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2, 1st Veshnyakovsky pr., Moscow, 109456, Russia
Tel.: +7 (499) 171-22-91, Fax: (499) 170-51-01
E-mail: vestnikviesh@gmail.com

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Телефон: +7 (499) 171-22-91. Факс: (499) 170-51-01
E-mail: vestnikviesh@gmail.com

UNESCO ACTIVITY IN EDUCATION FOR SUSTAINABLE DEVELOPMENT AND AICHI-NAGOYA DECLARATION

I. Tyukhov
All-Russian Scientific-Research Institute for Electrification of Agriculture, Moscow, Russia

Education for Sustainable Development (ESD) is one of the very important priorities of UNESCO. Agriculture and renewable energy are the main topics of VIESH. UNESCO Chair "Renewable Energy and Rural Electrification" at VIESH has been actively participated in many aspects ESD actively working in the World Solar Programme, EURONETRES, cooperating with International Sustainable Energy Development Centre. The 2014 UNESCO World Conference on Education for Sustainable Development (ESD) marked the end of the UN Decade of ESD (2005-2014) and saw the launch of the Global Action Programme (GAP) on ESD. The Aichi-Nagoya Declaration is important contribution to the debate on a new education agenda for 2015-2030 to support and guide the implementation of the future agenda The paper presents Aichi-Nagoya Declaration on Education for Sustainable Development. VIESH is starting new Magister Programmes on Agroengineering and Electrical Engineering (Power plants based on renewable energy). It will be more opportunities for young generation to be involved into sustainable development.

Keywords: *UNESCO, education for Sustainable Development, Aichi-Nagoya Declaration, new Magister Programmes*

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Agriculture and renewable energy are the main topics for the All-Russian Research Institute for Electrification of Agriculture (VIESH) and for the UNESCO Chair "Renewable Energy and Rural Electrification" at VIESH in particularly.

UNESCO Chair has been actively participated in the (1996-2005), which was started in Harare, Zimbabwe. Actually this Programme stimulated creating of the UNESCO Chair in VIESH.

Agreement concerning the creation of the UNESCO Chair on Renewable Energy and Rural Electrification at the All-Russian Research Institute for Electrification of Agriculture was signed by Mr. Federico Mayor, Director-General, The United Nations Educational, Scientific and Cultural Organization (UNESCO), and by Professor D. Strebkov, the director of the All-Russian Research Institute for Electrification of Agriculture.

The Chair is a co-founder and constant partner of the UNESCO European Network for Education and Training in Renewable Energy Sources (EURONETRES), sponsored by UNESCO Venice Office (UNESCO-BRESCE). Academician Dmitry S. Strebkov, Chair-Holder, has been elected the Head of EURONETRES's Work Group on PV-Solar. The Chair has hosted two international meetings of EURONETRES Work Groups, in 2005 and 2007, where professors of a number of European universities took par (Fig.1, left).

UNESCO Chair is cooperating with International Sustainable Energy Development Centre under the auspices of UNESCO (ISEDC) taking part in the international seminars and organizing scientific tours for specialists from developing countries and countries in transition in the framework of Fellowships Programme (Fig.1, right).


Fig. 1. EURONETRES meeting in VIESH (left), participants of Fellowships Programme in VIESH (right)

The 2014 UNESCO World Conference on Education for Sustainable Development (ESD) marked the end of the UN Decade of ESD (2005-2014) and saw the launch of the Global Action Programme (GAP) on ESD. The final report "Shaping the Future We Want" of the UN Decade of Education for Sustainable Development (2005-2014) is possible to load from the Internet in Russian, English or other languages [1, 2].

The conference took place from 10-12 November 2014 in Aichi-Nagoya, Japan. The lack of Russian participants at this important event should be compensated by this publication of the Aichi-Nagoya Declaration.

The Aichi-Nagoya Declaration is important contribution to the debate on a new education agenda for 2015-2030 to support and guide the implementation of the future agenda.

