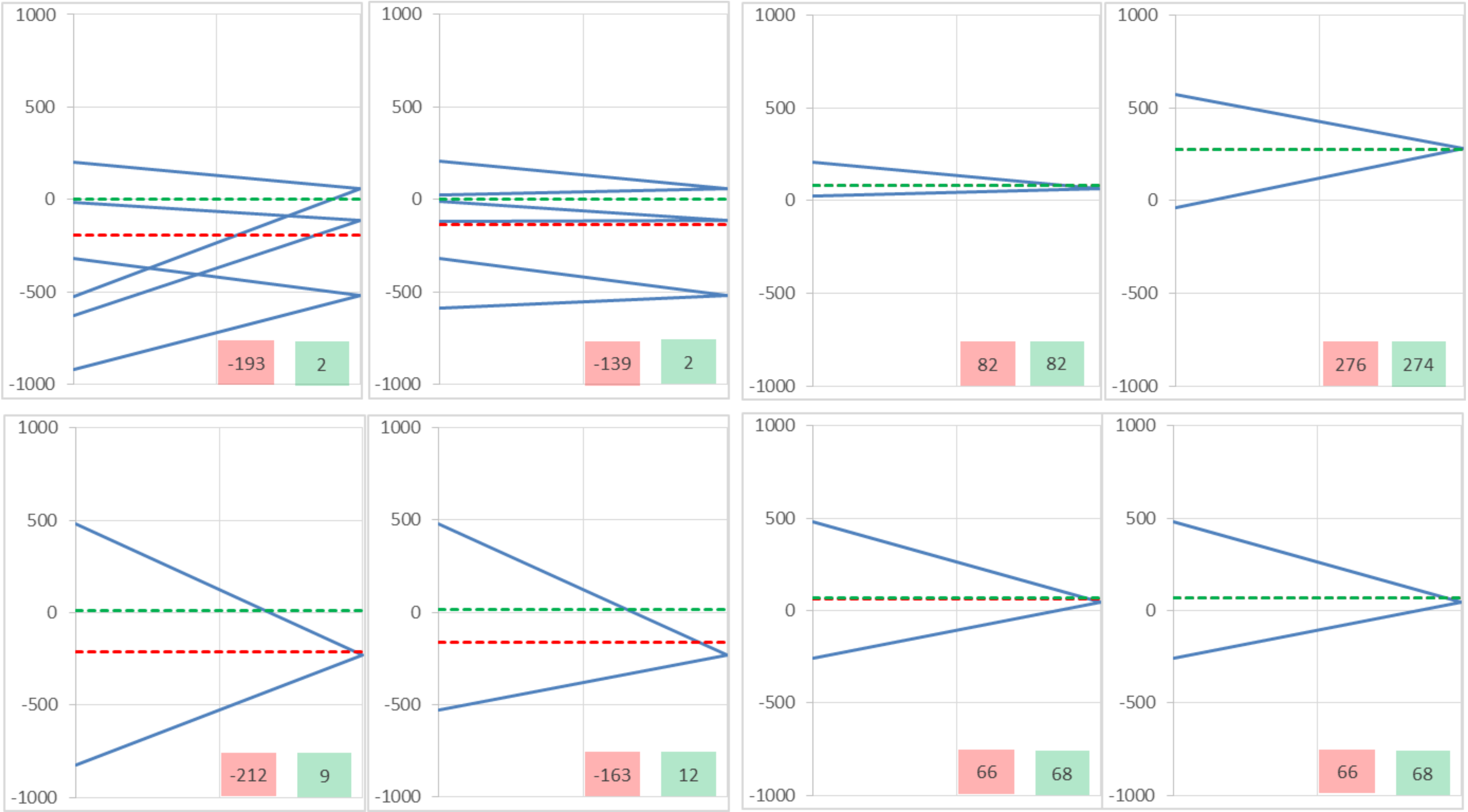

Figure 23. Overview off all results of fuzzy pay-off method.
First row – capacity scheme, second row – feed-in premium. Cases from 1 to 4 from left to right.

According to Table 14 internal factors worth managing under capacity scheme as it provides non-lose situation with pay-off distribution entirely in positive area for all three technologies. Solar investment represents the highest NPV with the lowest standard deviation in both, absolute and relative terms. Profitability index for this case would be 2.25, 2.60 and 2.12 for wind, solar and hydro respectively if CAPEX assumed to be the target one. And standard deviation relative to CAPEX would be 0.57, 0.11 and 0.35 respectively.

Thus, solar is the most attractive trade-off among three technologies, wind and hydro share second place with the former having higher PI but higher relative standard deviation as well.

To conclude, fuzzy pay-off method proves that capacity mechanism creates a real option to invest in renewable energy project by guarantying positive NPV regardless of external factors if internal ones are managed properly.

In the next section, we compare results obtained by Datar-Mathews method and fuzzy pay-off method.

5.5. Comparison of Datar-Mathews and Fuzzy Pay-off method results

Both Datar-Mathews (DMM) and fuzzy pay-off (FPOM) methods led us to the same conclusion based on distributions as well as their descriptive statistics. Both methods intuitively very close to each other as they present all possible outcomes as a distribution with possibility to calculate the same statistics. Let us compare distributions obtained for the case when internal factors are managed, represented by Figure 17 using DMM and Figure 21 using FPOM (Figure 24).

Upper graphs show pay-off method results (in terms of mln. rub.) and lower ones represent Datar-Mathews method results (in terms of thous. rub.). Left graphs are for capacity mechanism and right ones for feed-in premium. We can easily see almost the same form of distributions with the same borders. There is some difference in mean and real option values.

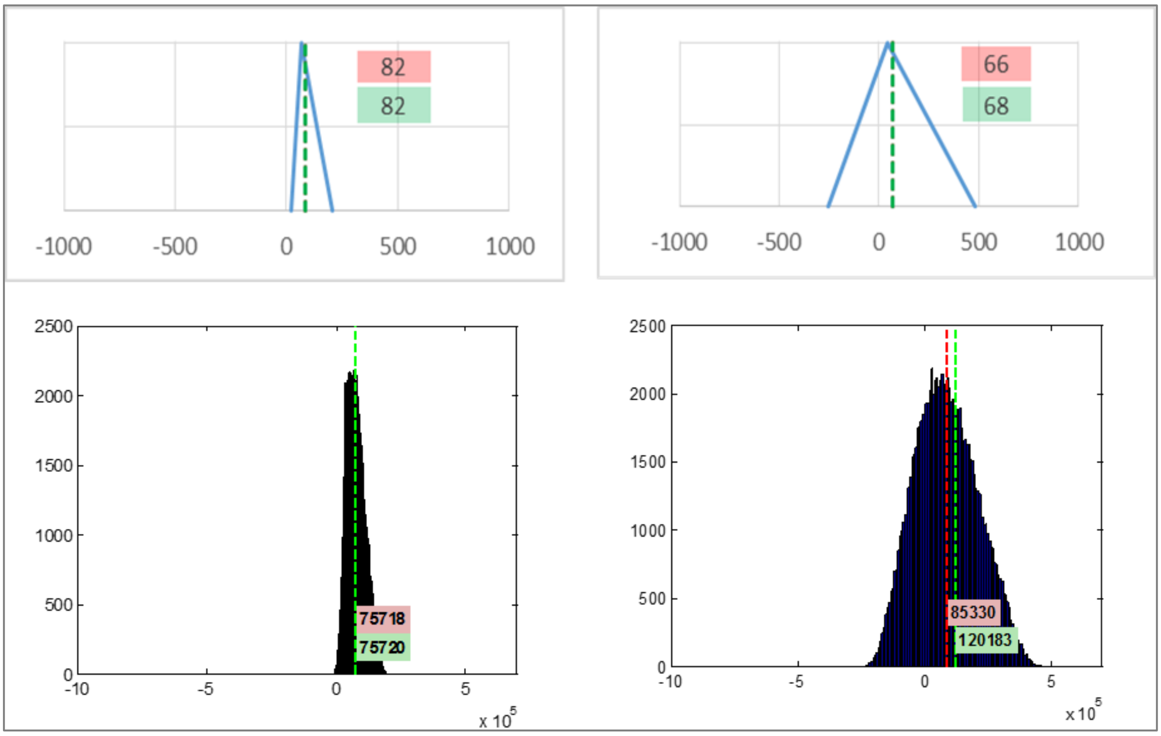

Figure 24. Comparison of FPOM (upper) and DMM (lower).

