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COMMODITY MARKETS - AUTOMATED TRADING AND RISK MANAGEMENT ON WHOLESALE ENERGY MARKET

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STATEMENT

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Introduction

The main purpose of this paper is to create a model (henceforth called ‘the Model’) which can automatically replicate, or if possible achieve better results on spot energy market, than average market price. The Model is going to represent large energy supplier (buying side of the market), where risk management is the most important factor as a result of huge market impact on prices and enormous exposure to unfavourable balancing market pricing, when demand is possibly not fulfilled through standard market transactions.

The Model will test its profitability on the *Towarowa Giełda Energii S.A.* exchange on an RDN market, which represents the biggest market for spot transactions in Poland. It omits any other markets as a result of small representations of their volume in the whole market. Moreover, the Model does not assume to estimate any fundamental data, even further market prices, it is only responsible for accurately splitting orders into smaller amounts with regard to previous market data, taking into account risk measures connected with them and preparing to different scenarios. What distincts this market from any other is that the energy cannot be stored, so energy bought for every hour has to be spend or resold for use immediately.

Some methods used in this model came into existence during internship in one of the biggest member of spot energy market that time, where replicating the market behaviour was hard to obtain in a long term for commodity traders, mostly due to its specific character and distinction from any other trading activities, and lacking the process of automation so necessary to carry on large amount of calculations in a small period of time. Additionally, many risk management concepts introduced during the studies were relevant, as well as creating some trading systems on U.S. securities exchanges might help as well.

Tool used to write the Model is Python Programming Language, which is going to be one of the most popular programming languages for scientific computing in recent years, due to its large scientific libraries and clear syntax enabling even non-programmers to write efficient, fast and reliable code, with support of any modern language design. The program, which should be a physical representation of the Model, is created in order to be modified and adjusted to day-to-day analytics of the commodity trader's team and with addition of some other advanced features and optimization able to run as real-life software.

Chapter first, being more theoretical one, introduces to global commodity markets. In this chapter basic concepts related to commodity markets are explained and its history with a great emphasis on an importance of commodities and impact on development of today's world they have. Then it would go through particular commodities as where they are in a modern world, ending with recent changes on commodities market due to expansion of new finance products and global need for diversification of assets.

The second chapter stands more for both methodological and research purposes, starting with short, but concise characteristics of polish commodities with great emphasis to energy market. Then, it follows to brief explanation of methods used to model creation. Next, the Model's specification is explained, trying to capture any unfamiliar concepts residing in the code itself.

Appendix A contains a program which converts proper files downloaded from data sources and organize them in the database used by the Model. In Appendix B is located a source code of the Model. Appendix C consists of real-life usage of the program, with most useful features to read what the Model produces and where particular results come from.

I. Development and organisation structure of commodity markets

1. Basic concepts of the commodity markets

Origins of the word commodity descend from a French word *commodité* [1] and going further back from Latin word *commoditatem,* which means benefit or profit[2]. Commodity in a widest sense of the term is an object produced to satisfy human needs. Each object can be perceived from two different perspectives: the exact purpose it was made to and as a subject of interchange into another object.[3] In that sense commodities possess twofold aspects: use-value and exchange-value. Use-value coincides with the physical existence of the commodity and its realization comes with the process of direct consumption. Every object can be used in a different ways, but the range of its potential functions is limited as a result of its physical characteristics. Additionally, what is always connected with commodity usefulness apart from quality is its qualitative measurement, amount of weight or volume it consists of. Another feature which can describe commodity is exchangeability, which

[1] N. N. Chatnani, *Commodity markets,* Tata McGraw-Hill Education, New Delhi 2010, p. 2.

[2] D. B. Lindenmayer, J. F. Franklin, *Towards forest sustainability,* CSIRO Publishing, Collingwood 2003, p. 231.

[3] Aristotle, *The Republic*.

means it possesses the same attitudes regardless place and the way of production.[4]

The ambiguity of the word market comes from the broad historical background of this concept. At the beginning the word market stood for a central place of the town, where the main economic and social life took place. It comprises of buildings like town hall, stalls, scales, well, halls, and undeveloped ground served as a place for exchanging goods and encounter meetings. Further, together with expansion of commerce, the term acquired more meaning in a study of economics. Nowadays, the market embraces entire sale and purchase transactions of the given good or a factor of production, made on a given territory within a certain time. Prices and quantity of goods sold are determined, at least in part, as a result of the interactions between buyers and sellers of those goods. Supply and demand takes part on the market, which interact with each other, resulting in the formation of a market equilibrium price. Markets can be divided according to:

- sectors
- the criterion of extension:
    - local
    - regional
    - national
    - international
    - the world
- the changes in time for markets:
    - stable
    - seasonal

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[4] K. Marx, *A Contribution to the Critique of Political Economy* contained in the *Collected Works of Karl Marx and Frederick Engels*: Volume 29, International Publishers, New York 1987, p. 269.

    - diminishing
    - expanding
    - developing
- the turnover in the market:
    - small
    - medium
    - large
- the theory of the market economy:
    - goods and services
    - labour
    - capital
    - financial

One of the general characteristics of the market is competition. Depending on the degree of concentration of supply and demand, four market structures can be distinguished: perfect competition, imperfect competition and monopolistic competition covered by monopoly and oligopoly.

The market was created as a result of the historical process of division of labour. A necessary condition for its existence is the manufacturing by the producers more goods than they can consume, and create the exchange surpluses. Functioning of the market depends not only on the structure of supply and demand, but also on the institutions and legal regulations (protection of property, protection of the circulation of money, the banking system, settlements of liabilities, regulation of stock exchanges, etc.). Whilst the historical process of the development of societies progressed, markets have seen considerable evolution. It was effected in many dimensions: in expansion of markets from small (local) to the world's major markets, emergence of new branches of production, which resulted on the one hand with the deepening of the social and international division of labour, on the

other hand - the placing under the market regulation new fields of knowledge (intellectual property, organizational) and politics (market regulatory services).[5]

Commodity market is a physical or virtual marketplace for purchasing, selling and trading raw or primary products. Within the products traded on commodity market there is a differentiation on hard commodities, which has to be mined or extracted, and soft commodities, comprising agricultural products or livestock.[6] Every good which is produced has to be in the end traded on a marketplace. There the market makes a price settlement, meeting together a supply side, represented by the sellers and buyers, representing a demand side. Price on the commodity markets is set up in the process of the auction mechanism, often through intermediaries (brokers). Modern commodity markets have their origins in the agricultural market, which lasts from a centuries. Commodity markets faced a rapid development in the 19th century, where major economic implications in the transportation, storage and financing facilities took place. As a result, commodity exporting countries took advantage of the growing international trade by creating more revenue. Alongside as the commodity trade rose, the money entering this market entered through indices, hedge funds, exchange-traded funds and short-term momentum players. With the expansion of financial engineering more sophisticated products appeared, as: weather derivatives, freight futures, telecommunications bandwidth, natural gas, power derivatives and

[5] G. Boguta, red. nacz. J. Kofman, *Encyclopedia Popularna PWN*, wyd. dwudzieste piąte zmienione i uzupełnione, Wydawnictwo Naukowe PWN Spółka z o.o., Warszawa 1995, str.477.

[6] http://www.investopedia.com/terms/c/commodity-market.asp, 03.09.2012 r.

environmental emissions trading. The main distinction in commodity market trading reflects direct physical trading (spot trading) and trading derivatives.[7]

Commodity exchanges represent the exact places where the commodity markets operate. Commodity exchanges are formal markets, where in a specific time and place, supply and demand is confronted. Purchase and sell of mass commodities is made, which are highly standardized in terms of degree of quality. The main task of commodity exchanges is to facilitate domestic and foreign trade, easiness of business contacts and economic development. The concept of exchange originally was related to money exchanges, where members meet at meetings within a place and time to perform the banker's duties. Before the exchanges were formed, the markets of low degree of organization existed, such as fairs, which initially meant annual meetings of the merchants. With the passage of time, the term exchange began to be used for all, repeatedly growing number of business meetings. Markets emerged from the tradition of fairs, when they began to have a fixed location. These commercial institutions passed the steps by which gradually developed into a modern commodity exchanges. The first step was the sale of large parts of commodities without its presence, the second introducing brokers, and third was to initiate different terms and forms of payment.[8]

Over the counter market is the market for securities, where transactions take place directly between market participants, without the mediation of a third party (the stock exchange). On this market, share price is determined between the two sides (brokers) for each transaction separately. Over the

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[7] N. N. Chatnani, *Commodity markets,* Tata McGraw-Hill Education, New Delhi 2010, p. 4-5.

[8] https://www.ewgt.com.pl/index.php?option=com_docman&Itemid=83&task=doc_download&gid=113, 03.09.2012 r.

counter market allows companies to raise capital without having to meet high requirements of the stock exchange. It is intended primarily for smaller and less reliable companies that do not meet the standards imposed by the stock exchange listed companies on the main market. Over the counter market is characterized by a high level of risk, and in many countries opportunity to invest on this market is limited to specialized entities and investors with relevant experience. Over the counter markets are in most countries regulated markets and are subject to supervision.[9]

2. History of trading commodities

Market is the most favourable meeting place in human history. Within early societies, only religious events could gather people together in a similar way. Differently, barter brought crowds together in a more random fashion (not as a result of some tribal or family connections), spreading out new ideas between communities on the way. First trading goods were agricultural products and everyday household needs. On a more distant way, it was a need to use a middleman, who could undertake high risk in order to gain huge returns. The first discovered trading city, Sumerian Elba, comes from a middle of the third millennium BC. First trading commodities had to be imperishable and relatively valuable comparing to their size, like: spices, textiles, silver, gold, copper, bronze and iron. When roads were still not common, water transportation was the easiest method of carrying goods on large distances. The earliest trade routes covered the biggest rivers alongside the backbones of early civilizations, the Nile, the Tigris and Euphrates, the Indus and the Yellow River. First extensive maritime trade emerged in Mediterranean, from Egypt to copper rich Crete, and further then explored by

[9] http://www.findict.pl/slownik/rynek-pozagieldowy-over-the-counter-otc , 08.10.2012r.

Phoenicians. Those Sea Peoples carried trade of luxurious products from cedar (timber of great resistance) and ivory, dye (Tyrian purple), fine linen and glass. Through domestication of camels, deserts become available for carrying trade. As a result connection between India, Mesopotamia and Egypt was possible. The great wealth of Petra was achieved, on the crossroads of many caravans following the Silk Road and for many years past mark out the circulation of goods between continents. Global economics took precedence, providing huge amounts of gold to China with simultaneous decline of Roman Empire. The rise of trade was seen globally, from a port of Malacca to Calcutta, with Singapore in the middle. The rise of trade in Africa was driven mostly by gold and slaves, alongside with ivory, ostrich feathers, cola nut and salt. Vikings successfully run trade throughout rivers between the Baltic and the Black Sea, giving a birth of Russia. The centre of triangular trade between Byzantine Empire, wild forests of north and steppe lands in between was established in Kiev. They traded gold, clothes, wine and fruits from Greeks, silver and horses from Czechs and Hungarians, and furs, wax, honey, and slaves from the Rus.[10] The world economy experienced drastic change after European Voyages of Discovery in the late fifteenth century. Christopher Columbus and Vasco da Gama aimed to destroy the monopoly in spice trade carried by Italian city-states (mainly Venice and Genoa) and Egypt, trying to find another way to reach India avoiding Silk Road.

The most urbanized and developed regions that time were Islamic controlled territories from Atlantic to Himalayas and China. Western Europe was rather underdeveloped rural area. The most rapid changes in a structure of world dominance begin with Black Death spreading in Europe in the 1340s, reducing the population by about a third. This smaller volume of production

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[10] http://www.historyworld.net/wrldhis/PlainTextHistories.asp?groupid=1916&HistoryID=ab72&gtrack=pthc, 04.09.2012 r.

and trade is seen as a Renaissance in Europe. The plague raised per capita wealth, incomes and wage rates, changing stagnant economy being at its Malthusian limits into rapidly growing area with the same amounts of gold, natural resources and farmland. This growth resulted in more demand for luxurious products manufactured by the East with outflow of precious metals. The inflationary economic policy could eventually reach its limits of production as before. However, different circumstances led to alternatives in many areas. Greater scarcity of labour forced feudal relationships and encouraged labour-savings innovations. What is more, increased demand for Asian merchandise coincided with the decease of *Pax Mongolica* and affiliated overland trade route, and in a consequence giving an Indian trade into hands on monopolistic Egyptian and Venetian middlemen. These circumstances increased the motivations to find alternate, sea route to Asia.