Aichi-Nagoya Declaration on Education for Sustainable Development

We, the participants of the UNESCO World Conference on Education for Sustainable Development held in Aichi-Nagoya, Japan, from 10 to 12 November 2014, adopt this Declaration and call for urgent action to further strengthen and scale up Education for Sustainable Development (ESD), in order to enable current generations to meet their needs while allowing future generations to meet their own, with a balanced and integrated approach regarding the economic, social and environmental dimensions of sustainable development. This Declaration recognizes that people are at the center of sustainable development and builds on the achievements of the United Nations (UN) Decade of ESD (2005-2014); the deliberations of the UNESCO World Conference on ESD in Aichi-Nagoya; and the Stakeholder Meetings held in Okayama, Japan, from 4 to 8 November 2014, namely, UNESCO Associated Schools Project Network (ASPnet) International ESD events, the UNESCO ESD Youth Conference, the Global Regional Centres of Expertise Conference, and other relevant events and consultation processes, including regional ministerial meetings. We express our sincere gratitude to the Government of Japan for hosting the UNESCO World Conference on ESD.

1. CELEBRATING the significant achievements made by the UN Decade of ESD (2005-2014), in particular, in putting ESD higher on national and international agendas, advancing policy, improving the conceptual understanding of ESD, and generating substantive good practice amongst a wide range of stakeholders,

2. EXPRESSING our appreciation to many governments, UN entities, non-governmental organizations, all types of educational institutions and setups, educators and learners in schools, communities and workplaces, youth, the scientific community, academia and other stakeholders who have actively committed to and participated in the implementation of the UN Decade of ESD, and to UNESCO for the leadership role it has played as lead agency of the Decade,

3. RECALLING the international commitment to further promoting ESD that was included in the outcome document of the 2012 UN Conference on Sustainable Development (Rio+20), The Future We Want,

4. NOTING that the Global Action Programme (GAP) on ESD, endorsed by the 37th session of the General Conference of UNESCO as a follow up to the Decade of ESD and a concrete con-

tribution to the post-2015 agenda, aims at generating and scaling up ESD actions in all levels and areas of education, training and learning,

5. REAFFIRMING ESD as a vital means of implementation for sustainable development, as recognized in intergovernmental agreements on climate change (Article 6 of the UN Framework Convention on Climate Change and its Doha work programme), biodiversity (Article 13 of the Convention on Biological Diversity and its work programmes and related decisions), disaster risk reduction (Hyogo Framework for Action 2005-2015), sustainable consumption and production (Sustainable Lifestyles and Education Programme of the 10-Year Framework of Programmes on Sustainable Consumption and Production 2012-2021), and children's rights (Articles 24[2], 28 and 29 of the UN Convention on the Rights of the Child), among many others,

6. WELCOMING the growing international recognition of ESD as an integral and transformative element of inclusive quality education and lifelong learning and an enabler for sustainable development, as demonstrated by the inclusion of ESD as a target in the Muscat Agreement adopted at the 2014 Global Education For All Meeting and in the proposal for Sustainable Development Goals (SDGs) by the Open Working Group of the UN General Assembly on SDGs,

7. RECOGNISING the establishment of the UNESCO-Japan Prize on ESD approved by the Executive Board of UNESCO at its 195th session,

We, the participants,

8. EMPHASISE the potential of ESD to empower learners to transform themselves and the society they live in by developing knowledge, skills, attitudes, competences and values required for addressing global citizenship and local contextual challenges of the present and the future, such as critical and systemic thinking, analytical problem-solving, creativity, working collaboratively and making decisions in the face of uncertainty, and understanding of the interconnectedness of global challenges and responsibilities emanating from such awareness,

9. STRESS that ESD is an opportunity and a responsibility that should engage both developed and developing countries in intensifying efforts for poverty eradication, reduction of inequalities, environmental protection and economic growth, with a view to promoting equitable, more sustainable economies and societies benefiting all countries, especially those most vulnerable such as Small Island Developing States and Least Developed Countries,

10. UNDERSCORE that the implementation of ESD should fully take into consideration local, national, regional and global contexts, as well as the contribution of culture to sustainable development and the need for respecting peace, non-violence, cultural diversity, local and traditional knowledge and indigenous wisdom and practices, and universal principles such as human rights, gender equality, democracy, and social justice,

11. APPRECIATE the commitments to ESD expressed by all concerned stakeholders through their specific contributions to the GAP Launch Commitments,

12. COMMIT ourselves to building and maintaining the momentum of the launching of the GAP, in its five Priority Action Areas for ESD, namely policy support, whole-institution approaches, educators, youth, and local communities, through inclusive quality education and lifelong learning via formal, non-formal and informal settings,