To investigate this closer we present comparison of all statistics for the same case in Table 15. All figures correspond with the same case when internal factors are managed properly.

Table 15. Comparison of DMM and FPOM.

		Datar-Mathews method		Fuzzy pay-off method	
		CM *(1)*	FiP *(2)*	CM *(3)*	FiP *(4)*
wind	Real option value	76	120	82	68
	Weighted mean	**76**	85	**82**	66
	Standard deviation	36	123	37	150
	Success ratio	100%	86%	100%	70%
solar	Real option value	163	243	175	151
	Weighted mean	**163**	207	**175**	165
	Standard deviation	18	178	13	196
	Success ratio	100%	96%	100%	82%
hydro	Real option value	153	273	163	158
	Weighted mean	**153**	219	**163**	166
	Standard deviation	51	234	51	272
	Success ratio	100%	92%	100%	76%

From the table above it is clear that although results are close and they change in the same direction among different technologies, they are not exactly the same. FPOM offers a little bit higher values for real options and expected means for capacity scheme and vice versa for feed-in premium scheme, implying that it is more sensitive to the width of the distribution.

This arises from the different logic of identifying weighted mean of the fuzzy distribution (Carlsson and Fullér 2001). Standard deviation is mostly the same for capacity scheme and higher for feed-in premium evaluated with FPOM. Success ratio is more strictly defined by FPOM for all cases.

Although there are some minor differences in descriptive statistics due to different computational logic, fuzzy pay-off method demonstrates much similarity with Datar-Mathews method in terms of information content and conclusions derived. However, FPOM is much easier in use, as it does not require any special software, does not need to work with random numbers; it might be built on the top of existing financial model in Microsoft Excel® with less effort and not so time-consuming. Considering both, simplicity in use and informativity of FPOM, it can be recommended to any investor.

The next section presents the decision tree of an investment under the capacity mechanism.

5.6. Decision tree

Based on the results obtained by Datar-Mathews or fuzzy pay-off method we can build decision tree to illustrate how capacity mechanism shapes investors' decision-making process (Figure 25).

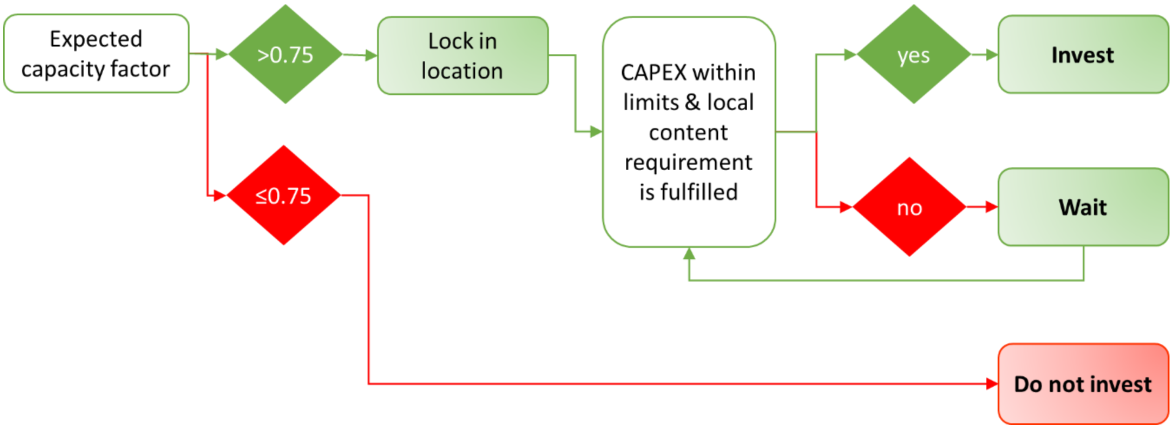

Figure 25. Decision tree.

According to the results, one of the most crucial factors is production performance. Investment in all three technologies is commercially viable only if average capacity factor is higher than 75% of target one, that corresponds to 20,3% for wind, 10,5% for solar PV and 28.5% for small hydro power generation. Thus, first decision emerges from location selection, whether it can provide at least specified capacity factor or not.

Then to limit the distribution of all possible outcomes entirely in positive zone, capital expenses should be equal or less than the limit (Table 3) and localization requirement must be fulfilled. If these two criteria are met, positive investment decision can be made. If at least one criterion is not achieved, there is no sense in abandon investment, but there is one in waiting. Since all renewable energy technologies have high leaning curves, meaning their cost decrease, waiting itself can lead to fulfilling CAPEX criterion. Local content requirement involves production of equipment and services for the planning power plant locally, within the country. Essentially, renewable energy manufacturing and service sector have been developing since introducing this RE policy in 2013 in Russia. Thus, waiting might be a proper solution to achieve these requirements and making project unconditionally profitable. One should remember to lock in an appropriate location if competition is expected in a particular region.

In the next section, we discuss all obtained results, highlight main conclusions and provide ideas for further research.

6. DISCUSSION AND CONCLUSION

Introduced in May 2013 Russian renewable energy policy based on capacity mechanism aims to increase share of renewables in the Russian energy mix. This paper shows that this capacity mechanism makes investment projects into wind, solar and small hydro generation not only profitable under particular circumstances, moreover, it creates a real option to invest in those projects by ensuring project effectiveness under fulfilling some requirements.

Capacity mechanism provides remuneration in terms of installed capacity of a power plant by arranging 15-year capacity delivery agreements. Capacity price under this agreement is not fixed, it is a function of a number of internal and external factors, that is formed to ensure a particular return on investment. Capacity price is calculated as a variable annuity in a way to offset changes in external factors, such as electricity price, inflation and base rate and simultaneously motivate investor to manage internal factors such as capital costs, production performance and localization. The latter implies producing equipment and services for a planned power plant locally in Russia. This complex influence of capacity mechanism creates severe punishment for capacity cost overrun, poor production performance and failing localization requirement, while ensuring project profitability if these factors are managed properly meaning capacity costs equal or less than corresponding limits (Table 3), capacity factor higher than 75% from target one (Table 6) and fulfilling local content requirement (Table 5). An important feature of the policy is that it aims to provide a specified return on investment, particularly 12% (for projects auctioned after 1.1.2015) plus the difference in the base rate, namely yield of long-term government obligations. This feature allows investors to meet their floating debt obligations and keep project profitability even in crisis circumstances when interest rates are substantially higher. All these attributes of the capacity mechanism create a real option, which is a right to invest if one is able to meet all requirements and consequently get commercially viable project regardless of market conditions, but not the obligation to invest when some requirements are not met that allows avoiding possible losses.

The thesis is appears to provide several contributions to the academic literature and business. Detailed description of capacity price formation for renewable energy within Russian capacity mechanism presented in this thesis was not available in English before. With respect to methodology novelty, on the top of investment profitability model such advanced approaches are applied as Datar-Mathews method and fuzzy pay-off method. Comparison of effects of Russian capacity mechanism and feed-in premium contributes to policy comparative studies and exhibits useful inferences for researchers and policymakers.

Our findings reveal important implication for investors. By strategically approaching renewable energy investment under capacity mechanism an investor is able to totally avoid possible negative outcomes of its investment making an investment project unconditionally profitable. This strategy implies first, defining an appropriate power plant location, where average capacity factor more than 75% of target one can be achieved, in particular 20,3% for wind, 10,5% for solar PV and 28.5% for small hydro power generation; second, locking in this location in case of competition and investigating whether capital cost criteria can be met. This includes keeping capital costs within specified limit and fulfilling localization requirement. If they are met, positive investment decision can be made with no further risk to project profitability. If not, reliable option is to wait until these requirements can be met. This strategy of decision-making process is illustrated with decision tree (Figure 25).

Comparing renewable energy project profitability across different technologies we can conclude, that solar parks represent the most attractive option because of higher profitability and higher cash flows predictability when internal factors are managed properly. This occurs because of initial differences. Solar project has high upfront costs implying high capacity remuneration, but the lowest capacity factor comparing with wind and small hydropower meaning relatively less electricity production and consequently lower share of revenues from electricity sales. The latter imposes higher share of capacity payments in total revenues and relatively less uncertainty from electricity price movements. Thus, under capacity mechanism solar power becomes more investment attractive.