After the period of European Voyages of Discovery, the world economy was shaped drastically, linking Old and New World and reshaping previous trade structure and directions, even if the evidence would be seen in the next centuries. The origin of global trade is accounted as foundation of Manilla, which directly linked the trade from Europe, Asia, Africa and the Americas. Firstly, when the costs of transportation were still very high, the most long-distance shipment was done for commodities with high ratio of value to weight and bulk: spices, silver, silk and slaves. With a continuously development of technological change, capital accumulation and population growth, world trade systematically grow in volume. The first, most important influence on global economy was huge inflow of silver, which was called “price revolution of the sixteenth century”. Iberian Peninsula took its prominence from Venice and other Italian cities, breaking their monopoly on the spice trade through the Red Sea. The Kingdom of Portugal was soon replaced by the Dutch Republic, with Amsterdam as “the Venice of North”. Then the rivalry took place between the Dutch and the English West India companies. At the beginning the goods

being trade overseas were non-competitive; the only reason for trade was that they cannot be produced in target areas.

The time from sixteenth to the end of the eighteenth century is characterized by the steadily evolvement of the commodities being traded. As the time was passing, more and more bulkier goods were shipped. Usually, the goods as sugar or raw cotton did not have perfect substitutes as honey or wool, and faced gradual growth of trade volume. In fact, the nineteenth century brought decline in transport costs through technology improvements, making bulk commodities homogenous, for example wheat, iron and steel. Only shortly discovery of the Cape route to India made the Venetian trade diminish. Portuguese traders never accomplished to monopolize the spice trade. In the sixteenth century the amount of overland spice trade surpassed the amount from before sea route to India discovery. Nevertheless, the new route didn't make the prices of spices fall lower, finally it was made only in the struggle between England and Dutch in the first half of the seventeenth century. The amount of pepper production and export rose not only due to growing consumption in Europe but also from China. Chinese settlers in the Southeast Asia successfully increased the yields per acre using labour-intensive methods, which led to production growth. Pepper was the primary commodity imported from Asia, with gradually broaden basket of incoming goods. Other commodities imported were fine species, textiles, cotton, tea and coffee. Total imports from Americas are harder to find out, because there were not a few big companies which carried the trade. Main products are gold and silver, than sugar alongside with tobacco. Gross amount of American silver carried to Europe was used to pay for the Indonesian import of spices, Indian textiles and Chinese porcelain, silk, and tea. On the other hand, the excess of silver created monetary problems causing inflation.

Japan took also a huge part of the international exchange of goods that time. Primarily the source of silver and copper, Japan become importing

Chinese silk and cotton textiles. When the Ming dynasty ban the Japanese trade, Portugal use this situation to successfully arbitraging the silk market. They bought silk from China for American silver, and then sold it to Japan with a 70-80% profit. The unification by the shogun Hideyoshi in the second half of the sixteenth century after the civil war resulted in enormous growth in the economy. Especially, Korean miners brought forward new smelting technology which boosted extraction. Moreover, imported ammunition were used for firearms, copied from Portuguese and manufactured. Japanese silver mining diminished during the closing policy of Tokugawa ruler, making Americas silver the main source of global demand.[11]

The oldest stock exchange in Europe was founded in the sixteenth century in Antwerp in order to conduct speculations on pepper trade. Later on, exchanges in Lyon and Amsterdam were created. Amsterdam Stock Exchange is famous for its first crisis, which took place in 1636 when tulip bulbs bubble burst. To the oldest European stock exchanges belongs London Stock Exchange (1536), Paris (1724), Berlin (1740) and Vienna (1771). Futures markets were already known in the ancient Greece and Rome. In the thirteenth century in France and the UK practice of trading standardized goods with delayed delivery was commonly used. [12]

Undoubtedly, the greatest impact on creation of the stock exchanges in the world has the U.S. stock market. The first stock exchange was established in New York in 1725. One located on the east end of Wall Street, offered trade in wheat, tobacco and slaves. The second one located on Broad Street

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[11] R. Findlay, K. H. O'Rourke, *Commodity Market Integration, 1500-2000,* contained in the M. D. Bordo, A. M. Taylor, J. G. Williamson, *Globalization in Historical Prerspective,* University of Chicago Press, January 2003, p.25.

[12] https://www.ewgt.com.pl/index.php?option=com_docman&Itemid=83&task=doc_download&gid=113, 04.09.2012.

conducted trade in butter and eggs. The first future transaction accompanied in March 1851 (transaction included 3,000 bushels of corn for delivery in June with price of 0.01 dollar lower than in March). Futures were initially signed between domestic buyers and forward customers with the intention of physical delivery of goods. In the mid-nineteenth century, transactions often changed owner before the physical transfer of goods was established. After some time, many people began to trade with no intention of receiving purchased goods.

More than a hundred years ago, the first modern futures contract was created on the grain market. At the beginning of the second half of the nineteenth century, Chicago was the main centre of the grain trade in the U.S. market. There imports of wheat produced on the east coast of the U.S. were made and sent away to the west, in order to supply the settlers on the Pacific coast. Large and rapidly growing market for cash appeared. Participants on the market were exposed to the risk of abrupt changes in the prices of the goods due to the influence of many factors, including in particular weather. Atmospheric conditions affect not only the size of the yield, but also the routes, as long as the transport of grain was carried by the system of canals and lakes that froze during the winter. Undeveloped system of grain storage limited potential actions to decrease an impact of weather on supply and demand. The grain market for producers and buyers side was dominated by large companies, which specialize in one area of activity (farmers growing food and merchants dealing with trade). These entities were mainly interested in guaranteeing the appropriate high profit margins from their core business, even at the expense of profits due to possibility of extraordinary favourable price. They were trying to find a third party to move the risk of price fluctuations out.

At the same time, with the development of the financial markets and progressive process of capital accumulation, a group of financial investors, so called speculators, was interested in taking over this type of financial risk in

hope of gain a large profit. Appropriate infrastructural conditions were met, necessary for the proper functioning of the exchange. Infrastructure and regulations were not created by the state, but by the local government. Proper example could be the Chicago Chamber of Commerce. It was able to develop an effective circulation system, which beard in mind specific futures market participants, standardize the instruments to enable the widespread trade on them and create a system of clearing house which guaranteed the safety for all participants in the market.

The institution corresponding to the role of market-makers was created. There were investors from local community who conducted transactions on their own account directly on the floor. In these circumstances, the grain futures market had comfortable conditions for the development, which extends gradually for a long time. First future transaction was carried in March 1851. In 1972 introduced first futures contracts on the foreign currencies. There were also vast improvements in the trading and settlement technology, which affected the safety and increasing the efficiency of transactions. In 1975 a Commodity Futures Trading Commission was established (CFTC).

Trading futures based on grain, flour and cotton developed in earnest after Civil War in the United States. Additionally by the mid-seventies of the last century futures markets experienced a growing number of transactions amounting to: wheat, coffee, cocoa, sugar, pork and cotton. Breakdown of the agreements in an international conference in Bretton Woods demanded stable currency parities and led to a structural distortion in the field of interest rates. The financial turmoil has led to increased needs for the futures markets. They allowed market participants to not only protect against the risks associated with volatility of interest rates, but also against currency risk.

In 1972 futures trading on the foreign currency is introduced. In 1975 the futures of the interest rate on a given asset began. In 1981 there is an innovation in futures contracts whereby there is a possibility of paying a value

of the contract on the last day of each month. Cash execution of the contract is convenient tool for insurers and creates additional possibilities in contracts trading, which were no longer burdened by the high costs of delivery. On the largest commodity exchanges in the world millions of futures contracts are issued each year.

3. Commodities on a global markets

Commodities have substantial influence on amount of direct or indirect costs for every household. They exist on every place of our planet and can be invested in as a diversification of the portfolio. As a matter of fact, on the commodity market billions of euros are changing their owner each day.

Whilst two ways of markets on commodities exist: spot and futures, most volume of trading goes into futures market. Futures are not the commodity itself, they are contracts to purchase or sell them for a certain price by a stated day in the future. In a result, possibilities for sharp market instabilities occur, but on the other hand it creates likelihood for market participants to use volatility for achieving unusual profits.

In comparison to other investment activities, the goal is basically the same, to buy cheap and sell expensive. What is uncommon in the most markets, the level of leverage is huge and instruments are contracts not shares. Moreover, the markets operate twenty four hours a day, so the appearance of overnight risk is non-existent.

The most important commodities traded on the world market are:

- cocoa
- coffee
- copper

- corn
- cotton
- crude oil
- feeder cattle
- gold
- heating oil
- live cattle
- lumber
- natural gas
- oats
- orange juice
- platinum
- pork bellies
- rough rice
- silver
- soybeans
- sugar

The beginnings of harvesting cocoa reach for thousands years. They were brought to light for European market together with explorations of South America by conquistadors from Spain. Having its original flavour, it spread throughout Europe in seventeenth century. Being a bitter drink of the aristocracy in Mayan Empire, cocoa emerged as broadly traded good. Nowadays, cocoa is harvested mostly in West Africa and primarily processed by the United States and Netherlands. After the system of procession, it is consumed on every continent, mostly by the form of chocolate. The cocoa plant demands peculiar conditions in order to give good harvests. It is small evergreen that reaches from four and a half to eight meters and requires to be grown in regions which are distant at most 20 degrees from the equator.

There are not many places where cocoas can be cultivated and West Africa has been a leading region. Apart from its variety, production cycle of each type is similar. Cocoa trees usually need five years to be mature and have fruits. Ivory Coast, Ghana and Indonesia are producing more than 70% of world cocoa crops, where most part of it is represented by the small farmers. Factors which are commonly influencing cocoa prices are: global weather changes with environmental factors having huge impact on the populations of common pollinators, mainly bees, butterflies and midge flies; political situations in unstable countries which dominate cocoa production; temperatures not less than 15 degrees Celsius and not more than 2 hundred millimetres of annual rainfall; financial and political decisions of a few companies controlling the industry; influence of reports about exploiting children on a cocoa farms.

Origins of coffee farming in the Ethiopian mountains date back to the ancient times. Gross popularization of coffee as a drink was done in Constantinople in the fifteenth century, mostly during the reign of Ottoman Turks. This drink has a prominent influence on human body, giving strength and eliminating feeling of tiredness. Cultivation of coffee spreads around the world, with leading producers such as Brazil, Vietnam, Indonesia and Colombia. Coffee beans are grown in a little evergreen bush, with a maturity reaching period of about three to five years. The most important factor of its flavour brings a roasting process.

Copper belongs to metals which were known to the people since antiquity, being mined and melted even since 8 700 BC. Its wide spectrum of usage and a fact that it stands independently were the most reasons for its popularity. Furthermore, copper is a very good conductor of electricity. There exists two different ways of copper extraction: in large pits or from the ground. Being the third mostly used metal in the world, Chile and the United States possess its reserves for about next 50 years. The by-product of copper output is molybdenum, used to strengthening steel. The most important demand for

copper comes from India and China and is crucial to modern urbanization. The price volatility also reflects finding copper replacements.

Discovered in the Americas, corn has been a source of human diet probably from about 12 thousand years. It is widely used in for a different purposes, and its cultivation and consumption has been shape throughout the history. Taking into consideration the volume of production, it becomes the most significant cereal. The cultivation of corn has spread worldwide and is used as an important food for both animals and people. United States are leading in corn production, then China and Brazil comes third, with comparable amounts of production only to rice and wheat. Popular applications are: feeding livestock, corn syrup, new plastics and alcohol, as a source of ethanol production.

One of the most controversial, fortune building and country emergence cause is the historical demand for cotton. With India as the primary source of its harvesting, cotton was a main purpose for existence of Silk Road and struggles between British West India Company and Dutch VOC in the eighteenth century. With proceeding slavery, United States becomes the new biggest producer. Nowadays, cotton stands as an important commodity. Cotton shrub is creating cellulose fibre, comparable to wool. Cotton needs much sunshine, prolific ground and temperatures over zero degrees Celsius. Due to its water requirements, it is not easy to move its cultivation outside subtropical climate. As cultivation move on, the substantial irrigation was needed to replace natural habitat. In order to maintain cost-effective production, huge mechanization of farming industry is required. In fact, many countries still depends on manual labour. China, India and the United States comprehend for a most of global production of cotton, with China leading role as a main source of demand for its manufacturing industry.

Crude oil became one of the most crucial resources in the world, mainly because of its versatile utility and scarcity, being not equally placed on the

earth. It appears natively as a substance occurring in some rock formations beneath the earth. To gain the most from oil, it has to be refined into petroleum goods. Products derived from crude are petrol, petroleum gas, naphtha, kerosene, gas oil and fuel oil. To extract oil from the earth, oil wells have to be installed. First oil wells for drilling were supposed to be used in China in fourth century A.D. from a bamboo poles for growing salt industry. In the twentieth century oil became a global energy source, destroying whale industry. There are many types of oil which differentiate from each other by the lightness or sweetness. The difference results in cost and production time of refinement. The amount of good quality oil is diminishing due to running out of resources. This emphasises a problem with increasing demand of oil globally, especially with growing economies of India and China. The top oil producers are Saudi Arabia, Russia and the United States. What is more, over 62% of accessible oil resources lie in the Middle East, in the Saudi Arabia, United Arab Emirates, Qatar, Iraq and Kuwait. As a matter of fact, some countries do not produce oil in a full capacity due to unstable politics. Oil prices are highly influenced by the dollar, which is priced in this currency worldwide. Some geophysicists argue that oil extraction has already reached its peak, and global oil production is now in the continuing depletion. Within the period of crude prices going higher with technological development, there are some alternative ways for oil extraction, as tar sands and oil shale as well as turning coal into oil substitutes. Moreover, increasing interests in green energy may lead to displacing oil in the future.