13. CALL UPON all concerned stakeholders, including governments and their affiliated institutions and networks, civil society organizations and groups, the private sector, media, the academic and research community, and education and training institutions and centers as well as UN entities, bilateral and multilateral development agencies and other types of intergovernmental organizations at all levels, to: a) set specific goals, b) develop, support and implement activities, c) create platforms for sharing experiences (including ICT-based platforms), and d) strengthen monitoring and evaluation approaches in the five Priority Action Areas of the GAP in a synergistic manner,

14. URGE all concerned stakeholders, in particular Ministries of Education and all ministries involved with ESD, higher education institutions and the scientific and other knowledge communities to engage in collaborative and transformative knowledge production, dissemination and utilization, and promotion of innovation across sectoral

and disciplinary boundaries at the science-policy-ESD practice interface to enrich decision-making and capacity building for sustainable development with emphasis on involving and respecting youth as key stakeholders,

15. INVITE governments of UNESCO Member States to make further efforts to:

a) Review the purposes and values that underpin education, assess the extent to which education policy and curricula are achieving the goals of ESD; reinforce the integration of ESD into education, training, and sustainable development policies, with a special attention paid to system-wide and holistic approaches and multi-stakeholder cooperation and partnerships between actors of the education sector, private sector, civil society and those working in the various areas of sustainable development; and ensure the education, training and professional development of teachers and other educators to successfully integrate ESD into teaching and learning;

b) Allocate and mobilise substantial resources to translate policies into actions, especially building necessary institutional capacities for both formal and non-formal education and learning at national and sub-national levels along the five Priority Actions Areas of the GAP; and

c) Reflect and strengthen ESD in the post-2015 agenda and its follow-up processes, ensuring, first, that ESD is maintained as a target in the education goal and also integrated in SDGs as a cross-cutting theme; and, second, that the outcomes of the 2014 World Conference on ESD are taken into consideration at the World Education Forum 2015 to be held in Incheon, Republic of Korea from 19 to 22 May 2015,

16. REQUEST UNESCO's Director-General to continue to:

a) Provide global leadership, support policy synergy, and facilitate communication for ESD, in cooperation with governments, other UN entities, development partners, private sector and civil society, within the framework of the UNESCO Roadmap to Implement the GAP;

b) Harness partnerships and mobilize networks including the UNESCO ASPnet, UNESCO Chairs, Centers under the auspices of UNESCO, the World Network of Biosphere Reserves and World Heritage Sites, as well as UNESCO Clubs and Associations; and

c) Advocate the importance of ensuring adequate resources including funding for ESD.

Author believes the readers of the journal "Research in Agricultural Electric Engineering" will take more attention to the very important topic "Education for Sustainable Development".

VIESH is preparing a new Magister Programs on Agroengineering and Electrical Engineering (Power plants based on renewable energy). It will be more opportunities for young generation to be involved into sustainable development.

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Corresponding author:
PhD (Engineering), Deputy UNESCO Chair Holder «Renewable Energy and Rural Electrification» **Igor Tyukhov**
All-Russian Scientific-Research Institute for Electrification of Agriculture,
1-st Veshnyakovsky proezd, 2, 109456, Moscow, Russia
Tel.: (+7-499) 171-19-20. E-mails: viesh@dol.ru, ityukhov@yahoo.com

ДЕЯТЕЛЬНОСТЬ ЮНЕСКО В ОБЛАСТИ ОБРАЗОВАНИЯ ДЛЯ УСТОЙЧИВОГО РАЗВИТИЯ И АЙТИ-НАГОЙСКАЯ ДЕКЛАРАЦИЯ

И.И. Тюхов
Всероссийский научно-исследовательский институт электрификации сельского хозяйства (ФГБНУ ВИЭСХ), Москва, Россия

Образование в интересах устойчивого развития (ОУР) является одним из самых важных приоритетов ЮНЕСКО.

Сельское хозяйство и возобновляемые источники энергии – приоритетные темы исследований в ВИЭСХ. Кафедра ЮНЕСКО "Возобновляемая энергия и электрификации сельского хозяйства" в ВИЭСХ активно участвует во многих аспектах ОУР, принимала активное участие в работе в рамках Всемирной Солнечной программы, EURONETRES, а также сотрудничает с Международным центром устойчивого энергетического развития.