Another implication can be drawn for an opposite group of actors – policymakers. Firstly, capacity mechanism represents easily controlling tool to promote renewable energy. As selection of projects is performed via centralized annual auctions and the installed capacity cap is set for each year (Table 4), installed capacity of renewable energy is under the control. Secondly, by ensuring profitability of an investment project (if requirements on internal factors are met), it provides renewable energy deployment in an efficient way (of course, if set requirements are not too strict). Thirdly, by partly offsetting positive effects on investment projects e.g. of electricity price increase or capital cost shrinking, capacity mechanism avoids imposing excessive burden on the whole energy system or, in other words, provides social benefit. Being efficient and cost-effective mechanism for renewable energy support, capacity mechanism might be an attractive solution for those countries, which seek to implement new RE policy, especially if they have capacity trade in place along with electricity market.

In practice, Russian capacity mechanism, being at its early stage, accidentally posed too strict capital expense limits and localization requirement for wind and small hydropower technologies, inhibiting their adoption. Fortunately, Russian authorities are open to discussion and mechanism adaptation to the Russian reality. Currently, these requirements are under consideration and they are expected to become softer enabling greater volumes of investments into wind and small hydropower. Solar PV technology requirements were fair enough from the very beginning empowering competition among investment projects and keeping adoption pace within the schedule. Overall, with setting proper requirement capacity mechanism is an effective tool to promote renewable energy.

Analyzing capacity mechanism with a number of different techniques allowed us to elucidate strengths and weaknesses of each approach. Calculating crisp values of net present value (NPV) and other effectiveness indicators demonstrate project performance under a single scenario and do not reveal influence of different factors and all possible outcomes that can be achieved. Sensitivity analysis solves first problem and deepens understanding of capacity mechanism incentives. However, it presents influence of different factors on NPV one by one without any inference on their mutual effects. Monte Carlo simulation performed within Datar-Mathews method eliminates this drawback and presents all possible project outcomes. The same results are gained with fuzzy pay-off method, but instead of running simulation 100,000 times just three scenarios are needed to obtain pay-off distribution. Both Datar-Mathews and fuzzy pay-off methods evaluate and visualize a real option as expected mean of the positive area of the distribution weighted on success ratio. However, fuzzy pay-off method has several advantages over Datar-Mathews method. It can be easily performed within already existing financial model e.g. realized with Microsoft Excel®, without much effort, additional computational resources or substantial time for building a new model for simulation. High information content and ability to draw the same conclusion as with Monte Carlo simulation, fuzzy pay-off method is highly recommended to investors, policymakers and researchers as an easy and comprehensive analytical tool.

6.1. Limitations and suggestions for further research

Capacity mechanism is implemented only for the wholesale power market that naturally limits current research as a study of renewable energy investment profile in Russia. Further research should capture supporting mechanism for retail power markets for smaller renewable energy generations, that is not in place now, but currently is under discussion and it is believed to be introduced in 2015. Another layer for renewable energy investment in Russia is remote areas that are not connected to the central grid. These areas already represent an attractive direction for small renewable energy investments, as diesel generation realized there is much more expensive than renewable energy. Covering all three layers of renewable energy investments in Russia would provide the whole picture of investment opportunities in this country.

Another limitation of the current study is that country-level average investment project was considered. However, electricity and capacity prices differ from region to region, as well as resource availability. Thus, creating investment opportunity map of Russia with detailed analysis for each region would further assist investor in decision-making process.

This thesis is an important step in deeper understanding of Russian renewable energy policy effects on investment decision-making process. Continuing current research by elimination of its limitations would allow creating the full picture of renewable energy investment opportunities in Russia.

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APPENDICES

APPENDIX 1. Literature review methodology

Literature review is performed in accordance with Webster and Watson’s guidelines (2002) that allow to make it effective and replicable. Literature selection process consists of three main steps as illustrated on the following figure.

Figure 1. Literature selection process

Initial literature search in the Web of Science database was limited by following criteria:

- Renewable energy policy research;
- The language of the article is English.

The following key phrases in different combinations were used as search criteria: ‘renewable energy policy’, ‘efficiency’, ‘real options’, ‘Russia’.

Search results contained many articles from inappropriate research areas, such as technology, ecology or sociology. Thus, research areas were limited to business economics. Total number of articles matched such criteria were 729.

Second step includes scanning results of previous search by title and abstract. 653 articles were removed as they didn’t match initial criteria leaving 76 articles suitable for the literature review.

Final step is backward tracking, where selected articles as well as found reviews on the topic were analyzed in order to define important references. 32 papers more were added resulting in 108 articles for the review.

Eventually, only 58 references were directly used in the literature review, however, summarizing statements imply inferences of the majority of observed papers.

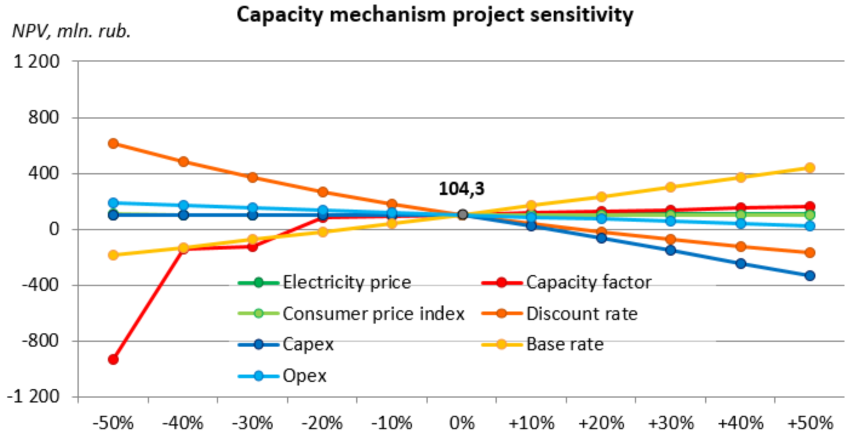
APPENDIX 2. Macros for sensitivity analysis

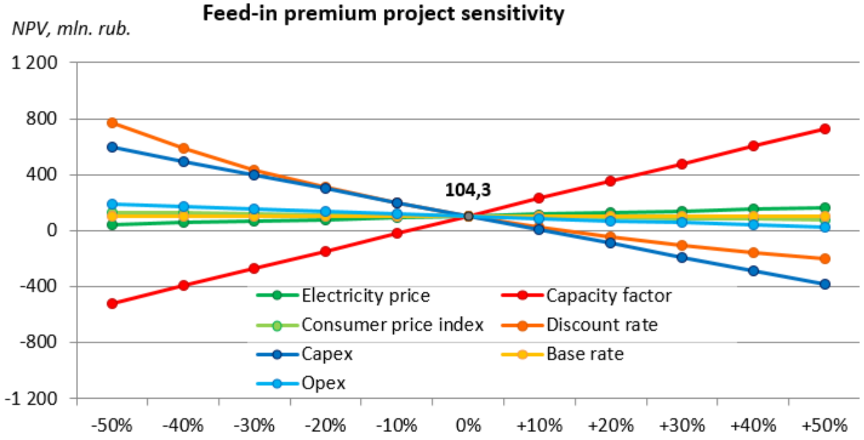
```
Sub Sensitivity()
    'line is row (factor), barPAR1vol and barPAR2vol are column
numbers for two tables with parameter values
    Dim line, barPAR1vol, barPAR2vol As Integer
    'volCof is factor multiplier value
    Dim volCof As Double
    line = 3 'first row of the table
    Do
       'setting factor multiplier as 1.5
       Cells(line, 2).Select
        volCof = 1.5
        ActiveCell.FormulaR1C1 = volCof
        barPAR1vol = 13 'right edge of the first table
        barPAR2vol = 25 'right edge of the second table
        Do
'selection of parameter value and copying it to the corresponding
cell
'for the first table, the eighth column contains the link to the
first parameter
            If (barPAR1vol > 8 Xor barPAR1vol < 8) Then
                Cells(line, 8).Select
                Selection.Copy
                Cells(line, barPAR1vol).Select
                Selection.PasteSpecial       Paste:=xlPasteValues,
Operation:=xlNone, Transpose:=False
            End If
'for the second table, the 20th column contains the link to the
second parameter
            If (barPAR2vol > 20 Xor barPAR2vol < 20) Then
                Cells(line, 20).Select
                Selection.Copy
                Cells(line, barPAR2vol).Select
                Selection.PasteSpecial       Paste:=xlPasteValues,
Operation:=xlNone, Transpose:=False
            End If
```

```
            barPAR1vol = barPAR1vol - 1 'decreasing column number by one
            barPAR2vol = barPAR2vol - 1
            volCof = volCof - 0.1 'decreasing factor multiplier by 0.1
            Cells(line, 2).Select
            ActiveCell.FormulaR1C1 = volCof
        Loop While (volCof > 0.4) 'the range of factor multipliers is from 1.5 to 0.5
        volCof = 1 'set factor multipliers back to 1
        Cells(line, 2).Select
        ActiveCell.FormulaR1C1 = volCof
        line = line + 1 'repeat everything for the next row (factor)
    Loop While Not IsEmpty(Cells(line, 2)) 'till all factors are covered
End Sub
```