Meat production is represented on the commodity markets by feeder cattle. These are weaned calves that are fed to attain some weight before being slaughtered. Beef consumption is widely popular in the whole world. The amount of cattle which become feeder cattle is strictly correlated with living cattle. The process of feeding takes about two years. Important impact had mad cow disease (BSE), which successfully limited beef consumption.

What is more, feeder cattle possess much more fat than other types of meat and are considered unhealthy.

Gold is famous for its representation of wealth and by its features is considered the safest way of saving and currency. Gold-backed and silver-backed dollar existed from 1792 to 1971. Since that time, volatility of gold increased enormously and now is priced many times above the levels from the seventies. Nowadays, gold is a source of investment, a part of jewellery and electronic devices. At the cores of global gold extraction are China, South Africa, Australia, Canada, Indonesia and Russia. Gold production is in continuing demise of meeting with demand. It is considered the best investment against inflation.

Heating oil is a spin-off from crude oil. It is a second largest fuel, started with the creation of the oil burner in the early twenties as a replacement of coal. Several advantages were brought together with heating oil: it did not require much space in basement, decreased level of pollution and ash, did not infect lungs and had a thermostat which could automatically manage temperature. Heating oil is widely used as a hedging against other fuels, but possesses its special qualities. Nowadays it stands as a substitute for homes with no connection to natural gas. Its price is affected mostly by the weather conditions in winter times, when the demand is correlated with frost. Moreover, as a by-product of oil, its production rises and price falls while more fuel for cars is needed.

Cattle were brought to the United States by the European settlers in the first half of the seventeenth century. It has been used to produce milk, leather, meat and labour. In order to achieve better products, cattle were subjected by diverse cross breeding experiments. In the middle of the twentieth century live cattle contracts were establish due to transfer risk of its price fluctuations. The biggest producers are the United States, India, Brazil and China. Rearing cattle is considered harmful due to greenhouse gas emissions.

The time of lumber introduction into commodity exchanges covers with the war periods. Standardization helped mills and lumber purchasers to make transactions with long distances away. Different uses of lumber make it volatile due to changing consumer interests, production facilities and real-estate market. Lumber originally has a very low correlation with other market instruments, decreasing risk measures in the portfolio. Canada is the largest wood exporter. Logging has been a part of agricultural debate since trees reduces negative effects of global warming.

The main source of heating homes in the United States is natural gas, as well as its broad use in industrial settings make it one of the most important energy carrier. The same attitudes have biogas extracted from the breakdown of organic substances. As a fossil fuel, after the process of filtration other by-products are emerging, additionally to methane come ethane, helium, hydrogen sulphide, propane and butane. Previously seen as unnecessary spin-off from oil refinement, it guarantees its strong market position due to efficiency and environmental friendliness. Natural gas is piped directly to recipients by the use of pipelines. Having problems with meeting the demands for a growing market, new sources have to be found. 96% of the natural gas lies outside the United States, with 15 countries possessing about 84% of its resources. Alongside with crude oil depletion, it has become a viable alternative energy source.

Oats belong to a group of firstly domesticated plants. Mostly oats are consumed as oatmeal, but its use as a food for livestock is the most popular. Having a tolerance to low temperatures, they guarantee good harvest even in small temperatures. The production of oats declined throughout the history due to car transportation, as a main feed for horses, and now they have been displayed due to soybeans and corn participation in the ethanol production. Nowadays, half of the production is used for hay. They have healing attributes as a reducer of heart diseases and are protein-rich.

The presence of oranges in Europe comes from Moorish occupation of Iberian Peninsula, having their origins in Southeast Asia and China. From that time, the orange industries emerged in Brazil and United States. Traditional way of consumption orange juice was fresh-squeezed, but the invention of frozen concentrated juice in 1947 allowed a huge expansion of the industry. Brazil represents about 80% of the wold orange juice production. Because of high exposure of two geographical regions (Brazil and Florida), orange juice prices are experiencing drastic shapes in the times of weather events in those territories. Another threat is connected with homogenous nature of orange trees, which exposed them to dangerous microbes.

Platinum played an important role in Native American cultures before the European discoveries. Platinum was always hard to melt, but its rarity made it more precious than gold. In the twentieth century Russia was producing around 90% of platinum. Its resistance to high temperatures, not oxidization and electrical properties make this metal very attractive. Huge resources of platinum have been found on the moon and in meteorites, but it appears very rarely on earth. 80% of deposits are found in South Africa. The original features of platinum guarantee its broad use in many industries: jewellery, automotive, health sciences, chemical refinement and high-tech electronics. Most of the platinum application is found in jewellery, so the price is very sensitive to consumer’s demand. Secondly, scientists are working on reducing its use in catalytic converters. It is one of the subjects of chemotherapy in cancer treatment.

Pigs comprehend firstly domesticated livestock independently in several regions around 9 hundred years ago. Christopher Columbus brought pigs to the American continent. Demand for pork bellies increased after expansion of the railways. Pigs are slaughtered in six to seven months, with the price highly influenced by the grain prices, which represent more than 65% of its costs.

Pork stands as a top meat consumed in the world, with China as a leader producer and consumer.

Rough rice represents the rice which is just harvested from a plant. Rice sustain as a great part of a diet for many people, especially in Southeast and Central Asia. Only small percentage of production is subjected to international trade, due to gross consumption in domestic markets mainly in India and China. The most rice exporters are Thailand, Vietnam and United States. Taking together those characteristics, rice is very attractive commodity to hedgers and speculators. Almost all production is used for food, but small percentage of output is distilled for alcohol in South Korea and Japan.

To the most valuable features of silver brightness, ductility and conductivity are classified. With its broad range of usage, as a source of money and jewellery are the most significant. It was considered as the prime mover to the conquest of Americas by the European settlers. While not being so scarce than gold, it was nevertheless used as a currency and its price moved along with gold. In many languages terms “silver” and “money” are synonyms. In the United States it was interchangeable for dollar before the Civil War by the central bank. After the 1971 abandoning of the gold standard, precious metals are experiencing systematically increase in value. The most important factor of silver price movement is its supply side, with most of the mining companies reaching its peak in production. It is also a by-product of extraction ore, such as copper, gold and zinc. Copper comprehends a quarter of overall silver production, so decreasing prices of copper which are highly influenced by the housing market are lowering silver production. Moreover, growing production of electronic equipment, especially popularity of solar panels, is driving the demand higher. Investments in silver belong to the currency hedging methods as well.

Soybeans became widely known after the Great Discoveries and from the XVIII century delivered oil and protein reach food, as well as animal feed.

Over a half of world production comes from Americas, where the export from the United States comprehends 37% of global production. Nowadays, small percentage of soybeans production ends as a foodstuff. The most important factors considering future pricing is genetic modification, with high political and consumers influence. The second largest soybeans producer is Brazil, facing problems with Amazon deforestation. The price of soybeans has huge impact on other grains, which could be used as substitutes, which makes the market highly influential.

Roots of commercial usage of sugar date back to the fourth century India, where Moors successfully improved the way of crystallization through mills and refineries. Then, after the Spanish and Portugal Reconquista, sugar production widen together with the discoveries in the New World. Sugar cane, the first source of sugar, is a perennial grass grown in tropical and subtropical areas. Another source of sugar is sugar beets. The leading producers are Brazil, India and the European Union. The sugar market faces many obstacles regarding subsidies and unfair market pricing. The most influence on price has frost damages in tropical regions, where sugar canes represent 78% coverage of the market production.[13]

[13] N. Drakoln, *Commodities: Introduction,* http://www.investopedia.com/university/commodities/default.asp, 05.09.2012 r.

4. Types of commodity derivative products

Commodity derivatives play significant role in risk management and are representing growing number of volume on the exchanges in recent years. Fluctuations of prices over time are considered as important risk factors of carrying business, and markets build tools to overcome those threats. Derivatives were created to reduce the risk of unexpected price changes. They are financial contracts, which price relies on the price of another asset. There are two main derivatives: futures and options. Futures and options trading offers possibilities to hedge against the risk, and also provide investments opportunities to speculators who are eager to acquire the risk in exchange for possible returns. Moreover, futures prices helped farmers in a decision making about what to grow. Derivatives market possesses important function in a modern business environment, but carries several threats to destabilization of economy due to much speculation activities.[14]

The futures markets and its instruments have advanced from what started as private negotiations to purchase and sell goods between producers and buyers. Those agreements which were granted through those mediations are recognized as forward contracts. Furthermore, standardized arrangements served also in a much faster way than privately negotiated contracts, and as a result future contracts were established.

Changes in agricultural trade began with formation of organized and centralized grain trade in the nineteenth century. Price stabilization and diminishing shortages and surpluses of production output between growing

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[14] N. L. Ahuja, *Commodity Derivatives Market in India: Development, Regulation and Future Prospects,* International Research Journal of Finance and Economics – Issue 2, 2006, p. 155-156.

and harvest times started stabilizing the industry. Nevertheless, prices still were not efficient enough through many fluctuations. In order to moderate price risks, farmers and tradesmen started engage in forward contracts. A forward contract is private agreement to establish price of a given good to be delivered at a specific date in the future. Presence of forward contracts helped with stabilization of the prices, but only if two parts survived to the end of the agreement. There was a possibility when the market price of a product was favourable for companies or farmers to default, not covering the contract obligations. To solve this problem, exchanges began to demand a deposit, also called margin, with a third party. In the case of default, the other side took the margin as a benefit.

Risk exposure of merchants and farmers has been successfully reduced by the forward contracts traded on the exchanges, with both market and default criteria. Another improvement was standardization. Each contract was equally the same in size, quality, delivery date and location. Trading became much more convenient when every contract was the same, and avoided conducting negotiations each time. The only variable was the price itself, which was determined in the marketplace. Although futures contract was created in order to carry the goods themselves, according to Chicago Mercantile Exchange only 3% of the futures contracts end with physical delivery of underlying commodity. In reality existence of two markets in modern trading take place, cash market and futures market. Cash market, or spot, is connected with physical delivery. Futures market only carries obligations of delivery, not the actual commodity.[15]

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[15] C. Garner, *A trader's first book on commodities: an introduction to the world's fastest growing market,* FT Press, New Jersey 2010, p. 18-21.

5. Recent changes on the commodity derivatives market.

Rapidly growing volume on commodity markets is experienced for more than decade. Regarding recent data from 2010, the number of contracts traded extended by 47% in three years. Commodities are more widely used as an asset class and easier access to options are the two main factors of this growth. Therefore, notional value of over the counter trading commodities experienced strong decrease by 66%, preluded by the five times growth in a previous period. The most important centres of the commodity trading are London, New York and Chicago. Commodity assets under management experienced extreme growth, multiplied by four times to 360 billion of dollars in 2010 corresponded to 90 billion in 2005. The bulk of funds engaged in trading into precious metals and energy products. Rise in commodities under management was highly influenced by the increase in value of commodities themselves, with gold reaching its 30 years high.

The value of commodities trading on exchanges increased by around a fifth in a previous decade to over 2 500 million contracts, mainly by growing numbers from China and India. Outstanding value of indices, medium term notes and exchange traded products investments by the funds equalled 310 billions of dollars in the end of 2010 from 113 billion in 2008. This increment was accounted mostly due to additions in value of precious metals.

Physical trading is largely conducted on the over the counter markets, where individually tailored contracts are arranged. Another part of wholesale market is represented by spot trading, typically done by intermediaries in a delivery based system. There is no central place of the trade in the most of commodities - only small percentage of total trade is conducted.

Derivatives trading on the over the counter market dropped by two-thirds, mostly due to reduction of risk reduction and uncertain global economic conditions. Significant amount of OTC derivatives represents interest rate

contracts and foreign exchange contracts. Over the counter market is responsible for trading twice as much as gold than in exchanges, where silver represents only 40% of its trade.

Competitive, transparent and open environment is the main characteristics of gathering together large numbers of buyers and sellers through the exchange trading. Derivatives exchanges are more standardized in sizes, margin and maturity dates than their OTC counterparts, as well as domination of soft commodities. Futures markets are now mostly traded on commodity exchanges, which evolve into places where hedging to protect against losses and speculation for gains took precedence over physical delivery. Agricultural producers and consumers can cope with price risks through derivatives markets.