Всемирная конференция ЮНЕСКО по образованию в интересах устойчивого развития 2014 года завершила Десятилетие ООН по ОУР (2005-2014 гг.) и запустила программу Глобальных действий по ОУР.

Айти-Нагойская Декларация вносит важный вклад в дебаты по новой повестке дня для образования и поддержки будущей повестки на 2015 – 2030 годы. В статье представлен текст Айти-Нагойской декларации по образованию для устойчивого развития.

ВИЭСХ занимается подготовкой новой магистерской программы по агроинженерии и электротехнике (энергетические установки на основе возобновляемых источников энергии). Это даст больше возможностей молодому поколению участвовать в устойчивом развитии нашего общества.

Ключевые слова: ЮНЕСКО, образование в интересах устойчивого развития, Айти-Нагоя декларации, новый Магистр программы.

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Сведения об авторе:
Тюхов Игорь Иванович – канд. техн. наук, доцент, заместитель заведующего кафедрой ЮНЕСКО «Возобновляемая энергетика и электрификация сельского хозяйства», ФГБНУ ВИЭСХ, Москва, Россия,
e-mails: viesh@dol.ru, ityukhov@yahoo.com

NON-POLLUTING ENERGY SOURCES AND TECHNOLOGIES

D. Strebkov
All-Russian Scientific-Research Institute for Electrification of Agriculture, Moscow, Russia

Current situation in the field of fuel and energy is characterized by unstable prices for fossil fuels and ever growing technogenic pressure on environment. These factors determine main political, economical, legislative and technological trends. In scientific and technological sphere this stimulates the search for new possibilities in biofuels production, notably, the use of bioresources that do not cause considerable disbalance in the structure of agricultural production traditionally oriented at meeting demand for food products. In recent years, due to considerable increase of biomass use for energy purposes, serious problems emerge related to deforestation and transfer of considerable part of agricultural products from food and forage industries to energy area. Intensive wood procurement for biodiesel production leads to failure of ecosystems.

In biomass production rate algae many times exceed the most productive land plants and, more over, produce more useful products per unit area. Biofuels made of algae oil are termed third generation biofuels. It can be concluded, that at the present stage of the world economic and technological development there are great opportunities of microalgae use as alternative vegetable raw materials for biodiesel production.

Innovative approach to the reduction of costs for motor and stove fuel is the production of composite multicomponent fuel with diesel oil content 80% for motor fuel and 64% for in stove fuel. Plasma technologies for solid domestic waste processing into electric energy and the technologies for liquid organic waste processing based on supercritical water oxidation of organic substances into liquids for thermal and power plants with 1 MW capacity are under development.

The results of comparison of parameters of a classical electric power supply system with an electric power supply system using single-wire wave-guide lines with high frequency, proposed by N. Tesla 100 years ago show, that in such characteristics as current density and line losses, energy transmission distance, transmission capacity, the possibility of cable and wireless power transmission the Tesla electrical systems exceed the classical energy supply systems. In future electrified mobile robots with external power wireless power supply will make it possible to organize agricultural production on the principles of «Industrial Factories on Fields» with full automation of technological processes.

The energy model of the future world based on direct solar energy conversion and transcontinental terawatt power transmission with the use of resonant wave-guide N. Tesla technology is proposed. The advanced Russian technologies for solar energy include chlorine-free technologies for solar-grade silicon production, the technologies for silicon high voltage solar modules with 20% efficiency at 60-fold concentration of solar radiation, the technologies for assembling solar modules with 40-50 years' service life, the technologies of concentrator solar modules and non-carbon fuel.

Keywords: *Biofuels, food security, fast pyrolysis, microwave assisted combustion, plasma processing, non-carbon fuel, low carbon fuel, Tesla technique. Solar power system.*

Introduction

Energy consumption per head of population in Russia is half that of the USA and Canada, even though Russia is the coldest country in the world. Maximum load on the energy system occurs in the winter season, and fuel consumption for heat and electricity supply to residential and industrial buildings accounts for nearly 65% of total fuel and energy consumption. To reduce high-energy tariffs in the Russian Federation (RF), it is necessary to increase the fuel utilization factor through energy generation at highly effective cogeneration plants, to decrease fuel cost and to develop biofuel and low-carbon energy production with the use of renewable energy sources [1-3]. Research and development in renewable energy has been stimulated by the well-known requirement of funding energy sources alternative to fossil fuels, to prevent increasing atmospheric CO_2. For meeting the above need non-polluting energy sources should be found, which do not have health risks, are economically competitive when compared to oil sources that are easily discovered and exploited, and are naturally abundant. Many alternative energy sources have already been explored and tested, even on an industrial scale, including biomass, fuel materials of vegetable or agricultural nature used for heating, electric generation and transport purposes. The aim of the paper is to introduce methods for production, transmission and use of energy in an economic, convenient, reliable and repetitive manner, without producing hazardous waste materials.