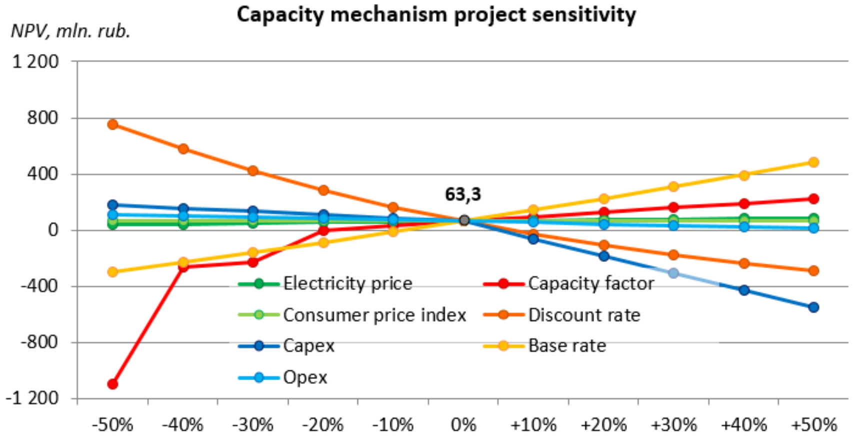
APPENDIX 3. Sensitivity analysis for solar and hydro power

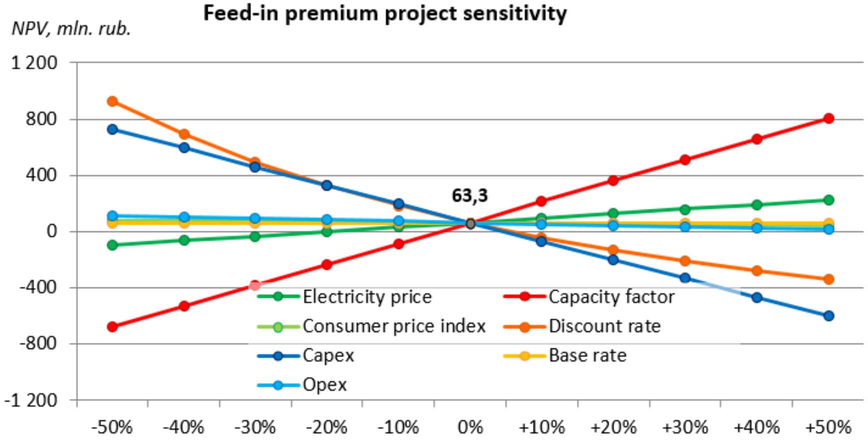
Solar PV power plant case





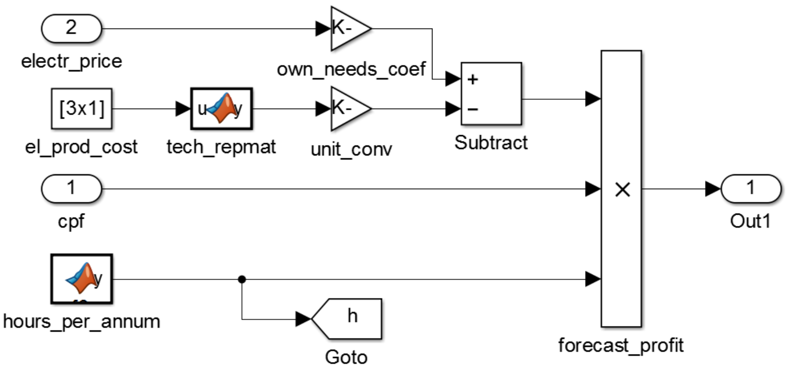
Small hydropower plant case



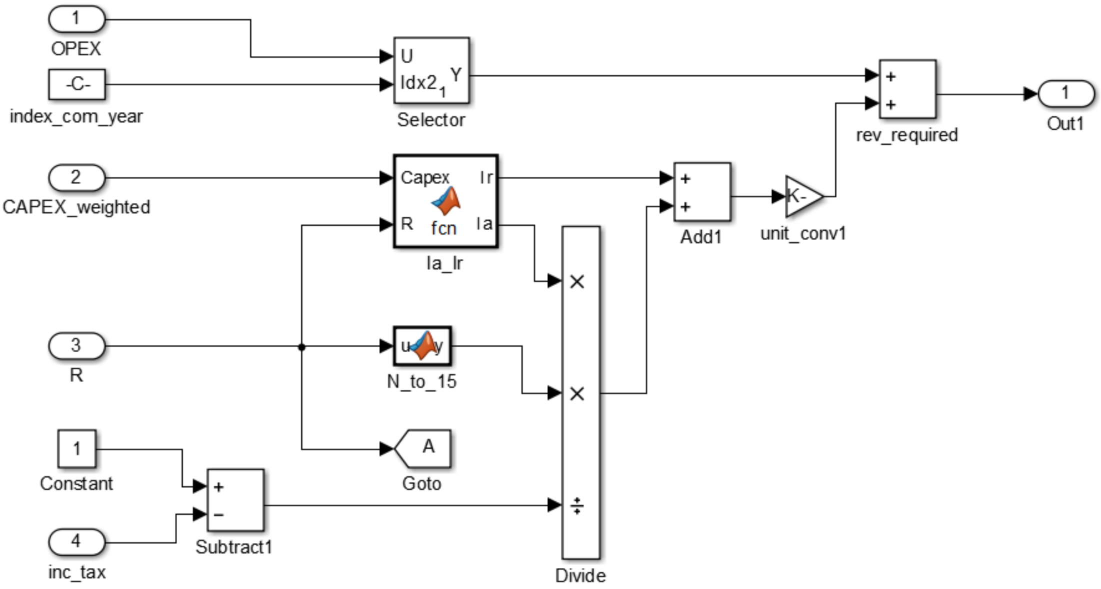


APPENDIX 4. Parts of Simulink model

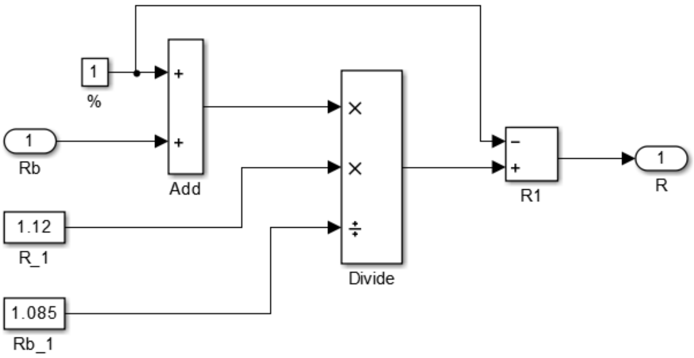
Capacity price block >> forecasted profit block (in accordance with 8)