More than 90 commodities are traded in around 50 major exchanges worldwide. Exchange trading comprehends mostly soft commodities globally, especially in Asia and Latin America. Exchanges with prevailing metal trading are London, New York, Chicago and Shanghai. New York, London, Tokyo and Middle East are also ruling energy contracts, with some energy exchanges in Europe were created lately. The following trends in the commodity market are seen in recent years: growing importance of China and India markets on global commodities, with rose of Chinese involvement of total commodities traded from 40% in 2008 to 60% in 2009.[16]

[16] M. Maslakovic, *Commodities trading,* TheCityUK, 2011r.

II. Structure and organization of wholesale energy market in Poland

1. Introduction to trading commodities

Exchanges in Poland have their origins reaching the Middle Ages. Trade relationships with neighbours, especially German states, as well as Flanders or France, often took on a formal character (like Hanza), which set certain standards for merchants. There is no doubt that the German influence was the strongest, especially during the development of commodity exchanges after the First World War. Traditions of trading commodities in Poland date back in the late eighteenth century. Polish term "stock market" is derived from the word "Guild", meaning the meeting of the merchants. These meetings were conducted on the similar habits of other European countries. Since 1775, the merchants met in Warsaw twice a week to discuss the most important commercial matters.

Poland's first mercantile exchange was opened on 12 May 1817 at the Saxon Palace in Warsaw. Exchange does not have its own legal legislation; it was maintained by the city budget and assisted by traders. Direct supervision of the exchange held the President of the city, and later President of the Polish Bank. This exchange has never possessed any greater economic importance because of its small volume, and the increased traffic was only twice a year, during the "general markets", which were held in Warsaw since 1817.

As a result of the November Uprising, the activity of the Warsaw Stock Exchange was interrupted to 1872. Stock exchanges in Krakow (1819), Lwów (1866), Wrocław (1822) were established in the nineteenth century. They were both cash and commodity exchanges. After gaining independence in Poland

the commodity boom began. In January 1921 a new law was introduced into the organization of commodity exchanges, which harmonized the solutions used to functioning markets in different parts of the country. In 1924 it was replaced by the President's ordinance. This legal act and subsequent amendments from 1928 regulating activities of stock exchanges during the interwar period is valid to this day. Members of the commodity exchanges could be: individuals, legal persons, consumers' organizations and public institutions. Prohibition of membership were: active military servants, clergy, professional judges, government officials, persons convicted for listed crimes, a person insolvent and found guilty bankruptcy and those who are excluded from the exchange.

Permission to open a commodity exchange issued Minister of Industry and Trade after hearing the opinion of the relevant chambers of commerce. In the case of boards on which traded agricultural products, decision was taken after obtaining the opinion of the Minister of Agriculture and Agricultural Reforms and the right of Agricultural Chambers. Stock exchanges have legal personality. They were regulated by the statue laws the same on whole country. The main bodies were: the General Assembly of Stock Exchange Members, The Stock Exchange, the Court of Arbitration and Disciplinary Commission.

At the beginning of the interwar period there were six commodity exchanges: four grain exchanges in Warsaw, Krakow, Lvov, Poznan; two wood markets: in Bydgoszcz and Warsaw, then meat exchanges in Warsaw, Krakow, Lodz, Lublin, and Vilnius were established. The most important exchanges for the whole interwar period are: Agricultural Exchange in Poznan, Grain and Commodity Exchange in Lwów, Grain and Commodity Exchange in Warsaw, Textile Exchange in Lodz and Wood Exchange in Lublin.

After the World War II feeble attempts to revive exchanges were made. The legal regulations referred to Act of 1924, and modelled on experience of

German and French organizations. Commodity Exchange in Bydgoszcz reactivated on 20th December 1946. Status of the stock broker was regulated initially by the ordinance of the Minister of Industry and Trade in 1938. In the following years responsibilities of a broker were expanded, while reducing his income. Commodity Exchanges were successfully abolished by the decree of the State Trade Inspection on 21th of September 1950. Exchange institutions were replaced by the polish companies of foreign trade. In the years 1950-1989 there were no conditions for any exchanges in a new socio-political system.

Launched at the end of the eighties era of free market has brought many new economic opportunities. In times of socialism trade of commodities was fully controlled by the state. Only after 1989 as a result of the changes that have occurred in the country, important role gained all the instruments related to the trade economy. At that time, there were created several institutions which use the name of the stock market.

A large part of them were forced to abandon their activity due to low turnover and problems with gathering adequate capital. Additionally they had nothing to do with the institution "commodity exchange" - usually these were ordinary office trade agencies, often represented by usual warehouses on which goods were physically stored.[17]

[17] https://www.ewgt.com.pl/index.php?option=com_docman&Itemid=83&task=doc_download&gid=113, 05.09.2012 r.

2. Energy as a main resource on commodity exchange

The basic principles of operation in the national electricity market are contained in *Prawo Energetyczne* and related legislation acts. Energy law does not provide specific restrictions to different ways of carrying trade. Currently, the Polish energy market is divided into three main parts:

- contract market,
- exchange market,
- balancing market.

In addition, electricity trade can be obtained through the internet-based power trading platform POEE. Energy trading on the contract market is based on bilateral contracts (agreements) concluded between energy producers and energy trading companies and final clients. Exchange market involves trading on the commodity exchange (*Towarowa Giełda Energii S.A*. furtherly called TGE S.A.). Trade on the TGE S.A. exchange represents most volume comparing to other energy trading exchanges or platforms, with the most popular RDN market for day-ahead transactions. TGE S.A. also provides Market Coupling with Sweden where energy imported is traded and derivatives market for electricity (RTEE).

Balancing Market (BM) includes transactions by network operator *Operator Systemu Przesyłowego* (OSP) to close the balance and adjust production of electricity for determining the technical requirements for carrying safe and reliable operations of the National Power System[18].

OSP is responsible for connecting and closure the balancing market based on offers reported by manufacturers and suppliers. In that way, balancing

[18] Godzinowy rynek bilansujący energię elektryczną w Polsce, Polskie Sieci Elektroenergetyczne S.A. – Operator Systemu Przesyłowego, Warszawa 2001

market prices are established. The balancing market allows liberal trade of electricity in the system on the national level through physical implementation of contracts for the sale of electricity, ensuring that:

- Balancing the actual electricity production with current power consumption
- Keeping in the good technical condition transmission system
- Maintain the standards of quality electricity supplied to customers

A competitive electricity market can be functioning only when the system operates on a standard state. In case of any threat to the system OSP freezes electricity market until liquidation of cause. Then, planning and operations take place in accordance with emergency procedures specified in the terms of the balancing market.[19]

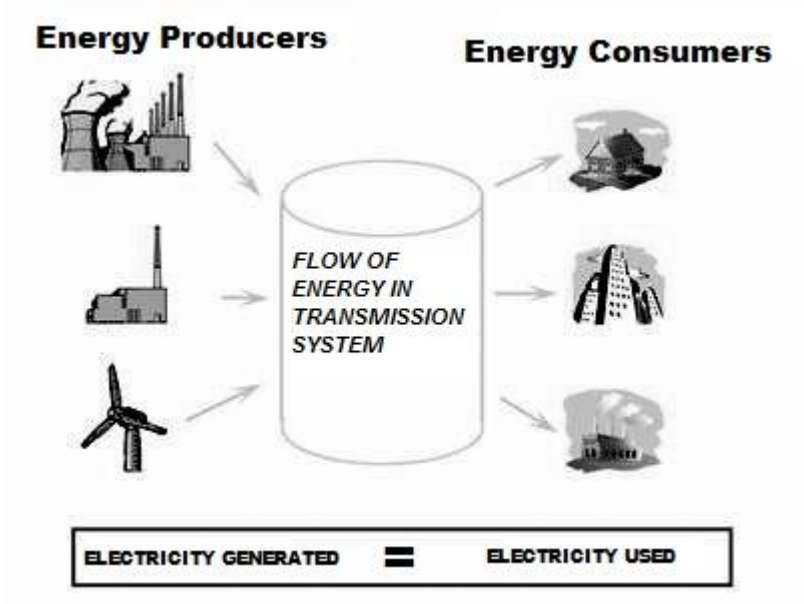

Figure 1. *Flow of electricity from producers through suppliers to consumers*

[19] Instrukcja ruchu i eksploatacji sieci przesyłowej

Functions performed by the OSP under administration of the market can be simplified to the following processes:[20]

- Coordination of planning, including the selection and distribution of production units load between them
- Conducting operative transmission
- Quantitative measurements and settlement of physical flows of electricity
- Settlement value of electricity being traded on the balancing market

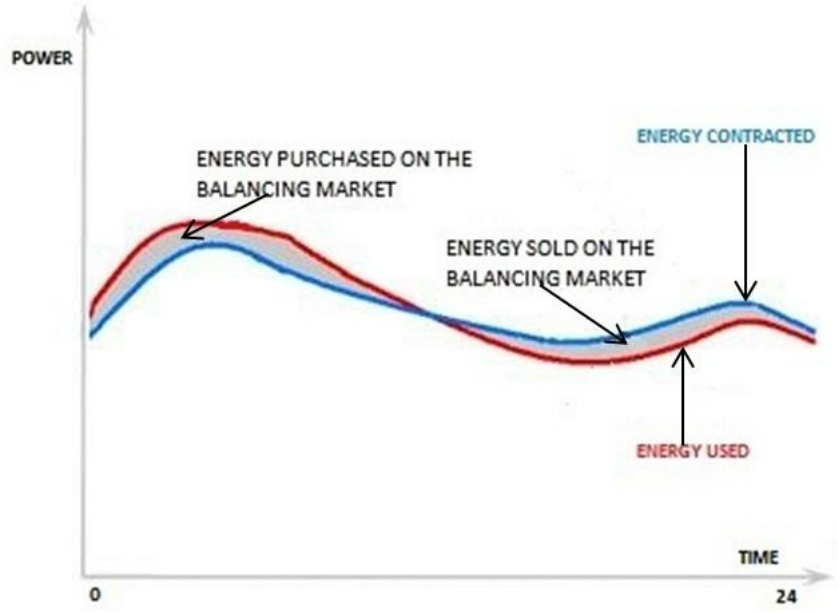

Figure 2. *Balancing market function - matching differences between contracted and used electricity*

Due to the costs emerging from balancing market, participants are exposed to the largest risk in the wholesale market. Any distinction from the plan that differs by ± 1% involves high financial consequences. Those prices, however, could be only one penalty for participants of the market, they neither bear any

[20] Zerka M., Mechanizmy rynkowe w elektroenergetyce – zagadnienia wybrane, Instytut Doskonalenia Wiedzy o Rynku Energii., Warszawa 2001

other consequences for their mistakes in the schedule, nor they can speculate and transfer purchases related to other segments of the market for balancing market.

3. *Specifics of RDN market* on *Towarowa Giełda Energii S.A.* exchange

Schedule for the liberalization of the electricity market and privatization of the energy sector were adopted by the minister of the Treasury in April 1999.[21] This document introduced structure of the commodity exchange market, mechanisms of operations and relationships between its members. From the point of view of existing legislation, there were not any restrictions present, which were suppressing arousal of new power trading in Poland. After the reform one major stock exchange was created named *Towarowa Giełda Energii S.A.* The Company was registered and commenced operations on 7th of December 1999. Important feature of the newly created exchange was development of objective market prices, which could be referenced back by any other energy contracts being available on the market.

Currently, *Towarowa Giełda Energii S.A.* offers to its participants the following services:

- The next day market (RDN)
- Futures market (RT)
- A one-day base (PJ)

[21] Ministerstwo Gospodarki i Urząd Regulacji Energetyki „Rynek energii elektrycznej w Polsce - Zasady działania rynku energii elektrycznej w Polsce w roku 2000 i latach następnych", Warszawa 1999

RDN states as main energy market on the exchange. This market is carrying out the day before physical delivery. It consists of 24 independent markets where members can freely buy and sell energy, according to their needs for every hour individualy. The price is created by the connection of supply and demand curves.

The rules for acceptance of orders are as follows:

- All offers for sale with prices below the fixed price for a given time are accepted
- All bids with prices above the fixed price for a given time are accepted
- All offers made at a price equal to the fixed price can be accepted in whole or in part (level of reduction is the same for all offers)

Derivatives Market - on the futures market contracts are listed with weekly and monthly base and for the several hours grouped together. The current rules of the instruments available on the exchange and trading hours can be found on *Regulamin obrotu TGE.*[22]

[22] Regulamin obrotu Towarowej Giełdy Energii S.A.

