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ENERGY SECURITYAS A MATHEMATICAL DEPENDING ON THE FUNCTION OF THE WORLD ENERGY DEVELOPMENT

BEZPIECZEŃSTWO ENERGETYCZNE JAKO MATEMATYCZNA ZALEŻNOŚĆ FUNKCJI ROZWOJU RYNKU ENERGII W UJĘCIU GLOBALNYM

ЭНЕРГЕТИЧЕСКАЯ БЕЗОПАСНОСТЬ КАК МАТЕМАТИЧЕСКАЯ ЗАВИСИМОСТЬ ОТ ФУНКЦИИ РАЗВИТИЯ МИРОВОЙ ЭНЕРГЕТИКИ

Abstracts

The article noted the assessment of the world energy. There are conducted mathematical calculation functions of its development. The most likely specified mathematical dependence of future development that will provide absolute energy security has been proposed.

Keywords: *world energy, energy security, mathematical dependence of world energy, traditional energy, alternative energy, natural way energy.*

Streszczenie

W artykule przedstawiono analizę rozwoju rynku energii w ujęciu globalnym. Opisane zostały matematyczne funkcje obliczeniowe rozwoju rynku energii w ujęciu globalnym. Zaproponowano najbardziej prawdopodobną matematyczną zależność przyszłego rozwoju zapotrzebowania na energię z uwzględnieniem kwestii bezpieczeństwa energetycznego.

Słowa kluczowe: *globalny rynekenergii, bezpieczeństwo energetyczne, matematyczna zależność energetyki globalnej, tradycyjna energetyka, alternatywna energetyka, naturalne źródła energii.*

Аннотация

В статье проанализирована оценка развития мировой энергетики. Проведено математический расчет функции ее развития. Указано наиболее вероятную математическую зависимость будущего ее развития, что обеспечит абсолютную энергетическую безопасность.

***Ключевые слова**: мировая энергетика, энергетическая безопасность, математическая зависимость развития мировой энергетики, традиционная энергетика, альтернативная энергетика, природно-укладная энергетика*

Introduction. The modern world energy has passed a long period of formation and development and counts more than 120 years. During this time there have been significant technological as well as structural changes in the generation of electric current. According to a statistical standpoint, the leading state and commercial structures analyzed powerful information base for increasing generating capacity, output and consumption of electric current. This allows us to take a deep and complete analysis of the structural factors of the dynamics of the development of the world energy.

Analysis of recent research and publications. In addition, significant contributions to the study of world energy problems have made Paul Denholm, Erik Ela, Brendan Kirby, Michael Milligan [1], David Timmons, Jonathan M. Harris, Brian Roach [2], Malcolm Keay [3]Vaclav Smil [4], Erich Zimmermann [5], R. Richard Geddes [6], Max Luke, Amy Meyer, Harry Saunders, Ted Nordhaus, Michael Shellenberger, Alex Trembath [7], KeywanRiahi [8], A. Korotaev, A, Malkov , D. Halturyna [9].

Unsolved aspects of the problem. However, despite the significant contribution to the world's leading researchers in the scientific community there is no complete overall model of the development of the world energy.

The purpose of research is identify trends in world production of electricity and attempts to describe them by mathematical relationship. Consequently are formed research objectives:

- to identify the main stages of the development of the world energy and their factors;
- to forecast stages and consistent pattern of the transition of modern world power to a whole new forecasted and predictable level.

1. The performance of the world energy development and its trends

The beginning of industrial production of electricity is considered in 1882, when in New York was built the first world's power plant with capacity 552 kW. Subsequently, the development of energy went to Russia (in 1883 in St. Petersburg was built TPP) and Germany (in 1884 in Berlin was built TPP).

This period is characterized by the development of energy carried entirely by individual units and individual introductions, which gave an opportunity to generate an electric current in small quantities and pass it on rather short and limited distance. The main consumers were large industrial plants and public transportation. Thus, at the beginning of the year 1900 the world's total power capacity amounted to about 10 thousand MW.

1900 started a new phase of development of world energy sector, characterized by the use of electricity generated for the everyday needs of large cities. In addition, in this period is mainly transfer of social production to a new kind of energy - electric current. That is, there was a transition from the industrial use of mechanical energy to electrical (transition from the steam engine to the electric motor). In this period quickly build new more powerful plants of various types, create energy infrastructure that allows increasing the area of electric representation to consumers (power lines, transformers and complete power systems).

By 1914, there is a rapid increase generating capacity for production of electric current. At the beginning of 1914 the total number of existing power plants in the world numbered 2355, with a total capacity of over 26,5 thousand MW, ensuring production of electric current in the amount of 37.5 billion KWh. So, therefore increasing power dynamics indicates that from 1880 to 1914, there was increasing capacity to 1320%.

Period until the end 20s the 20th century characterized by large-scale World War. Nevertheless, global energy development is not only stops, but characterized by a rapid pace of increasing capacity and the amount of electric use. So at the end of 1935 the amount of electricity was 170 billion kWh and generating capacity reached about 90 thousand MW. This was possible through faster construction of power plants in the cities and refocusing most countries to the industrial development path.

Taking into account that in economic terms the cost is quite significant impact in getting electric current is determined by coefficient of efficiency (COP). The current state of energy determines the level of COP from 15 to 65%. But the volume of production of electric current also depends on various factors, in particular, the intensity of industry, economic level of society.