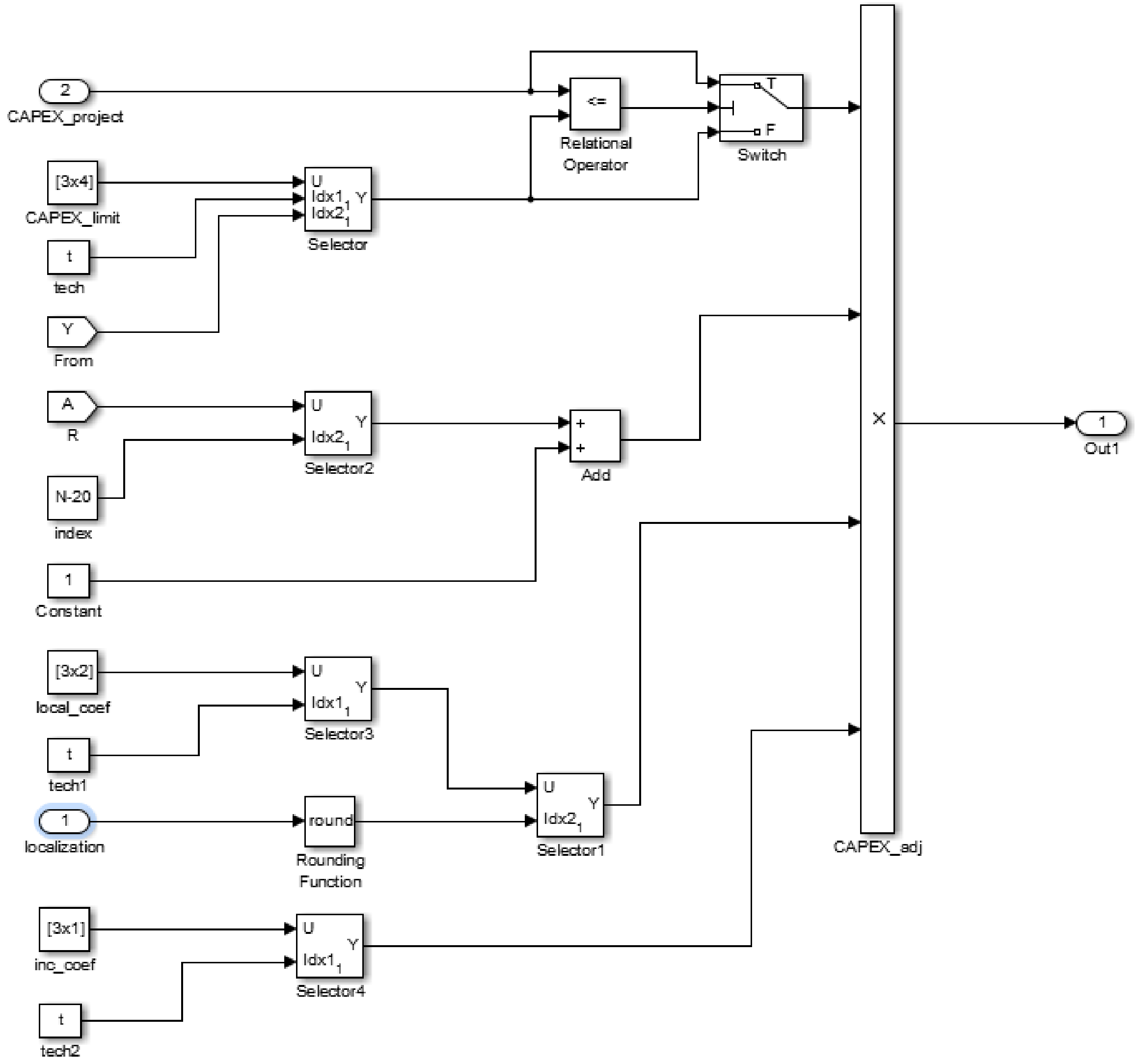
Capacity price block >> rev_required block (in accordance with steps 2 and 3)



Capacity price block >> required_rate block (in accordance with 1)



Capacity price block >> CAPEX_adj block (in accordance with 10)



Capacity price block >> expense_share Matlab function block (in accordance with step 2)

```
function e  = fcn(p,r,N)
k=N-19; % N - parameter, defined in the model workspace
e_0=1-p(:,k:k+14)./(r.*12); % preliminary expense share
e_0(e_0<0)=0; e_0(e_0>1)=1;

e_1=zeros(1,15);
e_2=zeros(1,15);
e=zeros(1,15);
% for uneven years of capacity contract expense share is an average
of this and previous year preliminary expense shares
e_1(1:13)=(e_0(1:13)+e_0(2:14))...
    ./2.*mod(1:13,2);
% for even years it equals previous values
i=1:14;
e_2(i+1)=e_1(i);
```

```
% for the last year of contract it equals last value of preliminary
expense share
i=15;
e_2(i)=e_0(i);
e=e_1+e_2;
```

Capacity price block >> Ia_Ir Matlab function block (in accordance with 11,12)

```
function [Ia, Ir] = fcn(e,R,Capex,N)
k=N-19; % N - parameter, defined in the model workspace
Ia=zeros(1,15); Ir=zeros(1,15);
Ia(1)=Capex(1).*e(1);
for i=1:15
Ir(i)=Ia(i).*R(k+i-1)./((R(k+i-2)+1)^(16-i)-1);
    if i==15
        break
    end
Ia(i+1)=(Ia(i)-Ir(i)+Ia(i).*((R(k+i-1)-R(k+i-2))*(1+R(k+i-1))))
...
    .*e(i+1)./e(i);
end
```

Capacity price block >> Capacity_price_component Matlab function block (in accordance with 13)

```
function cp0   = fcn(e,inc,R,Ia,Ir,O,N)
k=N-19; % N - parameter, defined in the model workspace
i=1:15;
cp0=zeros(1,15);
cp0(i)=(Ia(i).*R(k+i-2)./(1-inc)+Ir(i))./12 ...
+O(k+i-1).*e(i);
```

Capacity price block >> Property_tax Matlab function block

```
function y = fcn(CAPEX,pr_tax,N)
k=N-19; % N - parameter, defined in the model workspace
depr=20;
asset_cost=zeros(1,N); asset_cost(k-1)=CAPEX; i=k:N;
asset_cost(i)=repmat(CAPEX,1,N-k+1) ...
    -(repmat(CAPEX./depr,1,N-k+1).*(i-k+1));
tax_base=zeros(1,N); i=k:N;
tax_base(i)=(asset_cost(i-1)+asset_cost(i))/2;
y= tax_base.* pr_tax;
```

Capacity price block >> Load_factor Matlab function block

```
function y = fcn(cpf_plan,cpf,N,t)
k=N-19; % N - parameter, defined in the model workspace
thr=cpf(t);
capacity_factor_plan=zeros(1,15);
```

```
capacity_factor_plan(k-1:k+12)=cpf_plan(k+1:k+14); % shifting
values one step forward as load factor is calculated based on
previous year capacity factor
load_factor1=zeros(1,15);
load_factor1=(capacity_factor_plan>0.75*thr);
load_factor2=zeros(1,15);
load_factor2=(and(capacity_factor_plan<=0.75*thr,...
    capacity_factor_plan>0.5*thr)).*0.8;
load_factor=load_factor1+load_factor2;
load_factor(1)=1; % first operation year load factor is assumed
equal to 1
y=zeros(1,15);
y(:)=load_factor;
```

Capacity price block >> scaling Matlab function block

```
function y = fcn(u,N)
k=N-19; % N - parameter, defined in the model workspace
y=zeros(1,N);
y(k:k+14)=u;
```

NPV_cap block >> depreciation Matlab function block

```
function y = fcn(capacity,capex,N)
k=N-19; % N - parameter, defined in the model workspace
depr_period=20; y=zeros(1,N);
y(k:N)=repmat(capex,1,N-k+1).*capacity./depr_period;
```

NPV_cap block >> property_tax Matlab function block

```
function y = fcn(capacity,capex,prop_tax,N)
k=N-19; % N - parameter, defined in the model workspace
depr_period=20;
asset_cost=zeros(1,N); asset_cost(k-1)=capex.*capacity; i=k:N;
asset_cost(i)=(repmat(capex,1,N-k+1) ...
            -(repmat(capex./depr_period,1,N-k+1).*(i-
k+1))).*capacity;
tax_base=zeros(1,N); i=k:N;
tax_base(i)=(asset_cost(i-1)+asset_cost(i))/2;
y= tax_base.* prop_tax;
```