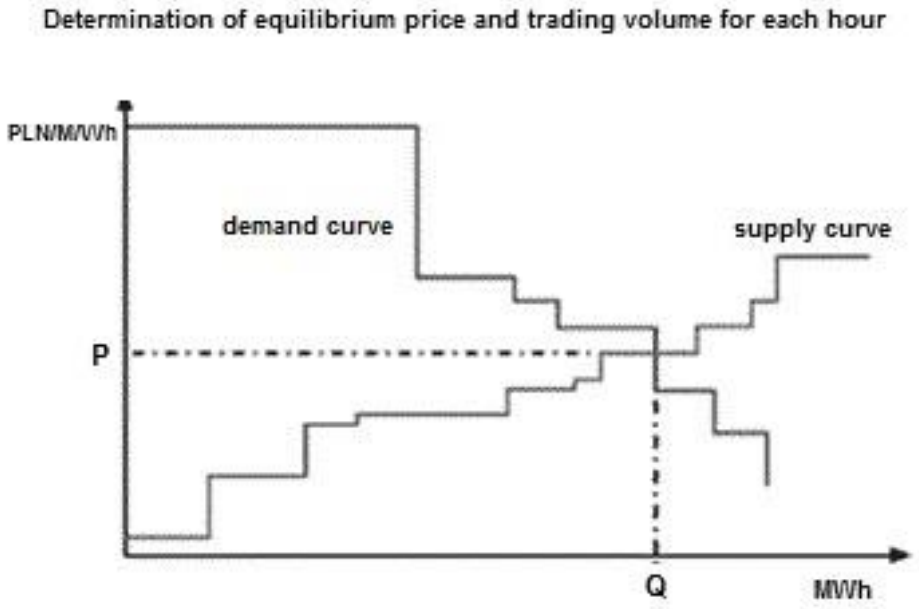

Figure 3. *Scheme of market price occurrence when all supply and demand orders are matched*

A futures contract is defined as a contract that requires the seller (issuer) to supply electricity in a specified period and after certain price, and that requires the buyer (the buyer) to purchase energy electricity in a specified period and at a specified price. Future development of TGE SA extended trading on the current day market (RDB), running on the same way as RDN with possibility of carrying out transactions 2-4 hours before physical delivery.

III. Construction of effective transaction model working on RDN fixings and Market Coupling for a big-volume energy supplier

1. Methodology and assumptions of model creation

Profitable participation on the wholesale energy market demands using sophisticated methods and due diligence in decision making process. Buying side encounters more difficulties, because their trading results can be strongly affected by the unfavourable balancing market prices. **Bearing in mind, that prices there can often skyrocket, successful risk management is the key to success in their trading process.**

The aim of this model has twofold aspects. Mainly, risk measurement should provide tools to avoid rare but very disadvantageous energy prices on the balancing market, efficiently identifying dangerous scenarios. Moreover, strictly applied risk tools should help to maintain profitability of the model, not to restrict it only by the risk aversion.

The implementation of the model should be useful in an everyday analytics and order preparation duties of the broker representing the buying side of the market. For that reason, the code needs to be accessible for extensions and all parameters easily to modify with back testing feature. Alongside, it has to work on multiple time frames and be updated to future market conditions efficiently and without much effort.

Specification of the model comprises several assumptions in order to avoid over complication and stands more as a representation of the concept rather than the system ready for deployment. Even though it is based on historical market data it is not optimized to represent the best result, just to verify the

stated hypothesis. What is more, it does not aim to predict any of the future market prices, but rather undertakes decisions by conditional cause and effect analysis. Model aims to help big volume buyer, so its performance concentrates on three fixings being part of TGE exchange, because of small volume to be found on any other market type or exchange.

Obtaining relevant financial data is a first step for making any forecast. What is more, this data should be well organized, and separated from the main program. This could be obtained by creating a database, where two types of data sources are present which are organized differently. Market prices from TGE exchange [23] are available to be inserted in the database when all individual contracts for RDN market are chosen with all options. Alongside balancing market data can be updated by downloading specified period from the main page of OSP.[24] Data in the database is organized in relational model, with respect to Boyce-Codd Normal Form database design.[25]

Many calculations are needed to be done in order to proper evaluation of the model's performance and using a computer power seems to be necessary. The most popular working environment for preparing such tasks is Microsoft Excel, but connection between different sheets and VBA code in larger projects is very unreadable and errors are difficult to handle. To avoid such threats, programming language with easy syntax, support of object-oriented paradigm and rich scientific libraries is needed. Thus, Python Programming Language[26] with built-in embedded SQLite database[27] and NumPy module[28]

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[23] http://wyniki.tge.pl/wyniki/archiwum/, 17.11.2012 r.

[24] http://www.pse-operator.pl/index.php?dzid=83, 17.11.2012 r.

[25] C. Ritchie, *Relational database principles,* Thomson Learning,

London 2004, p. 77-87.

[26] http://www.python.org/, 17.11.2012 r.

with support of many matrix operations are found to comply with all the requirements.

Additionally, in some trading hours energy prices on the balancing market tends to be higher than others, especially at day peak when demand for energy is the highest. To decrease the risk of high exposure to achieving rare big losses, Value at Risk can be a good measure to avoid unnecessary risk concentration. Value at Risk measure accepts specified value of risk exposure in whole portfolio or particular asset, when defining its confidence level.[29]

2. Preparation of data in a properly designed database

In order to produce reliable results, every research has to be done with clearly structured data and easy access to them. In this case the Model would be using two main sources of data: exchange data from TGE S.A. and balancing market prices published by PSE Operator, both available at their internet websites. Unfortunately, they are organized in a completely different way. Balancing market prices are published in a way, where unique keys are combination of date and trading hour. Exchange data is organized with unique keys as date and type (price or volume). Both of them have to be reorganized to reach certain criteria.

In the relational database design, there are three normal forms which every database tends to follow:

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[27] http://www.sqlite.org/, 17.11.2012 r.

[28] http://numpy.scipy.org/, 17.11.2012 r.

[29] G. A. Holton, *Value-at-Risk, theory and practice*, Academic Press, San Diego 2004, p. 22 – 24.

- No repeating elements or groups of elements
- No partial dependencies on a concatenated key
- No dependencies on non-key attributes

In compliance with above constraints, there should be four tables reflecting appropriate aggregation of data: day types, data types, dates and market data.

```
connection = sqlite3.connect('Energy.db')

with connection:

    current = connection.cursor()

    current.execute("PRAGMA foreign_keys = ON")

    current.execute("DROP TABLE IF EXISTS MarketData")
    current.execute("DROP TABLE IF EXISTS Dates")
    current.execute("DROP TABLE IF EXISTS DayTypes")
    current.execute("DROP TABLE IF EXISTS DataTypes")

    current.execute("CREATE TABLE DayTypes
(Id INTEGER PRIMARY KEY, Desc TEXT)")

    current.executemany("INSERT INTO DayTypes VALUES(?, ?)", daytp)

    current.execute("CREATE TABLE DataTypes
(Id INTEGER PRIMARY KEY, Desc TEXT)")

    current.executemany("INSERT INTO DataTypes VALUES(?, ?)", datatp)

    current.execute("""CREATE TABLE Dates
(Date TEXT PRIMARY KEY, DayType INT,
FOREIGN KEY(DayType) REFERENCES DayTypes(Id))""")

    current.executemany("INSERT INTO Dates VALUES(?, ?)", dates)

    current.execute("""CREATE TABLE MarketData
(Date TEXT, One REAL, Two REAL, Three REAL, Four REAL,
Five REAL, Six REAL, Seven REAL, Eight REAL, Nine REAL, Ten REAL,
Eleven REAL, Twelve REAL, Thirteen REAL, Fourteen REAL,
Fifteen REAL, Sixteen REAL, Seventeen REAL, Eighteen REAL,
Nineteen REAL, Twenty REAL, TwentyOne REAL, TwentyTwo REAL,
TwentyThree REAL, TwentyFour REAL,Type TEXT,
FOREIGN KEY(Date) REFERENCES Dates(Date),
```

```
FOREIGN KEY(Type) REFERENCES DataTypes(Id))""")

    current.executemany("""INSERT INTO MarketData VALUES(?, ?, ?, ?, ?, ?, ?, ?,
?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)""", mdata)
```

This database schema demands reorganization of downloaded raw data, and such reorganization can be seen below. Two scripts are responsible for filling up variables with corresponding data, and those variables are updating the database in a code seen above. What is more, to maintain simplicity, **trading days with non-standard trading hour number (days when time zone changes) are omitted**.

```
with open('RDN_20121011_1707.CSV') as file:
    file.readline()
    file.readline()
    file.readline()
    file.readline()

    for line in file:
        l = line.replace('\n', '').split(';')

        if l[3] == '' or l[4] != '':
            continue

        for i in xrange(2,77):
            try:
                l[i] = float(l[i])
            except ValueError:
                l[i] = None

        day = l[0].split()[0]

        if l[1] == 'Wolumen':
            fixtype = [5, 6, 7]
        elif l[1] == 'Cena':
            fixtype = [1, 2, 3]

        fixing = [l[2:27], l[27:52], l[52:77]]

        for i in range(len(fixing)):
            del fixing[i][2]
            fixing[i].insert(0, day)
            fixing[i].append(fixtype[i])
            mdata.append(fixing[i])
```

```
with open('daneRB.csv') as f:
    f.readline()

    for line in f:
        l = line.replace('\n', '').split(',')

        try: p
        except NameError:
            p = [l[0]]
            v = [l[0]]

        if l[0] != p[0] and len(p) == 25:
            p.append(0)
            v.append(4)
            mdata.append(p)
            mdata.append(v)
            p = [l[0]]
            v = [l[0]]
        elif l[0] != p[0] and len(p) != 25:
            p = [l[0]]
            v = [l[0]]
        else:
            pass

        p.append(float(l[2]))
        v.append(int(l[5]))
```

Demand for energy is determining the price, and it is mostly affected by the amount of production capacity in operation in the whole economy. Thus, working days represents the highest energy usage, and Sundays with holidays the lowest. These results in a diversification of energy days into three groups: working days (day type 0), Saturdays (1), and Sundays with holidays (2). With above distinction every analysis of energy market should be performed. To assign every day with corresponding day type value, the following code is executed for years 2010-2012 with all holidays explicitly stated. For the previous data, only holidays with fixed date are differentiated. To examine which day belongs to which type, calendar module is used, which possesses relevant methods.

```
import sqlite3, calendar, datetime

years = [2010, 2012]

timezone_change = [
    [2012, 10, 28],
    [2012, 3, 25],
    [2011, 10, 30],
    [2011, 3, 27],
    [2010, 10, 31],
    [2010, 3, 28]]

moving_holidays = [
    [2012, 1, 6],
    [2012, 4, 8],
    [2012, 4, 9],
    [2012, 5, 27],
    [2012, 6, 7],
    [2011, 1, 6],
    [2011, 4, 4],
    [2011, 4, 25],
    [2011, 6, 12],
    [2011, 6, 23],
    [2010, 4, 4],
    [2010, 4, 5],
    [2010, 5, 23],
    [2010, 6, 3]]

fixed_holidays = [
    [1, 1],
    [5, 1],
    [5, 3],
    [8, 15],
    [11, 1],
    [11, 11],
    [12, 25],
    [12, 26]]

day_types = [
    'working day',
    'saturday',
    'sunday/holiday']

data_types = [
    'BalMPrice',
    'Fix1Price',
    'Fix2Price',
    'Fix3Price',
    'BalMVol',
```

```
    'Fix1Vol',
    'Fix2Vol',
    'Fix3Vol']

mdata = []
cal = calendar.Calendar()
holidays = []
dates = []
years[1] += 1
excluded = []
wrk = range(5)

daytp = zip(range(3), day_types)
datatp = zip(range(8), data_types)

for item in moving_holidays:
    holidays.append(datetime.date(item[0], item[1], item[2]).isoformat())

for year in range(2001, years[1]):
    for item in fixed_holidays:
        holidays.append(datetime.date(year, item[0], item[1]).isoformat())

for item in timezone_change:
    excluded.append(datetime.date(item[0], item[1], item[2]).isoformat())


for year in range(2001, years[1]):
    for month in range(1, 13):
        for day in cal.itermonthdays2(year, month):
            if day[0] != 0:
                line = [datetime.date(year, month, day[0]).isoformat()]

                if day[1] == 6 or line[0] in holidays:
                    line.append(2)
                elif day[1] in wrk:
                    line.append(0)
                elif day[1] == 5:
                    line.append(1)

                if line[0] not in excluded:
                    dates.append(line)
```

3. Specification of the Model

Object-oriented paradigm can be used efficiently in programming the Model behaviour, where every trading day can be represented by an object which possesses special attributes. Initialization processes, where individual attributes are describing features in its primary state, are represented at the beginning of the class in __init__ method as a good practice in every Python code.

```
    def __init__(self, date, demand=[200 for x in range(24)], fixing=1, conf_level=0.90):
        self.date = date
        self.demand = demand
        self.fixing = fixing
        self.conf_level = conf_level
        self.daytype = self._retrieve('SELECT Daytype FROM Dates WHERE date = ?',
(self.date,))
        self.safe = self.safe_price()
        self.min = self.min_price()
        self.est = self.est_demand()
        self.ref = []
        self.market_data = []
        self.purchase = [[0 for x in range(24)]]
        self.var = self.VaR()
        self.calls = []
        self.result = []
        self.rest = []
```