Analyzing the global dynamics of electric current and increase capacity and power, we will identify common trends:

1. Increasing power curve repeats the curve electricity production.
2. Ratio (conventionally COP) between electricity production and its production capacity is 0,24.

Furthermore, the modern world economy characterized by overproduction of all commodities, so further rapid increase of electrical energy will not be observed.

The modern world economy based on market conception. Therefore, in its further development and possible adjustment by the price factor (setting appropriate tariffs for electricity consumption that are tied to basic energy resources - oil, gas, coal).

This model of global energy has a very low connection with generating capacity

However this relationship is very strong regarding technologies for electric current, because involves significant investment in the construction and operation of power generating facilities.

With this approach, the effectiveness of modern energy is extremely low, because the dominant energy technology of the current focuses on the use of hydrocarbons. This statement confirms that the COP of modern solar and wind stations is in order of higher (0,4-0,5). In addition, the most highest efficiency concerning energy of water of World Ocean (0,9). The difference between the tidal and hydropower, is necessary significant additional resources to the accumulation of a large water mass (water reservoirs), which is a potential concentration of water in a particular confined space, compared with the ocean. Tidal hydropower plants operating in the natural energy concentration of water in a particular geographical location.Therefore logical thinking lead to the fact that further development of the energy in the contemporary form is limited. This limitation is caused by understanding the energy and of the principles of interactionIn other words, humanity standing before challenge of entering the higher level of energy, which would be less connected with the carbohydrate base. So there is an urgent need to form a new technology of the generation electric current. One of the directions of these technologies is the development of natural way energy. Statistical data of the generation electricity allows analysis of the dynamics of increasing production of electric power in a global context (table 1.1).

Table 1.1The dynamics of increasing production of electric power during 1890-2015 years

Years	1890	1990	1914	1935	1940	1950	1960	1970	1980	1990	2000	2010	2015
The volume of productio n electricity billion KWh	9	15	37,5	379	429	950	2300	5000	8250	11800	14500	21500	24097
Generatio n capacity, thousand MW	2	10	26,4	73	83,5	1250	1320	1400	1976,8	2732,4	3396,1	5074,8	5699,4

Considering the increase in the world electricity production and generation capacity, is evident global trend from 1935 to 2008. During this period there was a sharp increase of the marginal generate electricity and limiting power.

According to the data, we can build graphical relationship of the world's production of electric current (figure 1).

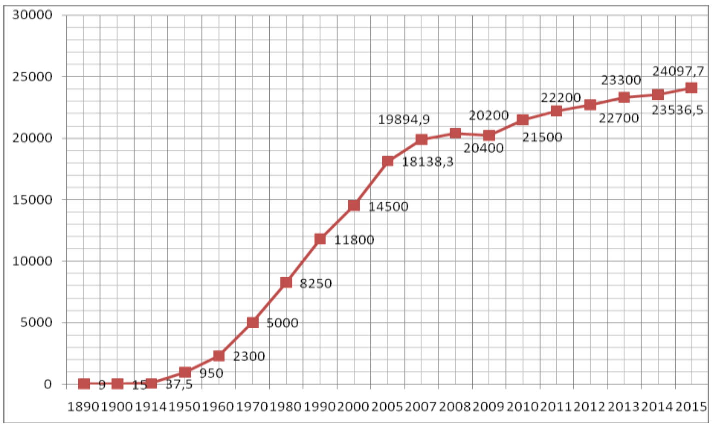

Figure 1.1 Graphical relationship of the world's production of electric current

2. Mathematical relationship of the world energy development According to graphical relationship of the world's production of electric current define mathematical pattern of world production of electric current. We use the program Graph. (figure2.1).

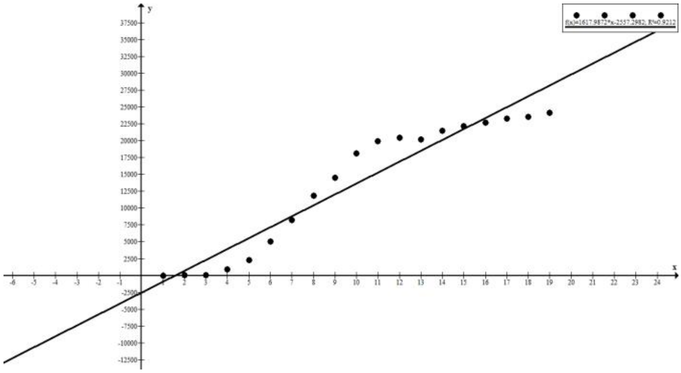

Figure 2.1 The linear relationship of the world energy development

The function of the linear relationship of the world energy development is:

$$f(x) = 1617{,}9872x - 25567{,}2982;$$
$$R^2 = 0{,}9212 \quad (1)$$

According a linear relationship the world energy development has rising sinusoidal character.

Thus, by 1980 the production of of electric current lower than the set trends, but from 1980 to 2011 production outstrips the trend. In modern conditions, production is in the backlog of linear relationship.