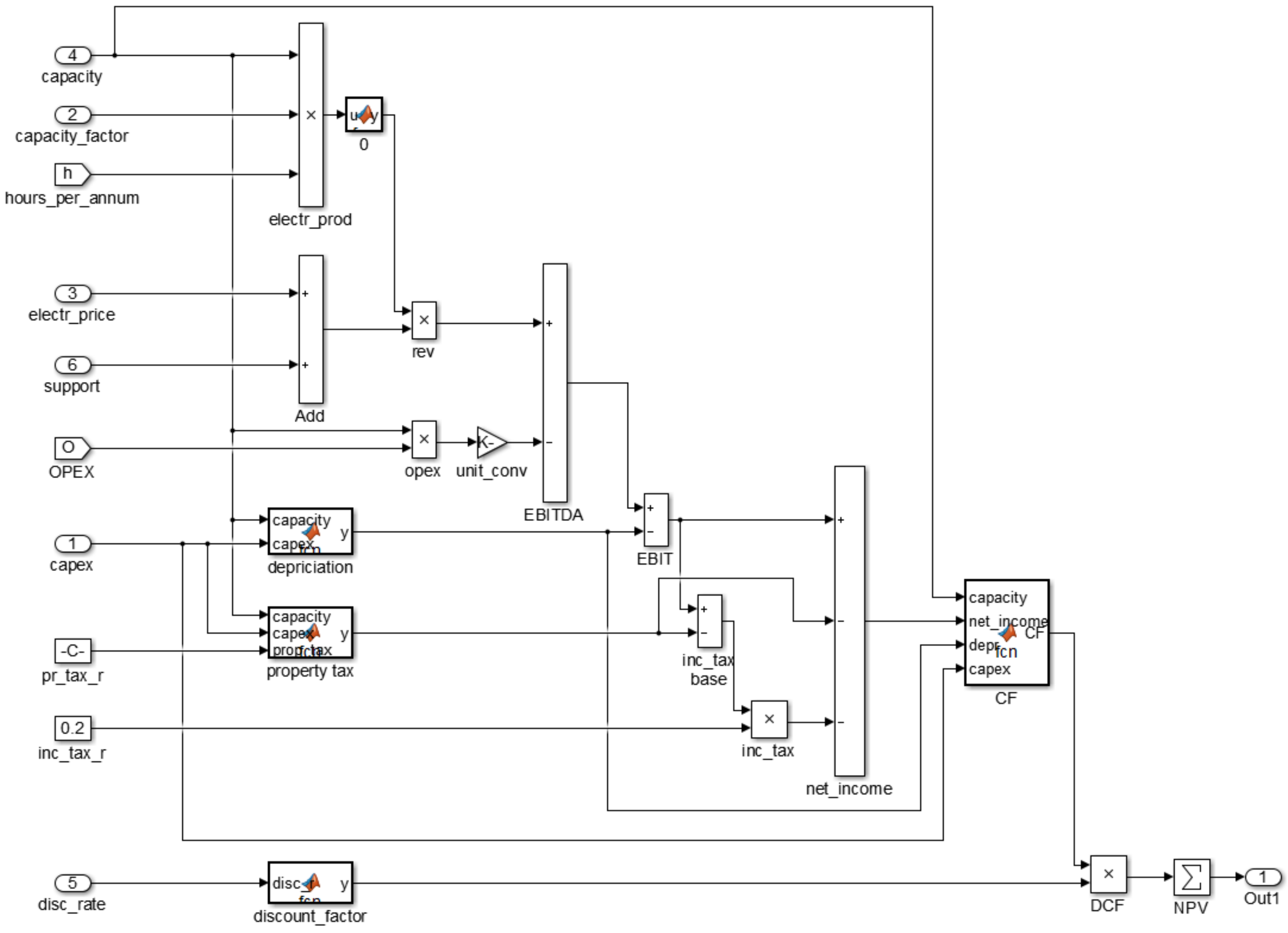
NPV_cap block >> discount_factor Matlab function block

```
function y = fcn(disc_r,N)
y=zeros(1,N); i=1:N;
y(i)=1./(1+disc_r).^(i-1);
```

NPV_cap block >> CF Matlab function block

```
function CF = fcn(capacity,net_income,depr,capex,N)
k=N-19;
d=0.05;
CF=net_income+depr;
CF(k-2)=-capex.*capacity.*d;
CF(k-1)=-capex.*capacity.*(1-d);
```

NPV_fip block (all Matlab function blocks are the same as in the NPV_cap block)



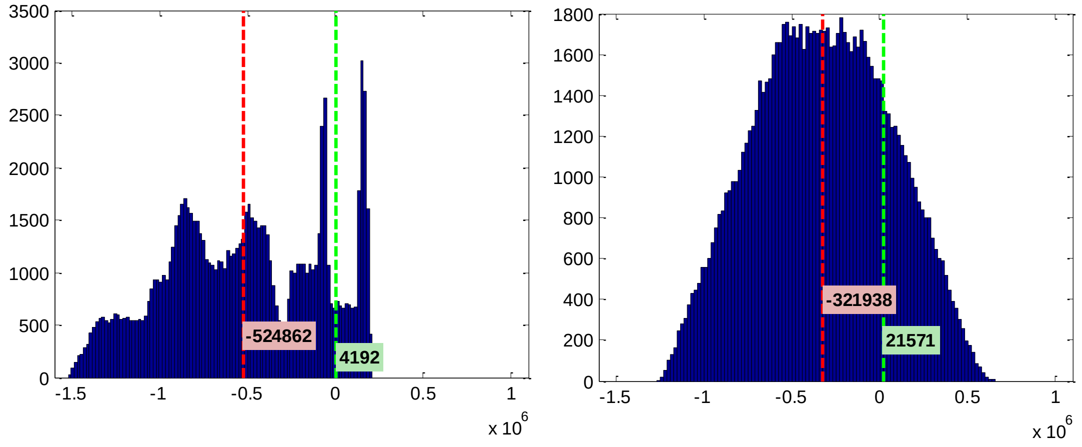
Histogram function

```
function h=hist_sim(NPV0)
%   INPUT:
%    NPV0     =     (1,1,100001) vector of NPV values generated in Simulink®
%
%   OUTPUT:
%    h    =     histogram (frequency distribution) with mapped mean and RO value

figure('Color',[0.6 0.7 0.9]);

% plotting distribution
NPV=permute(NPV0,[1,3,2]);
hist(NPV,100); hold on
% axis
axis([-10e+05 7e+05 0 1]); axis 'auto yz';
% plotting weighted mean
plot([mean(NPV),mean(NPV)],ylim,'r--','LineWidth',2); hold on
% plotting RO value
[w,v]=hist(NPV);
[w1,v1]=hist(NPV(find(NPV>0)));
E_plus=sum(w1.*v1)/sum(w1);
RO=E_plus*sum(w1.*v1)/sum(w.*abs(v));
            %RO_value=mean(NPV(find(NPV>0)));
plot([RO,RO],ylim,'g--','LineWidth',2); hold on
% text
text(mean(NPV)+17e+03,400,num2str(mean(NPV),'%0.0f'),'BackgroundColor',[.9 .7 .7],'fontweight','bold');
text(RO+17e+03,200,num2str(RO,'%0.0f'),'BackgroundColor',[.7 .9 .7],'fontweight','bold');

hold off
```

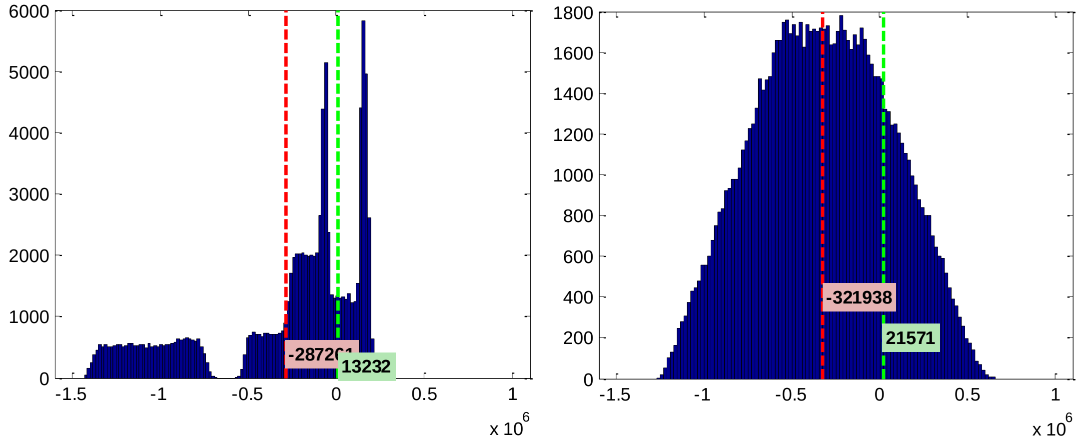
APPENDIX 5. Datar-Mathews method results

Solar PV power plant case. Pay-off distribution of projects under CM (left) and FiP (right), thous. rub.

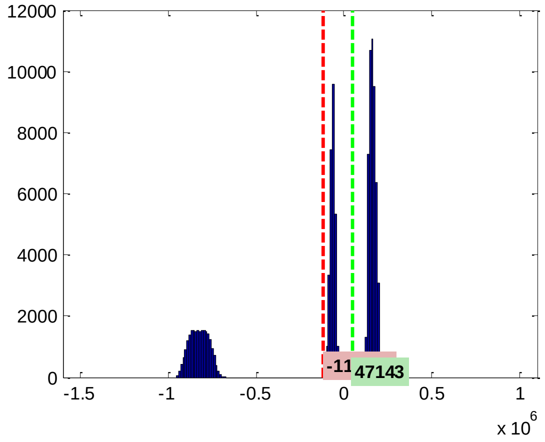
1. All factors random except base rate.