Currently, approximately 45%-50% of the total fuel and energy resources are used in boiler houses and other heating systems generating only heat. There are over 200 000 boiler houses in Russia, of which 73 000 are municipal. In boiler houses servicing heating networks, 47% of thermal energy is generated. In cities with populations of 100 000-500 000, the majority of consumers are provided with heat by boiler houses. Even in Moscow, 30% of thermal energy is generated by boiler houses. Energy transport potential is not completely utilized in boilers. In order to improve the existing situation it is necessary to upgrade and re-equip these boiler houses to the level of mini heat power plants where both thermal and electric power will be generated (cogeneration).

One objective in the development of electric power generation is increasing the share of distributed power generation so the energy production cost is reduced due to lower costs for energy transport from deposits to power plants and for electric power transfer from power plants to customers.

Biomass energy resources

In Russia, over 100 Mt of biomass available for energy purposes is produced per year. The energy equivalent of this amount of raw materials is more than 40 Mt of reference fuel (300 000 GWh). Only 10% of this renewable biomass resource is involved in recycling processes. One of the largest producers of waste is agriculture. According to statistics, in 2010 in Russia agriculture and forestry sectors produced almost 68 Mt of waste. Of the total amount of waste used or neutralized, 18.8 Mt accounted for at least 28% of the waste volume.

Effective and reliable sources of raw materials for bioenergy will come from the forestry sector. Russia's forest land and forests represent 69% of the country. The wood reserves are about 82 billion cubic meters, more than a quarter of world reserves. Over 500 million cubic meters of wood is harvested annually and this figure continues to grow [2-4].

Role of agriculture in the biofuel market

In 2013, the author was appointed as a member of the Oversight Group to review the report of the High Level Panel of Experts on Biofuels and Food Security. This report, under the guidance and oversight of the High Level Panel of Experts Steering Committee, analyses the issues of food security related to the development of biofuel world markets. Prospects for biofuels use remain a subject of debate around the world. Research and development in this area continues to find innovative approaches that may deliver not only solutions but also reveal new, unanticipated problems. However, there is no doubt that these problems are of vital importance for large areas of the globe [5].

At the same time, it has to be noticed that safety and sustainability of life are not only limited by food and potable water supply. The environmental issues are also of prime importance and the substitution of fossil fuels by biofuels is believed to be one of the most effective approaches to reduce the anthropogenic impact on the nature.

The use of fluid and solid biofuels around the world grows at 10% or more per year. Most intensively the biofuel market has been developing in the EU and is expected to exceed 10% by the year 2020 in the transport sector of Europe. So it is evident that the problem has to be solved in a way that accommodates multiple factors, including social, economic, environmental and technological aspects.

Our vision for the possible solutions for biofuel production and utilization is based on the recent trends in power and transport industries. These trends are decentralized power generation and increasing growth in electric traction. Therefore, the share of fuel for internal combustion engines derived from biomass, and the consequent demand for energy crops such as rapeseed and maize, will continue to decrease.

The role of burner biofuels for decentralized power generation will grow significantly. This trend has to be viewed as an advantageous one in many aspects.

Firstly, the existing burner biofuel preparation technology is relatively simple and does not require expensive biomass components extracted from plants traditionally used for food. Biomass pretreatment cycles are also substantially simpler in the case of biofuels designed for external combustion processes. For these purposes, various kinds of organic waste can be used that are commonly produced in huge amounts and constitute a great problem for their environmentally safe and economically expedient utilization.

Extensive biomass resources produced in rural areas have a powerful potential for local cogeneration sector development and independent heat and power supply, based on mini-cogeneration plants operating on composite burner biofuels, in areas with practically no access to the grid or where the grid power quality and/or reliability are poor.