Should be noted that in this study we will not consider the technological and economic factors impact on this trend, just state the facts that have already been implemented. Therefore, further development of energy have to be done in increasing output and exit zones backlog to zero level (the intersection curve production of linear relationship)

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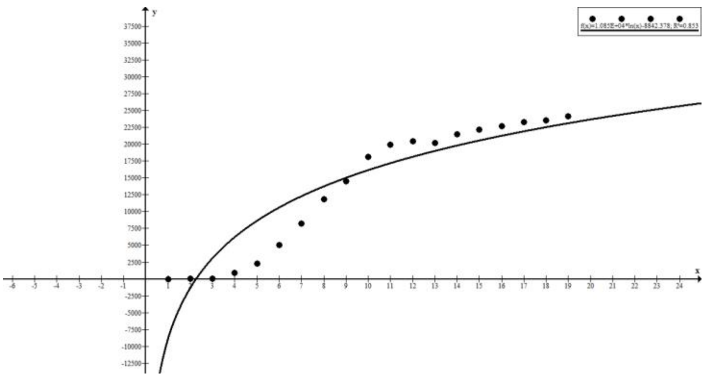

Figure 2.2 The logarithmic relationship of the world energy development

According a logarithmic relationship(figure 3), production of electric current since 2009 are clearly reflects this relationship. Therefore increasing world production of of electric current will fully comply with the logarithmic relationship and has a function:

$$f(x) = 1{,}085E + 0{,}4\ln(x) - 8842{,}37; \quad R^2 = 0{,}853 \qquad (2)$$

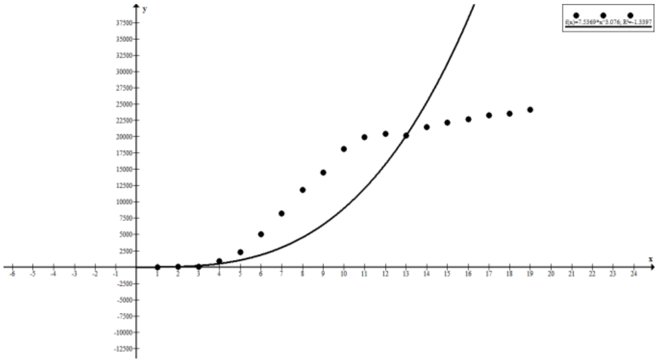

Figure 2.3 The power relationship of the world energy development

A power function quite accurately reflects the dynamics of increasing global energy production:

$$f(x) = 7{,}5369 \cdot x^{3{,}076} \qquad (3)$$

But in the interval from 1890 to 2005 this function more accurately reflects the trend of increasing world production. Therefore, the power function can be used only at the initial stage of the implementation and testing of new technologies in the energy sector.

An exponential function (figure 2.5) has a function that does not clearly reflect increasing production volume:

$$f(x) = 100{,}7609 \cdot 1{,}4588^{x}; \quad R^2 = 10{,}5677 \qquad (4)$$

This feature only functions notethe intersection of on finish advanced development and its power output to a new technological level.

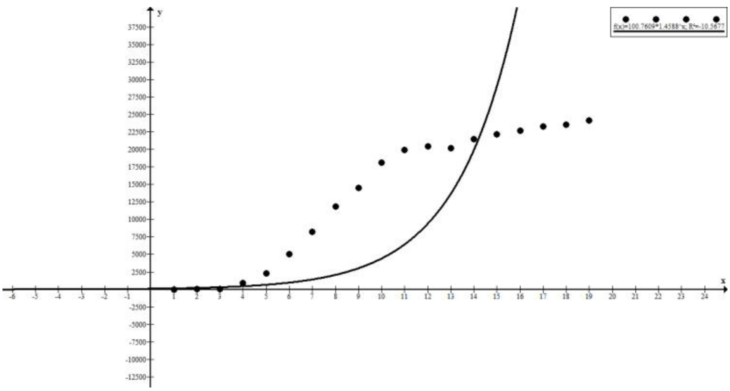

Figure 2.4 The exponential relationship of the world energy development

Let's analyze the production of electricity by using polynomial. According to this function we can divide it into six approaches:

1. Gradual fall;
2. Gradual growth;
3. Accelerated growth;
4. Accelerated fall;
5. The fall after an extreme growth;
6. Growth after an extreme fall.

The functions of the 2nd and 3th degrees polynomial are examples of gradual fal.

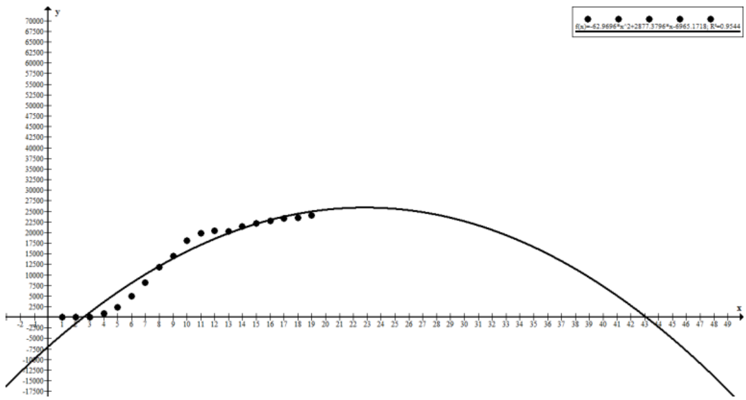

Figure 2.5 The 2nd degree polynomial relationship of the world energy development

The function of the 2nd degree polynomial reflects the inverse parabola, most of which will be reached in 2035, after which will the curtailment of electricity to zero.

The function of the 2nd degree polynomial relationship of the world energy development is:

$$f(x) = -62{,}9696x^2 + 2877{,}3796x - 6965{,}1718;\ R^2 = 0{,}9544 \qquad (5)$$

Accordingly in the economy such strategy of energy development is not acceptable, because at current technology and limited resources will begin their search for alternatives.