After importing the module, initialization state follows. Since every object represents one trading day, instance name for a class could be a weekday. Instance can be called with any attribute it possesses, for example date, day type and demand for energy in a given day (when demand parameter is not defined in the instantiation process, **it is assumed that for every trading hour 200 MWh is required**).

```
>>> from rdn import *
>>> wednesday = RDN("2012-02-29")
>>> wednesday.date
'2012-02-29'
>>> wednesday.daytype
0
>>> wednesday.demand
[200, 200, 200, 200, 200, 200, 200, 200, 200, 200, 200, 200, 200, 200, 200, 200,
 200, 200, 200, 200, 200, 200, 200, 200]
>>> wednesday.conf_level
```

0,9

As with many parts of the code, obtaining data from database is needed to select the appropriate data for making further use of them. In this case inner method _retrieve is written, which establishes connection with the database, run and return results of specified queries.

```
def _retrieve(self, query, options):
    data = []
    connection = sqlite3.connect('Energy.db')

    with connection:
        current = connection.cursor()
        current.execute(query, options)

        while True:
            row = current.fetchone()
            if row == None:
                break
            elif len(row) > 24:
                row = list(row)

                for i in range(len(row)):
                    if row[i] != None:
                        pass
                    else:
                        row[i] = nan

                data.append(list(row[1:25]))

            elif len(row) == 1:
                data = row[0]

    return data
```

As an example of using _retrieve, average method is a good example of using _retrieve, returning average data (can be both volume and price) with given criteria. This method is another method which is used a few times in the code.

```
def average(self, date, ext=3):
    query = "SELECT * FROM MarketData INNER JOIN Dates ON
MarketData.Date = Dates.Date WHERE MarketData.Date = ? AND Dates.DayType =
? AND MarketData.Type IN (1, 2, ?) ORDER BY Date DESC LIMIT 3"
    opt = (date, self.daytype, ext)
    prices = self._retrieve(query, opt)
    mprices = ma.masked_array(prices, isnan(prices))
    if ext == 3:
        volumes = self.est_demand()
    else:
        volumes = self.est_demand()[:2]
    mvolumes = ma.masked_array(volumes, isnan(volumes))
    avg = ma.average(transpose(mprices), 1, transpose(mvolumes))
    return avg.filled(nan)
```

Average market price on the RDN market can be obtained by the following equation:

$$P_{avg} = \frac{\sum_{i=1}^{n=3} Vol_i * P_i}{\sum Vol_n}$$

Calculating average market price involves using two variables: price and volume. Since the model does not aim to predict the price and such estimations requires too much complication and are burden by the low level of accuracy, there is a need to apply another approach. Much better results can be achieved determining average market prices by the estimation of volume,

and such estimations are far more reliable. In this manner, placing orders with much higher price with rightfully estimated volume has to result in following the market behaviour, and thus should be assumed as a benchmark. To maintain simplicity and for the use of this model, previous day proportion of market volume is assumed as valid. In fact much of the volume change has to come with fundamental data such as transmission capacity in Market Coupling (third fixing) and simply due to price fluctuations, but any of those events are not subject of estimation in this model.

```
    def est_demand(self):
        query = "SELECT * FROM MarketData INNER JOIN Dates ON
MarketData.Date = Dates.Date WHERE MarketData.Date < ? AND Dates.DayType =
? AND MarketData.Type IN (5, 6, 7) ORDER BY Date DESC LIMIT 3"
        opt = (self.date, self.daytype)
        volumes = self._retrieve(query, opt)
        sums = nansum(transpose(volumes), axis = 1)
        demand = divide(volumes, sums)
        demand = nan_to_num(demand)
        self.est = demand

        return demand
```

Product of the above code is a matrix of previous day (with the same day type) percentage distribution of volume in every fixing. In this case, 28th of February is standing for a basis of this calculations. To replicate market behaviour, the Model should purchase energy in the same proportion.

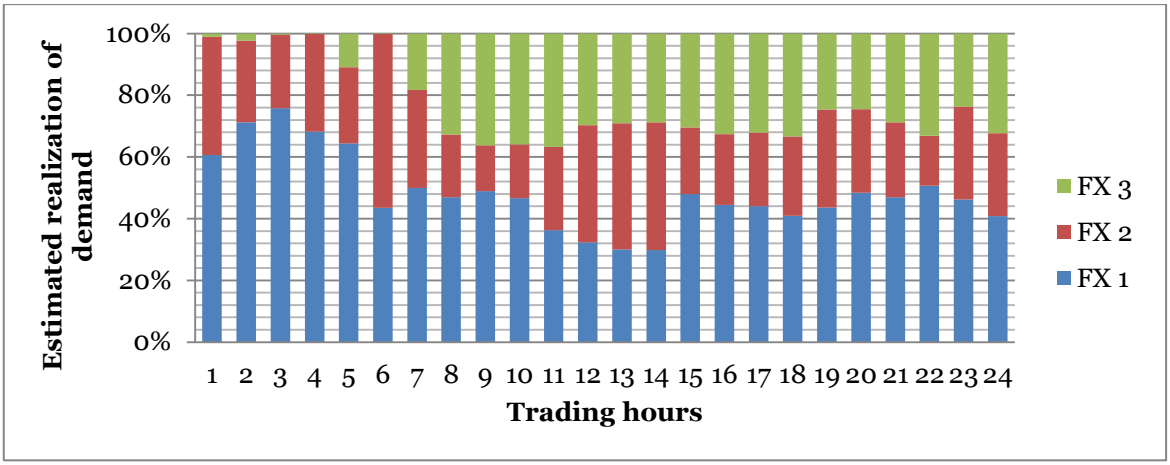

Figure 4. *Estimated realization of demand used in the Model - example of 29th February 2012*

>>> wednesday.demand >>> wednesday.calls

hour	FX 1	FX 2	FX 3	FX 1 [MWh]	FX 2 [MWh]	FX 3 [MWh]
1	60,60%	38,28%	1,11%	121,2	60,8	1,3
2	71,28%	26,44%	2,28%	142,6	81,4	2,3
3	75,82%	23,82%	0,36%	151,6	78,0	0,3
4	68,19%	31,71%	0,10%	136,4	118,0	0,1
5	64,39%	24,67%	10,94%	128,8	100,8	10,9
6	43,55%	56,31%	0,14%	87,1	130,0	26,3
7	49,97%	31,76%	18,27%	99,9	73,5	29,2
8	46,97%	20,28%	32,75%	93,9	59,3	71,4
9	48,95%	14,81%	36,24%	97,9	19,4	74,4
10	46,67%	17,40%	35,93%	93,3	53,5	64,7
11	36,31%	26,92%	36,77%	72,6	61,1	79,6
12	32,37%	37,92%	29,71%	64,7	82,3	67,7
13	29,99%	40,95%	29,06%	60,0	87,9	66,9
14	29,81%	41,44%	28,74%	59,6	100,8	67,6
15	48,01%	21,58%	30,41%	96,0	52,8	66,1
16	44,45%	22,94%	32,62%	88,9	54,8	52,2
17	44,04%	23,92%	32,04%	88,1	56,6	44,9
18	40,93%	25,78%	33,29%	81,9	59,7	72,6
19	43,59%	31,81%	24,59%	87,2	72,3	39,4
20	48,40%	27,10%	24,49%	96,8	43,9	39,2
21	46,96%	24,24%	28,79%	93,9	57,9	86,5
22	50,65%	16,18%	33,17%	101,3	12,6	68,9
23	46,23%	30,05%	23,72%	92,5	78,6	37,9
24	40,81%	26,86%	32,32%	81,6	78,2	51,7

Table 1. *Demand and calls methods output of the RDN class – example of 29th February 2012*

Prices in relevant fixings can be assumed to behave in a random walk. Some more sophisticated models can determine their belonging to time series or set a distribution. As a matter of fact, even their range is very useful in determining the area in which orders should be placed. One important remark is that even if many trading hours fluctuate in tandem, in the whole model every trading hour is treated independently and the whole computations apply only to one hour separately.

Upper range border should be established based upon the forecast of balancing market price. Therefore, if balancing market price is expected to be lower than market, it is reasonable to move realization of demand outside the market. Taking under consideration higher risk exposure, the average price is extended by a half of standard deviation. The time is specified as a parameter.

$$P_{max} = avg(P_{BM}) + \frac{1}{2} sd(P_{BM})$$

```
    def safe_price(self, limit=360):
        query = "SELECT * FROM MarketData INNER JOIN Dates ON
MarketData.Date = Dates.Date WHERE MarketData.Date < ? AND Dates.DayType =
? AND MarketData.Type = 0 ORDER BY Date DESC LIMIT ?"
        opt = (self.date, self.daytype, limit)
        prices = self._retrieve(query, opt)
        prices = transpose(prices)
        avg = mean(prices, axis = 1)
        sd = std(prices, axis = 1)
        safe = (avg + sd / 2)
        return safe
```

Following matrix represents maximum prices which are going to be achieved on 29th of February 2012, without taking into consideration Value at Risk measures. If not stated otherwise, historical prices are calculated by 360 days back.

>>> wednesday.safe

hour	1	2	3	4	5	6	7	8
price	176,62	172,87	172,23	172,08	174,71	182,78	199,8	219,99
hour	9	10	11	12	13	14	15	16
price	260,61	281,14	296,94	317,99	287	269,01	274,41	275,74
hour	17	18	19	20	21	22	23	24
price	292,34	292,93	298,98	294,06	240,51	204,79	201,33	186,69

Table 2. *Exemplary product of safe method within RDN class*

Lower range border can be simply the minimal value for a given period of time. There is no need for placing orders lower than this value, due to low probability of filling.

```
def min_price(self, limit=20):
    query = "SELECT * FROM MarketData INNER JOIN Dates ON
MarketData.Date = Dates.Date WHERE MarketData.Date < ? AND MarketData.Type
IN (1, 2, 3) AND Dates.DayType = ? ORDER BY Date DESC LIMIT ?"
    opt = (self.date, self.daytype, limit)
    prices = self._retrieve(query, opt)
    price = transpose(prices)
    min = nanmin(price, axis = 1)
    return min
```

Example of minimal range for 20 days back:

>>> wednesday.min

hour	1	2	3	4	5	6	7	8
price	134,56	109,55	105,22	105,61	107,38	138,42	145,76	155,17
hour	9	10	11	12	13	14	15	16
price	172,32	172,49	172,41	170,69	167,79	170,65	157,05	167,97
hour	17	18	19	20	21	22	23	24
price	162,55	185,04	188,27	183,07	172,62	150,08	156	119,22

Table 3. *Min method results returned – showing minimal price level for orders*

To beat the market, the model should buy more energy on lower price fixings than their volume ratio, and do just the opposite when the price is high. Splitting orders into smaller amounts can adjust purchased volume to price level. Orders can be split even to the level of 0,1MWh.

With combining two above methods, the results possess one important disadvantage. If the price in the next fixing is lower, the model would be always efficient. Not covered demand (named as ‘rest’) would be fulfilled in the next fixing for a better price. Nevertheless, when the best price would be offered on the first fixing, it would be difficult to significantly boost cost cutting and reach better results. For that matter, the model should purchase over the limit when market offers favourable price.

This behaviour can be obtained by buying the expected volume until the price reaches some level. Under this level, the model should be allowed to buy over the limit, up to satisfying the whole demand. The price which differentiates demand and over-demand orders is called ‘reference price’, and is arbitrary. It is assumed that for the first fixing, reference price should equal previous day average price (day should have the same day type). The second fixing should relate to the first one, and third to the weighted average of the prior two.