Composite biofuels are principally prepared on the basis of hydrous organic components of various plants. It is well known, that up to 20% of water contained in any fuel in the form of microfine emulsions acts as catalyst during combustion, making the process essentially more intensive and efficient. Thus, only 10% of water in uniform grade of heavy fuel oil results in a reduction in carbon soot of 80%-90%, NO_X by 50% and SO_X by 30% [6].

Main obstacles to biofuel production

The main obstacle to developing biofuel production in Russia is a misguided state excise policy, such that the cost of the new fuel will be higher than petroleum. Biofuel production in Russia is subject to the same taxes as vodka. Support for biofuels should be by the abolition of high excise taxes on motor spirit. Unless these taxes are removed, the production of biofuels will never be profitable.

Land availability, population density and per capita income may provide preliminary orientation to the desirability of biofuel policies and the type of policy that would be most appropriate. Innovative technology can identify tradeoffs of different systems of production and their positive and negative impacts on food security. The biofuel industry has a huge potential for revival of the rural economy and at the same time will contribute to energy independence and reduced greenhouse gas emissions.

In recent years, the development of the industry has slowed, as the production of biofuels from agricultural products has caused a global rise in food prices. It has been shown, that biofuels threaten food security through price increases. Changes in the structure of land investments have resulted in displacement of traditional communities, the replacement power supply and deepening food insecurity.

Sorghum energy plantation in Russia and economic parameters of biofuel manufacture are presented in Fig. 1 and Table 1.

Non-food crops competing for biofuel production should be evaluated in terms of their direct and indirect impact on food security as competing with food raw materials for the land, water, labor, capital and other investments. Numerous case studies on biofuels show the importance of the transition to a more comprehensive strategic approach to bioenergy. In countries with large hinterland biomass mobilization for different types of bio-energy may be the most effective strategy for the development of electricity and alternative energy, water management and the creation of local energy systems.

Fig. 1. Sorghum plantations in the Rostov area of a selection by the member of Russian Academy of Agricultural Sciences B.N. Malinovsky (on the right) yields 130 t/ha, producing 15 t/ha biofuel

Table 1

Economic parameters of biofuel manufacture from Sorghum and wheat

Expenses for Sorghum cultivation Yield of dry biomass Manufacture of biofuel The production cost of biofuel Sale price of biofuel Annual volume of sales per 1 ha:	100 USD/ha 30 t/ha 15.0 t/ha 250 USD/t 500 USD/t 500 USD/t; 15.0 ha = 7500USD/ha
Wheat cultivation Average yield Sale price Annual volume of sales per 1 ha:	 2 t/ha 300 USD/t 600 USD/ha

Biofuel from algae

One of the most promising biofuel-dedicated crops is microalgae (Fig. 2) [7-8]. The idea of producing biofuel from algae dates back to the 1970s when the world experienced a number of the oil shocks. The advantages of algae as a raw material for biofuel production are their enormously high productivity compared with terrestrial crops and the possibility to preserve arable lands for food production and other agricultural crops. Algae can be effectively cultivated in natural or artificial ponds on marginal lands, shallow lagoons and in water cooling systems of thermal power stations (TPS). In the latter case, it is technically easy to make use of rejected heat for optimizing algae productivity and to employ algae's explicit photo synthetic properties for utilization of CO_2 contained in TPS flue gases.

Algae cultivation in closed photobioreactors is an option that makes it possible to obtain phytomass of specific chemical composition for enhancement of biofuel chematological properties. So far, biofuel dedicated algae cultivation on a commercial scale has not been reported because the research in this field has remained focused entirely on biodiesel as the only option. The problem is that the cost of biodiesel produced from algae grown in ponds would amount to 240-332 USD per barrel (Lawrence Berkeley National Laboratory, 2010) while the current price of crude oil does not exceed 100 USD per barrel. This was the major reason that the US Department of Energy closed its algae