The function of the 3-th degree polynomial reflecting the dynamics increasing and decline in electricity production, and ultimately provides complete energy decay (figure 2.6).

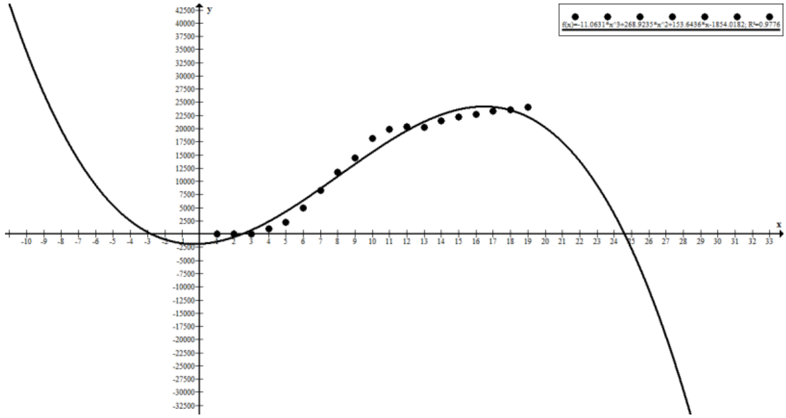

Figure 2.6 The 3th degree polynomial relationship of the world energy development

The function of the 3th degree polynomial relationship of the world energy development is:

$$f(x) = -11{,}0631x^3 + 268{,}9235x^2 + 153{,}6463x - 1854{,}0182;$$
$$R^2 = 0{,}9776 \qquad (6)$$

The functions of the 4th and 5th degrees polynomial are examples of gradual growth (figures 2.7, 2.8).

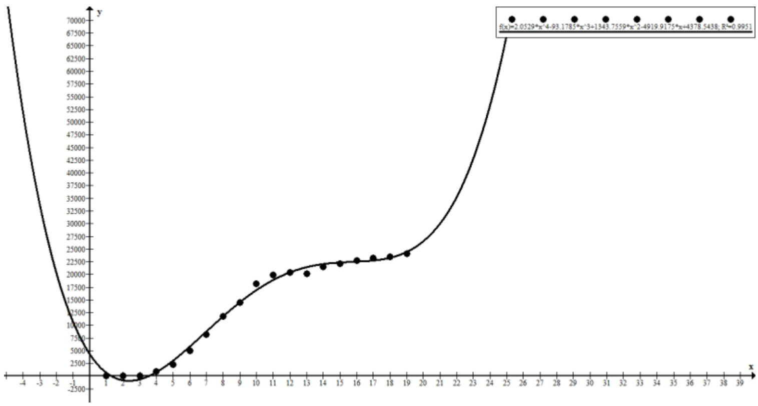

Figure 2.7 The 4th degree polynomial relationship of the world energy development

The function of the 4th degree polynomial relationship of the world energy development is:

$$f(x) = 2{,}0529x^4 - 93{,}1785x^3 + 1343{,}7559x^2 -$$
$$- 4919{,}9175x + 378{,}5438;\ R^2 = 0{,}9951 \qquad (7)$$

Since 1950, this relationship perfectly reflects the dynamics of increasing the electricity production, especially from 2017 shows the best prospects of further increasing. In technological terms it is mathematically describes the future development and natural way energy technologies.

By analyzing the 5th degree polynomial (figure 9), we can see that the function displays the tentative schedule with a single specific - ascending part of the curve is more inclined to the vertical axis y. That explains that the development of natural way energy technologies should follow rapidly. The function of the 5th degree polynomial is:

$$f(x) = 0{,}0238x^5 + 0{,}8626x^4 - 71{,}7146x^3 + 1175{,}9321x^2 +$$
$$+ 4387{,}7057x + 3896{,}734;\ R^2 = 0.9952 \qquad (8)$$

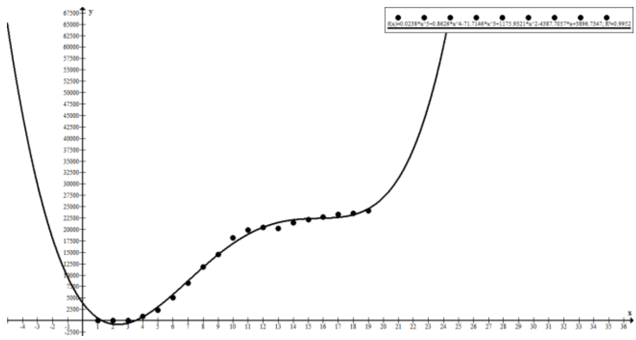

Figure 2.8The 5th degree polynomial relationship of the world energy development

The functions of the 6th, 7th, 10th and 11th degrees polynomial are examples of accelerated fall.