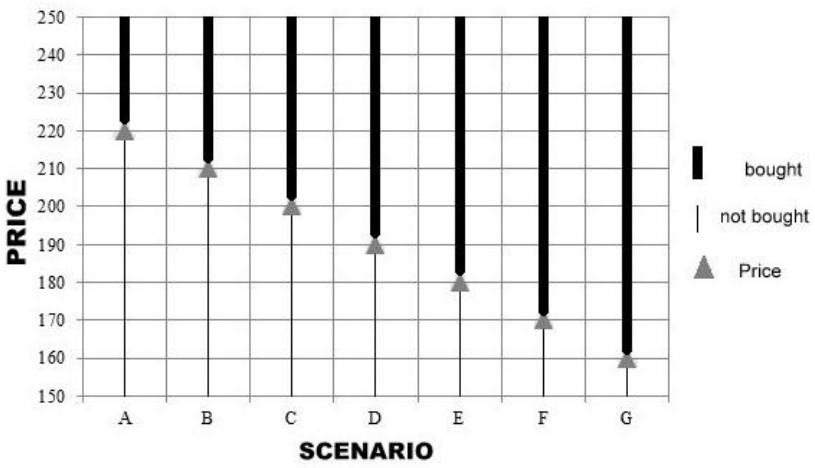

Figure 6. *Mechanism of volume accumulation depended on established price used in the Model.*

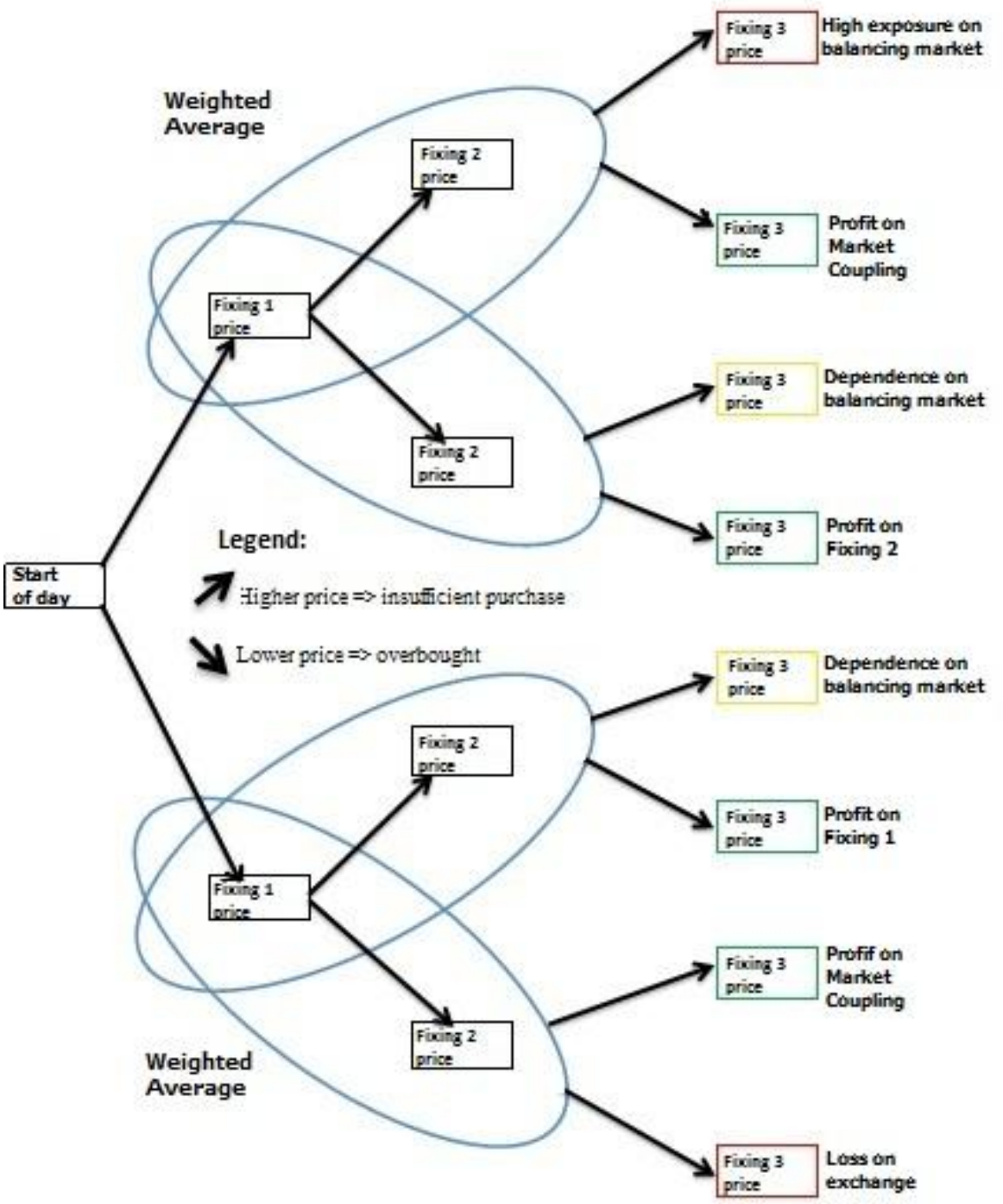

Figure 5. *Binomial tree representing all possible output scenarios of the Model*

```
    def fix(self, freq=10):
        if self.fixing == 1:
            dt = self._retrieve('SELECT Date FROM Dates WHERE Date < ? and
Daytype = ? ORDER BY Date DESC LIMIT 1', (self.date, self.daytype))
            self.calls.append(self.demand * self.est[0])
            self.ref.append(self.average(dt))
        elif self.fixing == 2:
            self.rest.append(self.calls[0] - self.purchase[1])
            self.calls.append(self.demand * self.est[1] + self.rest[0])
            self.ref.append(array([p for p, v in self.market_data[0]]))
            self.mitigate()
        elif self.fixing == 3:
            self.rest.append(self.demand * sum(self.est[:2], 0) - sum(self.purchase[:3], 0))
            self.calls.append(self.demand * self.est[2] + self.rest[1])
            self.ref.append(self.average(self.date, None))
            self.mitigate()

        f = self.fixing - 1
        ref = self.ref[f]
        prices = []
        volumes = []

        for i in range(24):
            if ref[i] < self.safe[i]:
                op = linspace(ref[i], self.safe[i], freq)
                bp = linspace(self.min[i], ref[i], freq)
                prices.append(list(op) + list(bp))
                ov = [self.calls[f][i]/freq for x in range(freq)]
                bv = [(self.demand[i] - self.calls[f][i] - sum(self.purchase, 0)[i])/freq for x in
range(freq)]
                volumes.append(list(ov) + list(bv))
            elif ref[i] >= self.safe[i]:
                prices.append(list(linspace(self.min[i], self.safe[i], 2*freq)))
                volumes.append([(self.demand[i] - sum(self.purchase, 0)[i]) / (2*freq) for x
in range(2*freq)])

        orders = []
        for i in range(len(prices)):
            orders.append(zip(prices[i], volumes[i]))

        return orders
```

After each day, there is possibility to analyse which part of demand was not covered according to assumptions, for that a rest method can be called. There is no further fixing after the third one, so there is no need for a program to calculate and provide such.

>>> wednesday.rest

hour	FX 1 [MWh]	FX 2 [MWh]
1	-15,8	0,9
2	28,5	-2,3
3	30,3	-0,4
4	54,6	-0,1
5	51,5	-10,9
6	17,4	26,0
7	10,0	-7,3
8	18,8	5,9
9	-10,2	1,9
10	18,7	-7,2
11	7,3	6,1
12	6,5	8,2
13	6,0	8,8
14	17,9	10,1
15	9,6	5,3
16	8,9	-13,0
17	8,8	-19,2
18	8,2	6,0
19	8,7	-9,8
20	-10,3	-9,8
21	9,4	28,9
22	-19,7	2,5
23	18,5	-9,5
24	24,5	-12,9

Table 4. *Unfilled required demand – 29th of February 2012*

Reference prices matrix is made upon previous market data, so the second and third columns are in fact prices of 1 and 2 fixings. First price refers to previous day average, as seen in an example of command line program output below:

>>> wednesday.ref

hour	FX 1	FX 2	FX 3
1	160,92	157,44	153,82
2	154,01	156,99	150,57
3	148,66	151,60	144,67
4	143,84	153,66	145,56
5	146,33	157,03	149,50
6	156,49	161,36	163,97
7	183,89	184,62	182,25
8	180,84	187,13	187,72
9	204,10	202,62	202,82
10	206,44	215,01	213,86
11	206,18	209,57	211,83
12	205,86	211,36	213,26
13	198,59	207,77	211,87
14	197,89	214,06	214,44
15	191,21	196,99	197,98
16	186,39	189,58	188,02
17	185,84	194,26	190,77
18	201,15	207,19	210,03
19	227,62	229,70	225,96
20	226,92	224,35	221,66
21	201,12	202,66	208,65
22	178,98	173,07	174,39
23	180,96	184,78	182,31
24	160,05	167,76	163,60

Table 5. *Example of reference prices – dividing purchase orders into two groups from this level*

Balancing market prices are characterized to possess long right tail (the prices can reach even 1500 PLN/MWh), but their occurrence is rare. Even though the measures setting maximum price for orders are averages with extension of a half of the standard deviation, still rare very high losses could be obtained as not beneficial. For that reason, applying Value at Risk as a relevant risk mitigation concept is crucial to avoid one-time big losses which are not anticipated.

```
    def VaR(self, limit=360):
        query = "SELECT * FROM MarketData INNER JOIN Dates ON
MarketData.Date = Dates.Date WHERE MarketData.Date < ? AND Dates.DayType =
? AND MarketData.Type = 0 ORDER BY Date DESC LIMIT ?"
        opt = (self.date, self.daytype, limit)
        prices = self._retrieve(query, opt)
        i = int(len(prices)*(1 - self.conf_level))
        queue = sort(transpose(prices))
        var = [queue[x][-i] for x in range(len(queue))]
        return var
```

Living example of VaR calculations on 29th of February 2012 can be seen below:

>>> wednesday.var

hour	1	2	3	4	5	6	7	8
price	189,38	187,91	187,48	187,95	188,38	193,07	212,11	221,00
hour	9	10	11	12	13	14	15	16
price	280,00	311,00	310,00	310,00	291,42	280,00	266,61	270,97
hour	17	18	19	20	21	22	23	24
price	310,00	350,00	312,90	310,00	254,76	220,77	216,00	200,00

Table 6. *Value at Risk at 29th of February 2012 – obtaining VaR prices have significant improvements on risk quantification*

Value at Risk method can identify prices based on confidence level and assume that outstanding volume (not acquired demand) would be bought for that price. If the average price extends accepted percentage loss for each hour, the price identified by Value at Risk method overwrite previously stated safe price.

```
    def mitigate(self, x=0.3):
        f = self.fixing - 1
        for i in range(24):
            ex = ((self.ref[f][i] * sum(self.purchase, 0)[i]) + (self.rest[f-1][i] * self.var[i])) /
(self.ref[f][i] * (sum(self.purchase, 0)[i] + self.rest[f-1][i]))
            if x + 1 < ex:
                self.ref[f][i] = self.var[i]
```

To prepare orders for every fixing and calculate the end result, looping over presented methods can be done. When the loop ends, it fetches outstanding volume with balancing market prices. The performance method is in fact the most important part of the Model, which connects together other parts of the program and provides output.