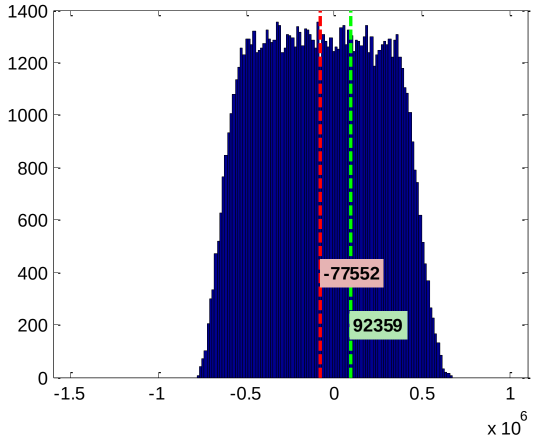


2. Localization is fulfilled.

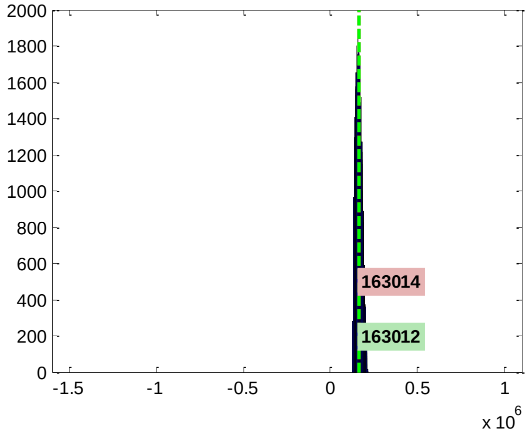


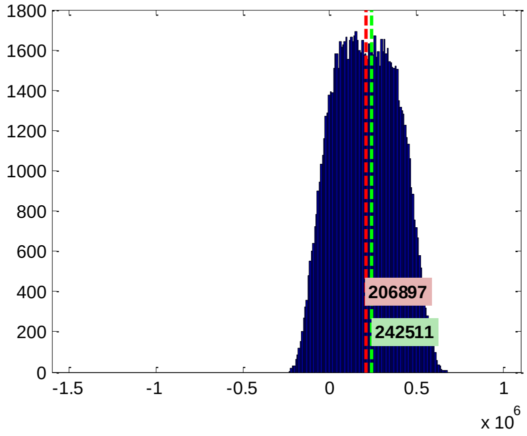
3. Localization is fulfilled, CAPEX 80-100%.



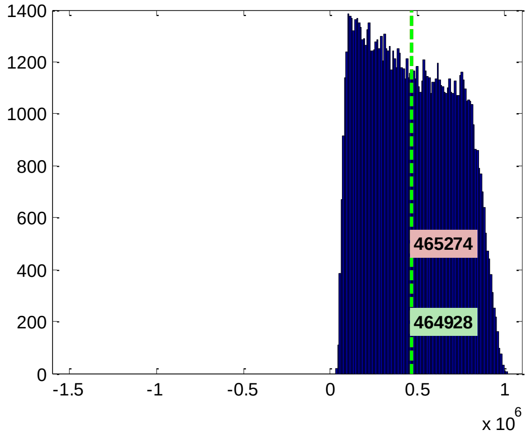


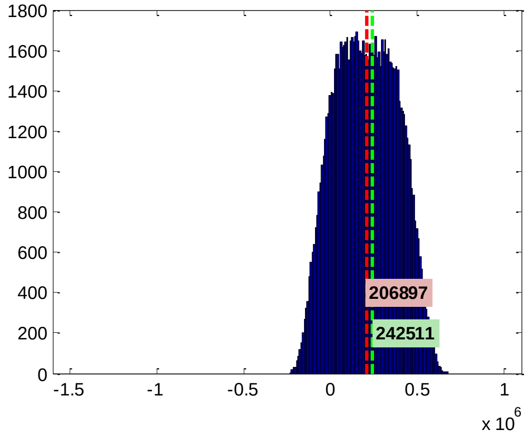
4. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target.





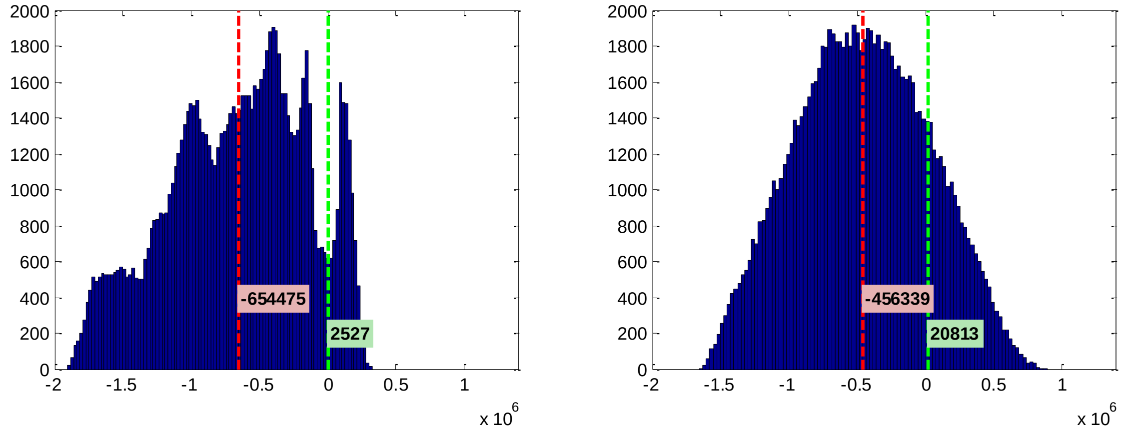
5. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target, base rate 8.5-20%.



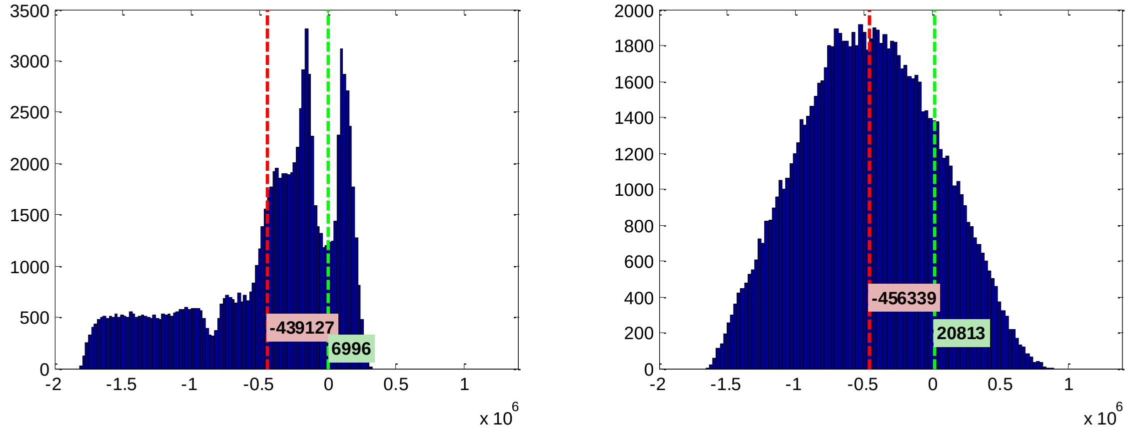


Small hydro power plant case. Pay-off distribution of projects under CM (left) and FiP (right), thous. rub.

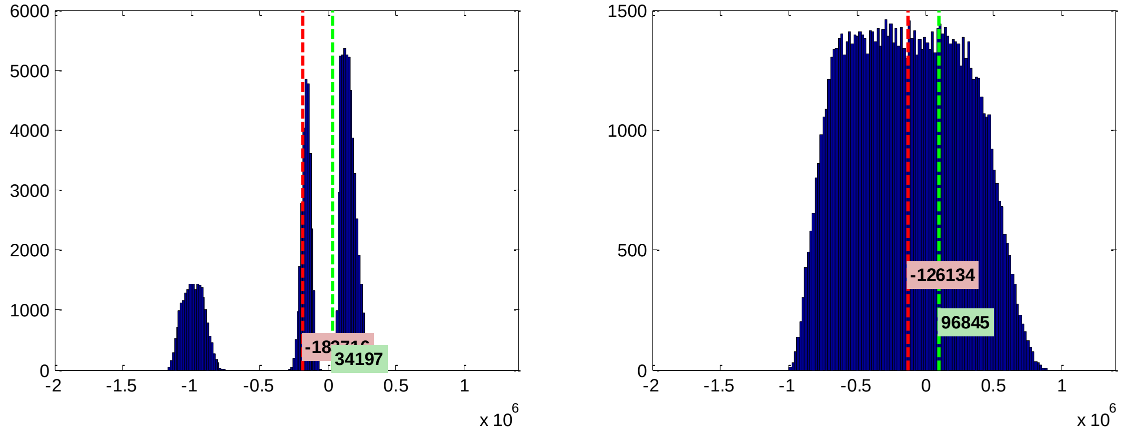
1. All factors random except base rate.