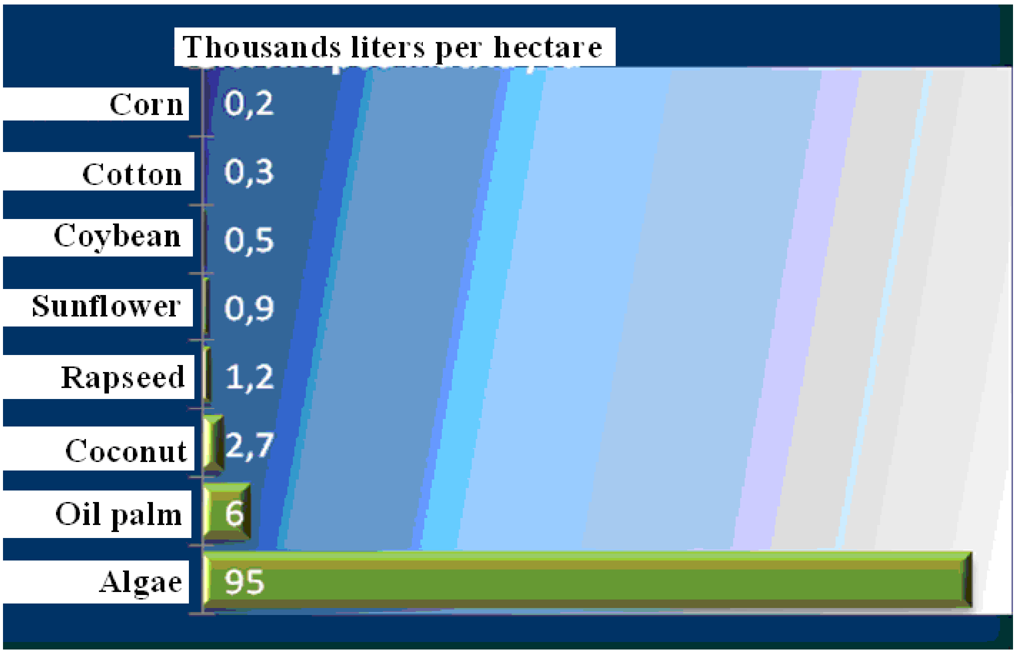

Fig. 2. Comparative data on raw oil production per ha of area allocated for crop cultivation

Fig. 3. Industrial cultivation of microalgae in open ponds [8]

Fig. 4. Cultivation of microalgae in photo bioreactors [8]

research program in 1996. A decade passed before it was started again, but algae derived biodiesel has not yet found commercial application [8].

Our research has demonstrated the possibility of overcoming the algae fuels production cost barrier within the concept of composite biofuels described above. As a hydrous component of composite burner biofuel, microalgae suspension is an ideal organic material featuring very high grade natural dispersiveness (down to 1 μm for planktonic strains derived from *Chlorella vulgaris*, the most common species in natural ponds in temperate climates). Microalgae suspension can be blended easily into heavy grade fuel oil using cavitation technology without any pretreatment insuring ultrafine and stable biofuel [7, 8].

There is a great opportunity for microalgae to be used as alternative raw materials for biodiesel production. Further progress depends on finding fast-growing and resistant microalgae strains with high oil content and algology development using the complete range of biotechnological, genome and biochemical methods, and on improvement of cultivation process using benefits of open methods of growing large amounts of biomass and photo bioreactor cultivation of strains with specified technological properties. This is possible through a combination of open and photo bioreactor cultivation (Fig. 3, 4) [7, 8].

A new trend is to use algae to remove CO_2 from the exhaust gas from TPS and other industries. The exhaust gases contain a high percentage of CO_2 (up to 20%). Typical thermal power generation using coal emits up to 13% CO_2. Thus, the thermal power plants are a major source of CO_2 air pollution. Exhaust emission of CO_2 and use of alternative energy will lead to stabilization of atmospheric CO_2 and prevent global warming. Microalgae absorb CO_2 during growth, so that they can be used to remove CO_2 from the exhaust gas of thermal power plants and other industries.

Currently microalgae is mostly grown on a commercial scale in artificial shallow ponds of up to thousands of square meters. Problems of cultivation of microalgae in ponds led to the development of new technology for growing, based on the use of photobioreactors for algae for the optimal functioning of the cultivation (or biofuel from microalgae).

Photobioreactors for growing algae can occupy 10%-20% of the land used in open ponds for the production of the same amount of algae. To use photobioreactors commercially, they need to have the most efficient use of solar energy, and the necessary conditions of cultivation to maintain the purity of the microalgae cultures.