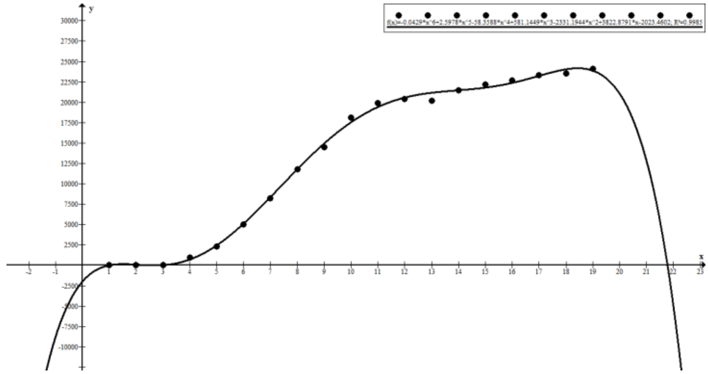

Figure 2.9The 6th degree polynomial relationship of the world energy development

$$f(x) = -0{,}0429x^6 + 2{,}5978x^5 - 58{,}3588x^4 + 581{,}1449x^3 - 2331{,}1944x^2 + 3822{,}8791x - 2023{,}4602;\ R^2 = 0{,}9985 \quad (9)$$

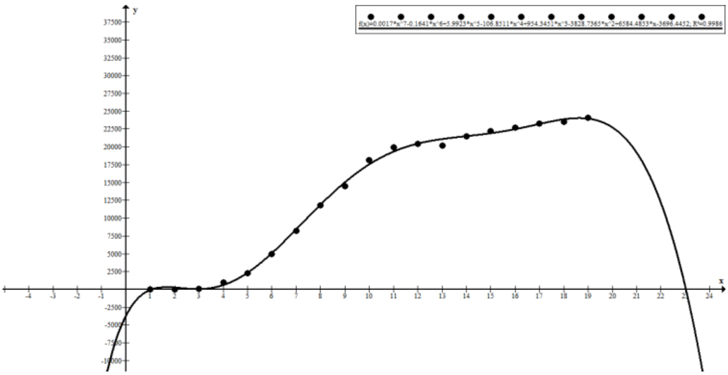

Figure 2.10The 7th degree polynomial relationship of the world energy development

$$f(x) = 0{,}0017x^7 - 0{,}1641x^6 + 5{,}9923x^5 - 106{,}8511x^4 + 954{,}3451x^2 + 6584{,}4853x - 3694{,}44;\ R^2 = 0{,}9986 \quad (10)$$

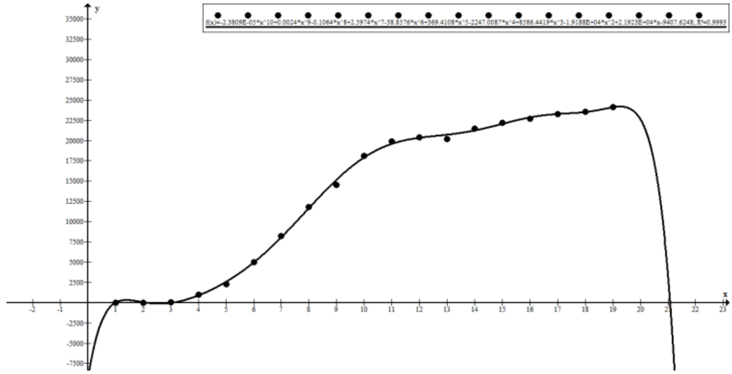

Figure2.11The 10th degree polynomial relationship of the world energy development

$$f(x) = -2{,}3809E - 05x^{10} + 0{,}0024x^{9} - 0{,}1064x^{8} + 2{,}5974x^{7} - 38{,}8576x^{6} + 369{,}4108x^{5} - 2247{,}0087x^{4} + + 8586{,}4419x^{3} - 1{,}9188E + 04x - 9407{,}6248 R^{2} = 0{,}9993 \quad (11)$$

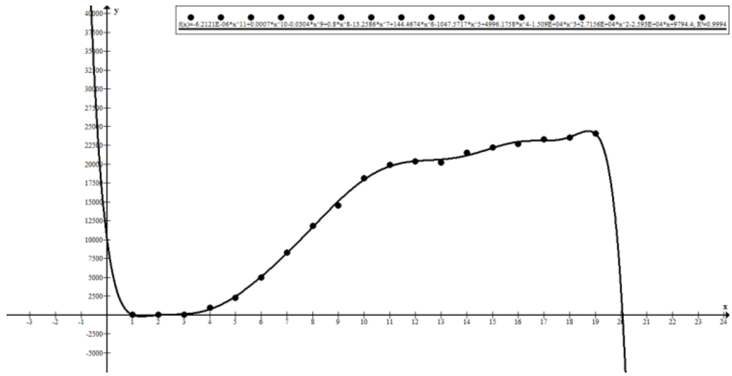

Figure 2.12The 11th degree polynomial relationship of the world energy development

$$f(x) = 6{,}2121E - 06x^{11} + 0{,}0007x^{10} - 0{,}0304x^{9} + 0{,}8x^{8} - 13{,}2586x^{7} + 144{,}4674x^{6} - 1047{,}5717x^{5} + 4996{,}1785x^{4} - - 1{,}509E + 04x^{2} - 2{,}593E + 0{,}4x + 9794{,}4;\ R^{2} = 0{,}9994 \quad (12)$$

In general these features reflect achievement highs electricity production at the last research year (2015). Then begins a sharp collapse. For the economy this is not a typical phenomenon, because economic processes continue and develop. This option is possible in exceptional cases - the complete destruction of the modern economy of the planet. However, this option is unlikely.

The functions of 13th, 15th, 17th and 18th degrees polynomial are examples of the fall after an extreme growth (figures 2.13-2.16).