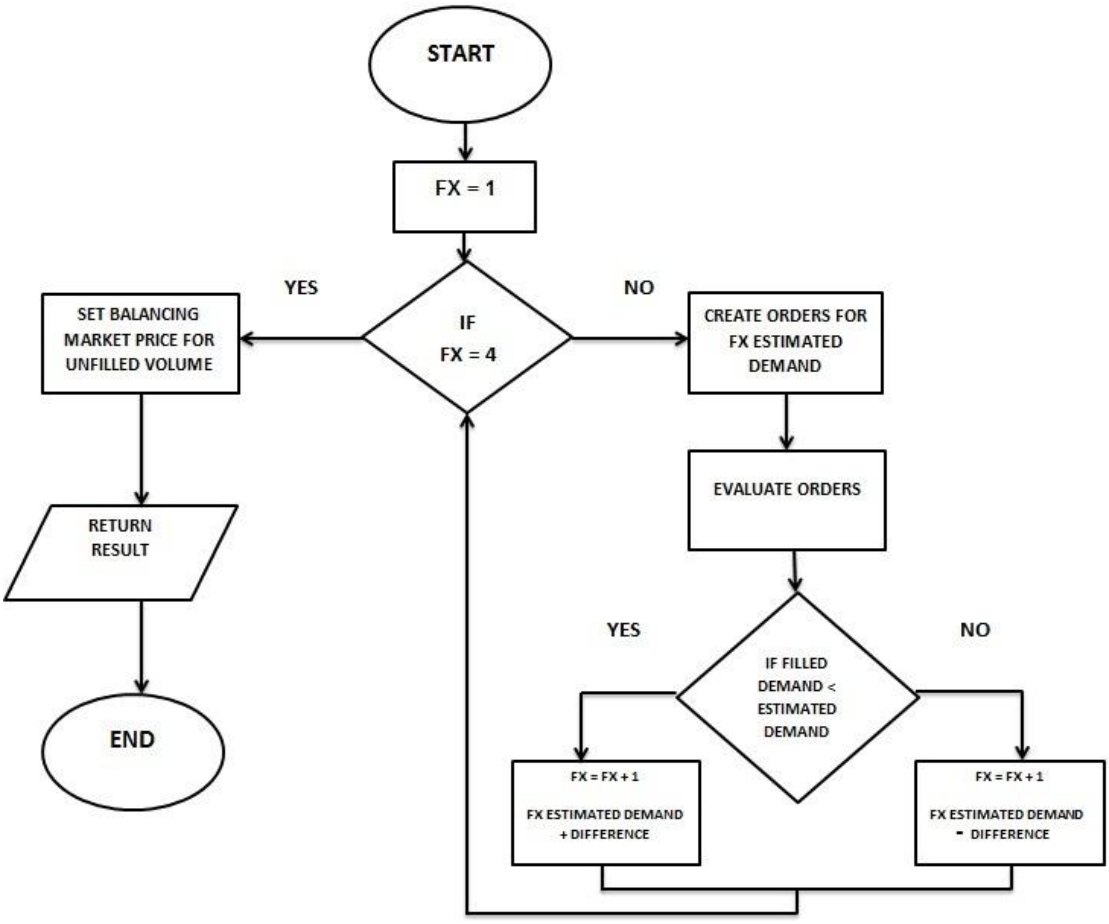

Figure 6. *Simplified block algorithm for calculating orders used in fixing method*

```
    def performance(self):
        while self.fixing <= 3:
            query = "SELECT * FROM MarketData WHERE Date = ? AND Type IN (?, ?)
ORDER BY Type"
            p, v = self.fixing, self.fixing + 4
            opt = (self.date, p, v)
            market = (self._retrieve(query, opt))
            f = self.fixing - 1
            self.market_data.append(zip(market[0], market[1]))
            purchase = []
            orders = self.fix()


            for i in range(24):
                vol = 0

                for j in range(len(orders[i])):
                    if orders[i][j][0] >= self.market_data[f][i][0]:
                        vol += orders[i][j][1]

                if vol > self.market_data[f][i][1]:
                    vol = self.market_data[f][i][1]

                purchase.append(vol)

            self.purchase.append(purchase)
            self.fixing += 1

        if self.fixing == 4:
            self.purchase.append(self.demand - sum(self.purchase, 0))
            opt = (self.date, self.daytype, 1)
            bm = self._retrieve('SELECT * FROM MarketData INNER JOIN Dates ON
MarketData.Date = Dates.Date WHERE MarketData.Date = ? AND Dates.DayType =
? AND MarketData.Type = 0 LIMIT ?', opt)
            del self.purchase[0]
            md = []
            for i in range(3):
                md.append([p for p, v in nan_to_num(self.market_data[i])])
            md.append(nan_to_num(bm[0]))
            self.cost = (sum(self.purchase * array(md), 0)) / self.demand
            self.avg = self.average(self.date)
            self.res = (self.avg - self.cost) * self.demand

            return sum(self.res)
```

>>> wednesday.performance()

7705,60

Purchase method can be used in examining how estimated demand fits with real sum of filled orders. More the model should replicate market behaviour, less the difference between those two should be.

>>> wednesday.purchase

hour	FX 1 [MWh]	FX 2 [MWh]	FX 3 [MWh]	BM [MWh]
1	137,0	61,7	0,0	1,3
2	114,0	83,7	0,2	0,0
3	121,3	78,4	0,3	0,0
4	81,8	118,1	0,1	0,00
5	77,3	111,8	10,9	0,00
6	69,7	104,0	0,0	26,28
7	90,0	80,8	29,2	0,00
8	75,2	53,4	71,4	0,00
9	108,1	17,5	67,0	7,44
10	74,7	60,7	58,2	6,47
11	65,4	55,0	71,7	7,96
12	58,3	74,1	54,1	13,53
13	54,0	79,1	53,5	13,38
14	41,7	90,7	60,8	6,76
15	86,4	47,5	52,9	13,22
16	80,0	67,8	47,0	5,22
17	79,3	75,9	44,9	0,00
18	73,7	53,8	65,3	7,26
19	78,5	82,2	35,4	3,94
20	107,1	53,7	39,2	0,00
21	84,5	28,9	43,3	43,27
22	121,0	10,1	62,0	6,89
23	74,0	88,1	37,9	0,00
24	57,1	91,1	51,7	0,00

Table 7. *29.02.2012 – demand fillings resulted in using the Model*

Back-testing feature is added to the model for historically checking performance with given parameters. This can help to make further decisions regarding development of the model and highlight risk areas. Back-testing feature is using generator, which for every date located in defined range of arguments creates separate instance of the class, and returns the result.

```
def results(start_date, end_date):
    dt = start_date
    delta = timedelta(days=1)
    time_change = [datetime(2012, 10, 28), datetime(2012, 3, 25), datetime(2011, 10,
30), datetime(2011, 3, 27), datetime(2010, 10, 31), datetime(2010, 3, 28)]
    while dt <= end_date:
        if dt in time_change:
            dt += delta
        day = RDN(dt.__str__().split()[0])
        yield datetime.date(dt).isoformat(), round(day.performance(), 2)
        dt += delta

def backtesting(start_date, end_date):
    start = datetime.strptime(start_date, '%Y-%m-%d')
    end_date = datetime.strptime(end_date, '%Y-%m-%d')
    profit = 0
    for res in results(start, end_date):
        print res[0], res[1]
        profit += res[1]
    return profit


     >>> backtesting("2011-01-01", "2012-09-30")

     5 403 353, 41
```

4. Results

Interpretation of results has to be taken under consideration the purpose and assumptions of the Model. The outcome of the model is satisfactory, with achieving nearly 8 500 PLN gain in comparison with a benchmark, an average market price. Both results over zero line and frequencies are visually higher in positive numbers, so the most daily transactions are successful. However, extremely high level of standard deviation is an obvious disadvantage, because swifts in different market directions could result in abrupt losses. Additionally, significant smaller median than average means, that the model benefits from big gains, which are not sure to appear in the future. Above all, considering that on each 24-hours trading day there were 200 MWh of energy bought, that gives **1,77 PLN / MWh** lower than average market price.

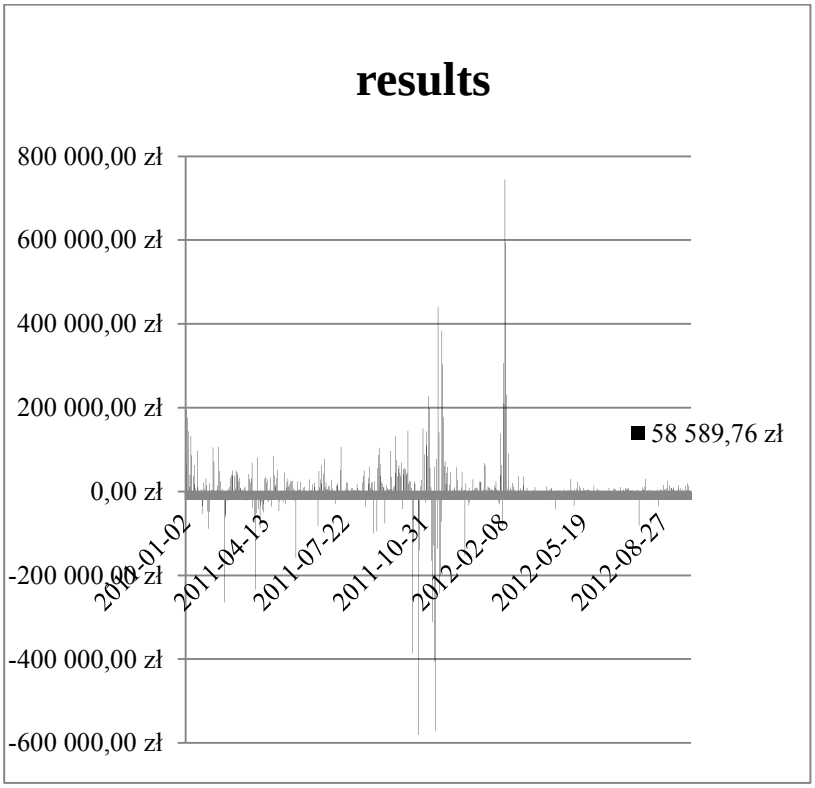

Figure 7. *Results obtained by the Model taking into account 200 MWh volume for each trading hour and 90% confidence level of Value at Risk.*

Results obtained by the Model in the following months:	
2011:	**2 660 972,44 zł**
1	1 004 483,72 zł
2	9 984,92 zł
3	128 513,52 zł
4	-76 297,69 zł
5	-37 067,26 zł
6	268 195,57 zł
7	281 796,98 zł
8	89 814,57 zł
9	1 008 021,25 zł
10	-450 655,55 zł
11	410 682,83 zł
12	23 499,58 zł
2012:	**2 742 380,97 zł**
1	340 727,16 zł
2	2 344 687,97 zł
3	14 640,15 zł
4	-52 264,26 zł
5	24 581,49 zł
6	1 382,04 zł
7	-103 749,62 zł
8	17 510,54 zł
9	154 865,50 zł
Total sum:	**5 403 353,41 zł**

Table 8. *Aggregated profits and losses by month for a period from January 2011 until end of September 2012 – assuming 90% VaR and 200 MWh required demand for each trading hour*

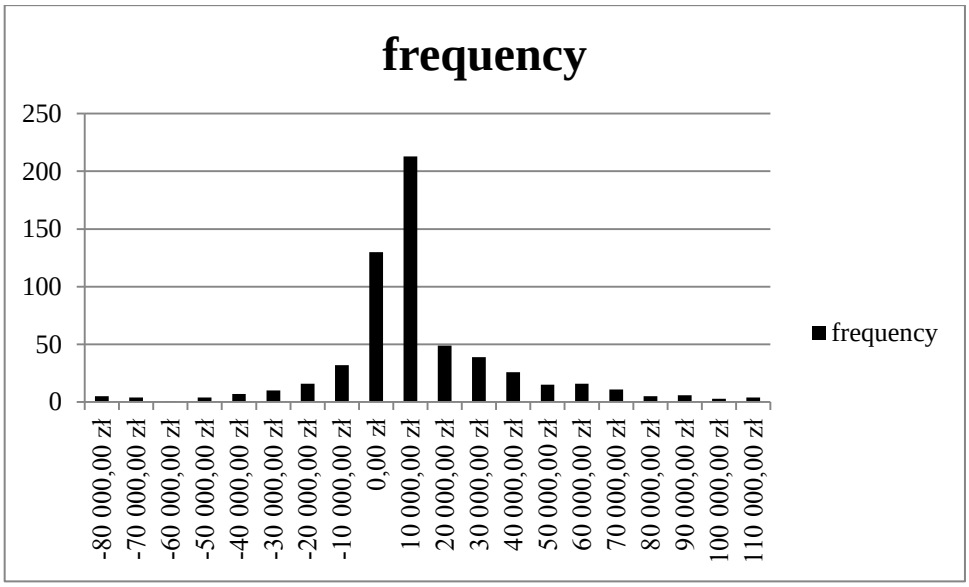

Figure 8. *Frequency of results taking into account 200 MWh volume for each trading hour and 90% confidence level of Value at Risk*

descriptive statistics	
average	8 495,84 zł
standard error	3 053,89 zł
median	2 871,49 zł
standard deviation	77 016,20 zł
sample variance	5 931 494 920,72
kurtosis	33,72
skewness	0,73
range	1 325 355,03 zł
minimum	-580 814,73 zł
maximum	744 540,30 zł
sum	5 403 353,41 zł
counter	636
the largest (1)	744 540,30 zł
the smallest (1)	-580 814,73 zł
confidence level (90.0%)	5 030,54 zł

Table 9. *Statistics describing output of the Model following stated assumptions*

Conclusion

The exact purpose of this dissertation was achieved entirely. The Model not only replicates the market behaviour, but also achieves results better than expected. These results are completely satisfying, leaving the field for optimizing its risk measures for the commodity trader itself on particular market conditions and timing.

Optimizing the output of the Model was not aim of this paper, and the gains are still not relevant as a business model. However, its performance could be much greater if sufficient risk measures will be applied, not only quantitative ones, but also fundamental analysis of production capacity and use of energy would cut much of the losses and identify key risk areas more accurately. This could result not only in extending profitability for more than 1,77 PLN / MWh, but also lowering the standard deviation and number of big unexpected losses. As a matter of fact, for the standard hour, the assumptions lying at the basis of the Model works fine both in theory and practice.

The thesis above produces altogether relevant side-effects. Firstly, it clearly extends risk management thinking in the real-world example, getting familiar with financial risk measures in the trading environment of uncertainty. Secondly, it helps organizing and developing knowledge of tools necessary to data manipulation and storage, with programming and database concepts like object-orientation and relational model, which rely on most software development practices. Then, it introduces more exotic commodities markets, as an extension for financial knowledge, especially when trading storage-less product like energy when completely different principles rely upon. Least but not last, it can be used successfully used when proper diligence will be applied.

To sum up, the Model with all of its assumptions appeared to be profitable in comparison with average market price. The global market of commodities was extensively described, including its vast history, available products and recent changes, all included in the first chapter. The second chapter began with short introduction to polish commodity markets and summarization of energy trading organization, followed by core methodology and specification for the Model in a form of a program written in Python Programming Language, inserted in appendixes together with its results.

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