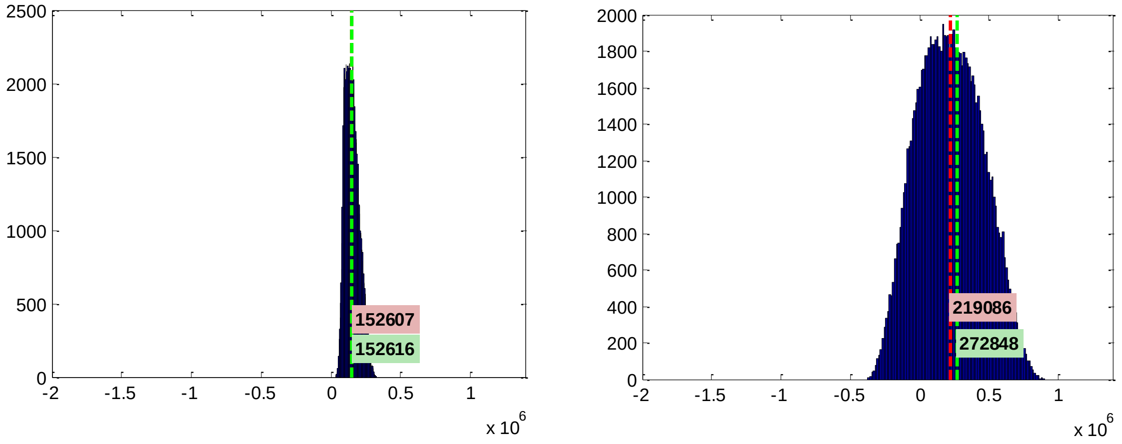
2. Localization is fulfilled.



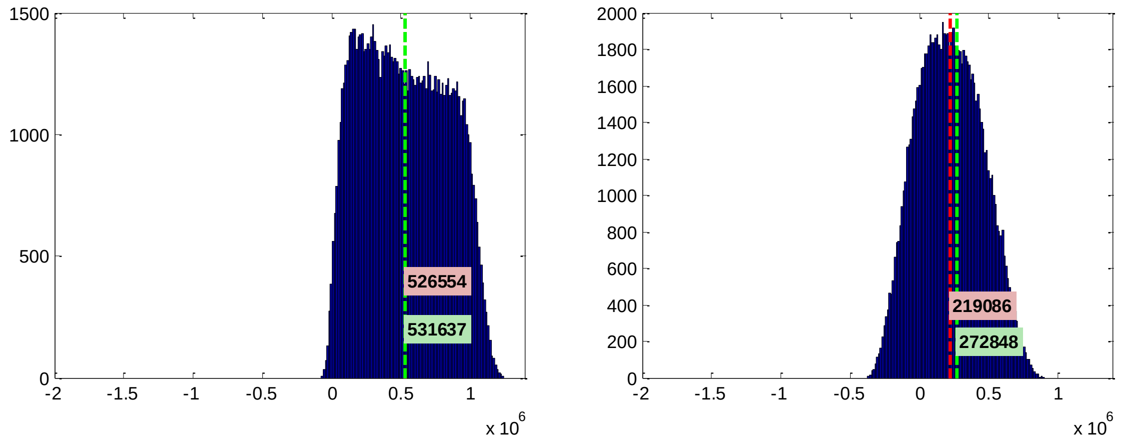
3. Localization is fulfilled, CAPEX 80-100%.



4. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target.



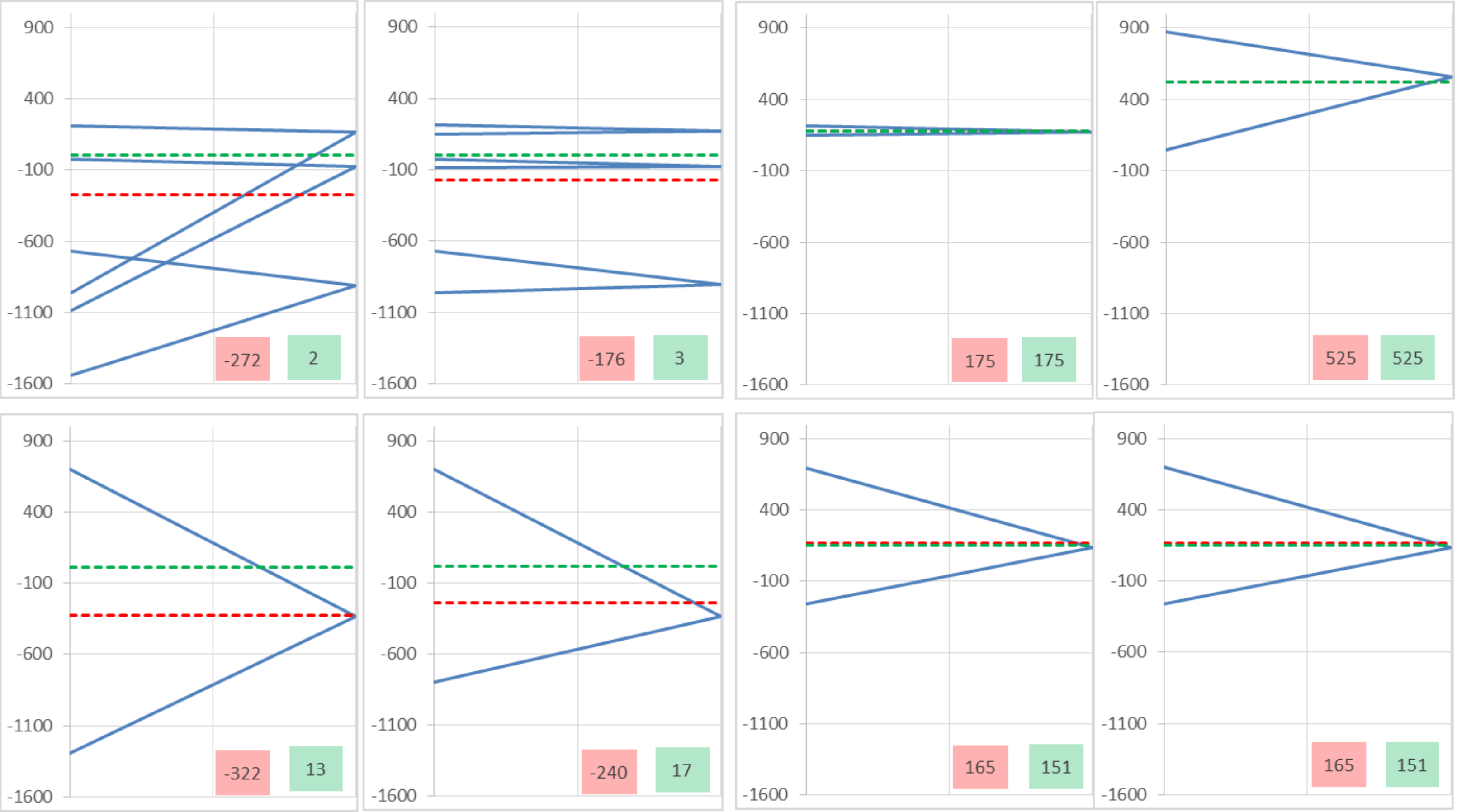
5. Localization is fulfilled, CAPEX 80-100%, capacity factor 75.1-120% from target, base rate 8.5-20%.



APPENDIX 6. Fuzzy pay-off method results

Solar PV power plant case. Pay-off distribution of projects under CM (upper) and FiP (lower), mln. rub.

From left to right: case 1 (all factors are variable except base rate), case 2 (+ CAPEX within limits and localization fulfilled), case 3 (+ capacity factor more than 75%), case 4 (+ base rate variable).



Small hydro power plant case. Pay-off distribution of projects under CM (upper) and FiP (lower), mln. rub.

From left to right: case 1 (all factors are variable except base rate), case 2 (+ CAPEX within limits and localization fulfilled), case 3 (+ capacity factor more than 75%), case 4 (+ base rate variable).