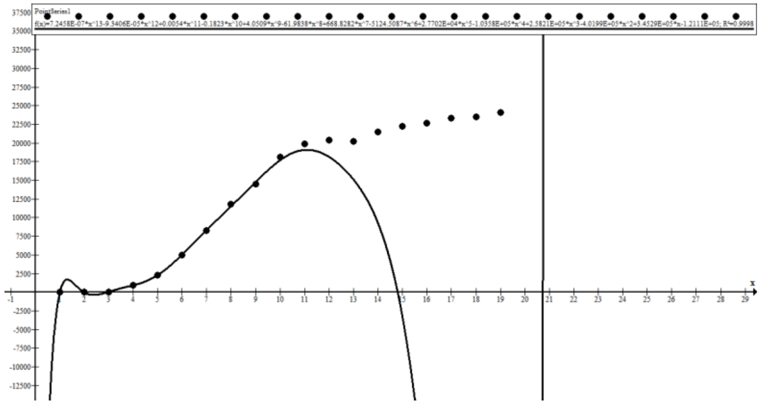

Figure 2.13The 13th degree polynomial relationship of the world energy development

$$f(x) = 7{,}2458E - 07x^{13} - 9{,}3406E - 05x^{12} + 0{,}0054x^{11} - 0{,}1823x^{10} + 4{,}0509x^{9} - 61{,}9838x^{8} + 668{,}8282x^{7} -$$
$$- 5124{,}5087x^{6} + 2{,}7702E + 04x^{5} - 1{,}0358E + 05x^{4} + 2{,}5812E + 05x^{3} - 4{,}0199E + 05x^{2} + 3{,}4529E + 0{,}5x -$$
$$- 1.2111E + 0{,}5;\ R^{2} = 0{,}9998 \qquad (13)$$

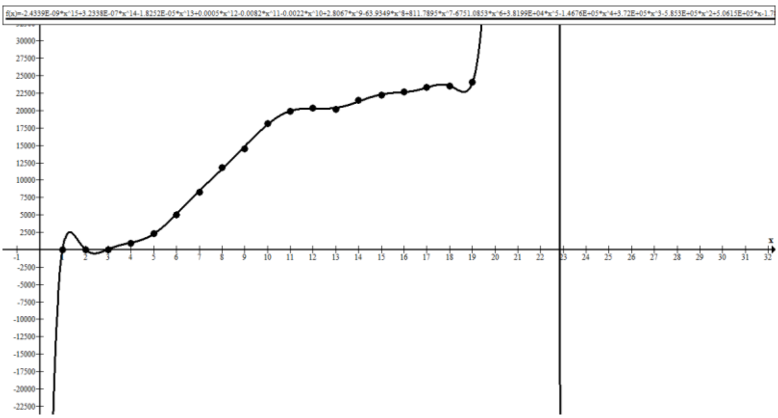

Figure 2.14The 15th degree polynomial relationship of the world energy development

$$f(x) = -2{,}4339E-09x^{15} + 3{,}2338E-07x^{14} - 1{,}8252E-05x^{13} + 0{,}0005x^{12} - 0{,}0082x^{11} - 0{,}0022x^{10} + 2{,}8067^{9} - 63{,}9349x^{8} + 811{,}7895x^{7} - 6751{,}0853x^{6} + 3{,}8199E+04x^{5} - 1{,}4676E+05x^{4} + 3{,}72E+05x^{3} - 5{,}853E+05x^{2} + 5{,}0615E+05x - 1{,}7829E+05; R^{2} = 0{,}9998$$

(14)

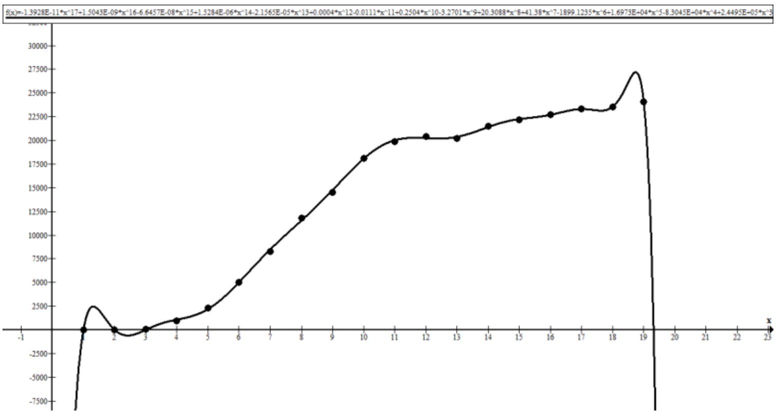

Figure 2.15The 17th degree polynomial relationship of the world energy development

$$f(x) = -1{,}3928E-11x^{17} + 1{,}5043E-09x^{16} - 6{,}6457E-08x^{15} + 1{,}5284E-06x^{14} - 2{,}1565E-05x^{13} + 0{,}0004x^{12} - 0{,}0111x^{11} + 0{,}2504x^{10} - 3{,}2701x^{9} + 20{,}3088x^{8} + 41{,}38x^{7} - 1899{,}1235x^{6} + 1{,}6973E+04x^{5} - 8{,}345E+04x^{4} + 2{,}4495E+05x^{3} - 4{,}2671E+05x^{2} + 3{,}9546E+05x - 1{,}4597E+05; R^{2} = 0{,}9998$$

(15)

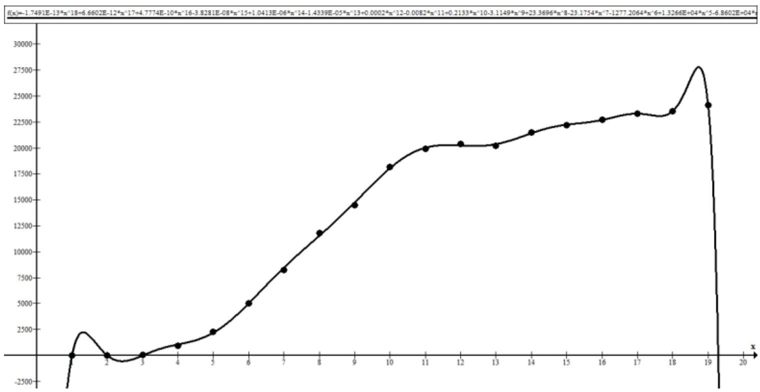

Figure 2.16The 18th degree polynomial relationship of the world energy development

$$f(x) = -1{,}7491E-13x^{18} + 6{,}6602E-12x^{17} + 4{,}7774E-10x^{16} - 3{,}8281E-08x^{15} + 1{,}0413E-06x^{14} - 1{,}4339E-$$
$$-05x^{13} + 0{,}0002x^{12} - 0{,}0082x^{11} + 0{,}2133x^{10} - 3{,}1149x^{9} + 23{,}3696x^{8} - 23{,}1754x^{7} - 1277{,}2064x^{6} + 1{,}3266E+$$
$$+04x^{5} - 6{,}8602E+04x^{4} + 2{,}0845E+05x^{3} - 3{,}6988E+05x^{2} + 3{,}471E+05x - 1{,}2905E+05;\ R^{2} = 0{,}9998$$
(16)

These functions are not acceptable in our analysis because they reflect a sharp breakthrough in technological terms in the early and in the end of the energy development. These zones (initial and final) do not reflect the real trends in the energy sector. History indicates that there was no initial technological breakthrough, followed by a sharp drop, energy developing incremental paces. The functions of 12th, 14th and 16th degrees polynomial are examples of the growth after an extreme fall (Figures 2.17-2.19)

In the graphs are allocated 2 zones: the early energy development, which is characteristic of a sharp increase and the end energy development, which is characteristic a sharp fall before growth.

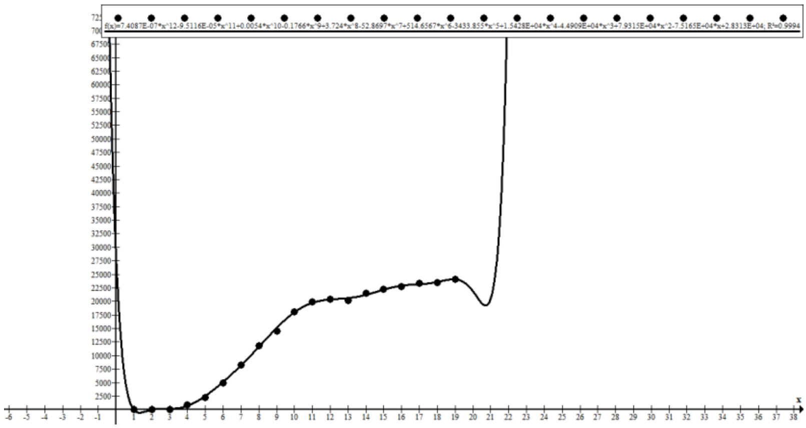

Figure 2.17The 12th degree polynomial relationship of the world energy development

$$f(x) = 7{,}4087E-07x^{12} - 9{,}5116E-05x^{11} + 0{,}0054x^{10} - 0{,}1766x^{9} + 3{,}724x^{8} - 52{,}8697x^{7} + 514{,}6567x^{6} - 3433{,}855x^{5} +$$
$$+1{,}5428E+04x^{4} - 4{,}4909E+04x^{3} + 7{,}9315E+04x^{2} + 2{,}8313E+04;\ R^{2} = 0{,}9994$$
(17)

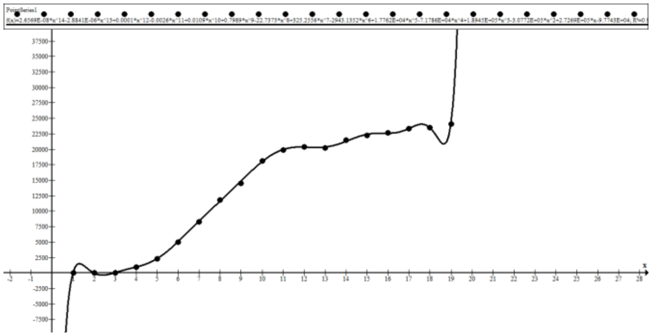

Figure 2.18 The 14th degree polynomial relationship of the world energy development

$$f(x) = 2{,}6569E-08x^{14} - 2{,}8841E-06x^{13} + 0{,}0001x^{12} - 0{,}0026x^{11} + 0{,}0109x^{10} + 0{,}7989x^{9} - 22{,}7373x^{8} + 325{,}255x^{7} - $$
$$- 2943{,}1352x^{6} + 1{,}7762E+04x^{5} - 7{,}1786E+04x^{4} + 1{,}8945E+05x^{3} - 3{,}0772E+05x^{2} + 2{,}7269E+05x - 9{,}7743E+0{,}4;$$
$$R^{2} = 0{,}9998$$
(18)

In the analysis of these functions are also eliminated because history did not indicate significant technological leaps in energy. At the country level, it is possible, but not at the level of global scale.

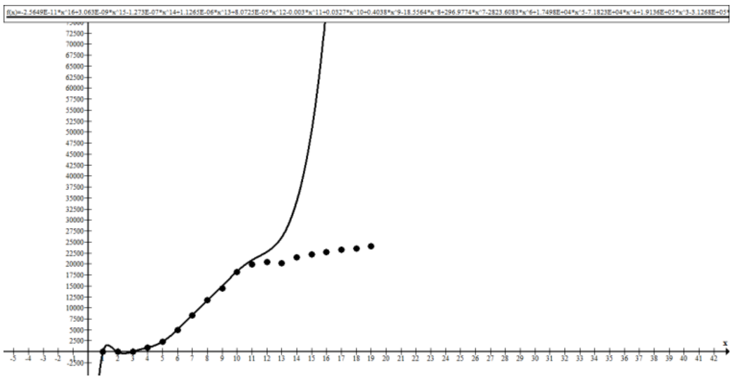

Figure 2.19The 16th degree polynomial relationship of the world energy development

$$f(x) = -2{,}5649E-11x^{16} + 3{,}063E-09x^{15} - 1{,}273E-07x^{14} + 1{,}1265E-06x^{13} + 8{,}0725E-05x^{12} - 0{,}003x^{11} +$$
$$+ 0{,}0327x^{10} + 0{,}4038x^{9} - 18{,}5564x^{8} + 296{,}9774x^{7} - 2823{,}6083x^{6} - 1{,}7498E+04x^{4} + 1{,}9136E+05x^{3} -$$
$$3{,}1268E+05x^{2} + 2{,}7813E+05x - 9{,}9924E+04;\ R^{2} = 0{,}9998$$
(19)

For accelerated growth are characteristic polynomial functions 8 and 9 degrees. These functions are logically explained the necessity and expediency of further development.

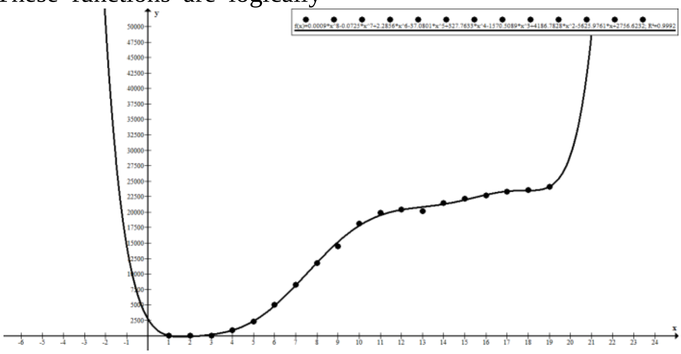

Figure 2.20The 8th degree polynomial relationship of the world energy development

$$f(x) = 0{,}0009x^8 - 0{,}0725x^7 + 2{,}2856x^6 - 37{,}080x^5 + 327{,}7633x^4 - 1570{,}5089x^3 + 4186{,}7828x^2 - 5625{,}9761x +$$
$$+ 2756{,}6232;\ R^2 = 0{,}9992$$
(20)

The function of the 8th degree polynomial should exclude because at the initial stage it already reflects the availability of electric undeveloped technologies for the industrial scale.

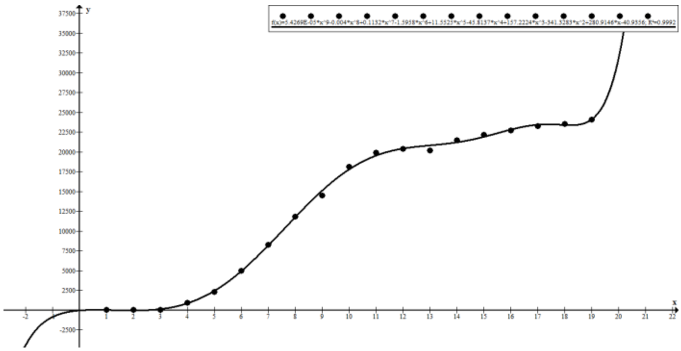

Figure 2.21The 9th degree polynomial relationship of the world energy development

The function of the 9th degree polynomial is clearly and consistently reflects the dynamics of getting the world's electricity. The prospect of this development is due to a technological breakthrough that will provide a rapid increase of production volumes at relatively small growth of new innovative capacities.

Therefore, according favorable, primarily political conditions (the complete exclusion of armed conflicts in the world and the elimination of state borders and the development of the Earth as a single cohesive social system of people) the most probable progressive energy development will take place accordance with the function of the 9th degree polynomial. This development provides a complete energy security on a global level.

Therefore, a mathematical function of the global energy should meet the equation

:

$$f(x) = 5,4269x^9 - 0,04x^8 + 0,1132x^7 - 1,5958x^6 + 11,5525x^5 - 45,8137x^4 + 157,2224x^3 - 341,3283x^2 + 280,9146x + 40,9356;\ R^2 = 0,9992 \quad (21)$$

Conclusions. Thus, this study indicates:

1. The current energy development came out almost to the maximum possible level (25 billion KWh / year) due to «traditional» energy technologies.
2. Alternative technologies of electric current (air, sun, wind) for the current period are only a complement of traditional energy; in no way they cannot fully compensate it.
3. Energy security on modern technological solutions in global terms is not guaranteed. It is a relative measure on the volume of electric generating receipt modern facilities.

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