Plasma processing of solid organic waste

The Russian scientists have developed ecologically-clean innovation technologies for processing solid organic waste of cities and agricultural enterprises into electrical energy and heat at plants with 100 t/day capacity with cogeneration of 1 MW of electric and thermal power [1, 9]. Waste is processed at high capacity in sealed reactors and not combusted as in plants from other countries. The application of such technologies will make it possible to considerably improve ecological sustainability and reduce energy intensiveness of the processes. The total volume of waste dumped at landfills in RF cities amounts to 95 000 Mt and is annually increased by 3 500 Mt. The total area of solid waste landfills in the RF is 2 500 km^2.

Advances in the RF provide gas reciprocating units with 1.3 MW electric and heat capacity as cogeneration power plants, using plasma technologies, to achieve rapid pyrolysis with a capacity of 100 t of solid organic waste per day and internal electricity consumption of 300 kW for gas fuel production from cogeneration power plants operation. These internal energy consuming cogeneration power plants will generate 1 MW of electric capacity into energy and process 36 000 tons of solid organic

Fig. 5. Equipment for testing fast pyrolysis at VIESH

waste per year. The RF is considering distributed cogeneration that does not require construction of main power transmission lines, as well as fuel extraction and transportation. In estimating payback periods of the energy projects being considered, it is necessary to take into consideration the economic effect from elimination of landfills, land recultivation and environmental improvement of cities and rural settlements.

Other solid organic waste resources include forestry and agricultural residues, and in woodless areas – energy plantations of fast-growing trees on land not suitable for agricultural production, for example, in areas around the nuclear power stations in Chernobyl and Fukushima, and deserts, marshy and saline lands.

In the fast pyrolysis method, a substantially higher decomposition rate and energy saving is obtained owing to rapid (10^4 $^{\circ}$C/s) heating of organic compounds (thermal shock). Under thermal shock conditions molecules of the processed materials have no time for energy exchange. That is why nearly all input energy is spent on their chemical decomposition. The specific heat of combustion for the liquid phase intended as the base fuel component for internal combustion engines was estimated as 23.027 ± 2.093 MJ/g. An experimental demonstration model of the plant has been designed and manufactured. This technique has an important social objective: providing consumers with local reliable power supply insuring independence and ecological safety [9, 10].

A pilot production plant has been designed and manufactured for decomposition of any type of solid combustible feedstock (e.g. coal, peat, biomass and vegetable wastes) into mainly gaseous and liquid fractions (Fig. 5). An efficient decomposition method has been developed and the block diagram of the industrial plant for manufacturing of liquid internal combustion engine fuel components has been described. Fast pyrolysis related technological solutions have patents pending at VIESH, Russia.

Plasma processing of liquid organic wastes

Key sources of environmental pollution that can also be used as renewable fuel resources for cogeneration power plants include liquid sewage effluents of cities and settlements, liquid effluents from pig farms, liquid waste from sugar refineries and distilling plants.

To process liquid organic waste with 80-95% water content into electric energy, pyrolysis technologies are not suitable because of high-energy costs of the process of preliminary drying liquid organic waste. Russian scientists have developed new technologies for liquid organic waste processing based on supercritical water oxidation of organic substances into liquids. For a cogeneration power plant with 1 MW capacity, processing of 150 t of liquid organic waste per day is required because of lower organic content in liquid organic waste in comparison with solid organic waste. For cities, this allows a reduction in areas occupied by waste treatment facilities and to eliminate sewage disposal into the sea, as in Sochi, Gelendzhik, Malaga, Barcelona (Spain), in towns on the sea in Australia and other countries.

Large-scale pig farms keeping several sediment ponds for dung effluents, will be able to provide electricity and heat, not only for their own needs, but also for villages and rural areas situated nearby [1, 9].

Microwave assisted combustion

In the Laboratory of Biofuel Technologies of VIESH, experiments are conducted on microwave-assisted combustion of composite biofuels comprising 50%, or even more, of liquid and/or solid organic components of various natures, using flame cups of unique design. Composite burner biofuel typically contains 20-50% of hydrous organics (e.g. plant biomass and cattle dung) blended in a heavy, low grade, oil derivative such as fuel oil using energy efficient technological methods that employ hydrodynamic and ultrasonic cavitation processes to obtain a stable microfine multi-component emulsions/suspension (Fig. 6, 7).

This approach makes it possible to implement the environmental advantages of biofuels at substantially lower production cost without the need for additional large areas arable land [1, 9].

Plasma conversion of liquid organic wastes

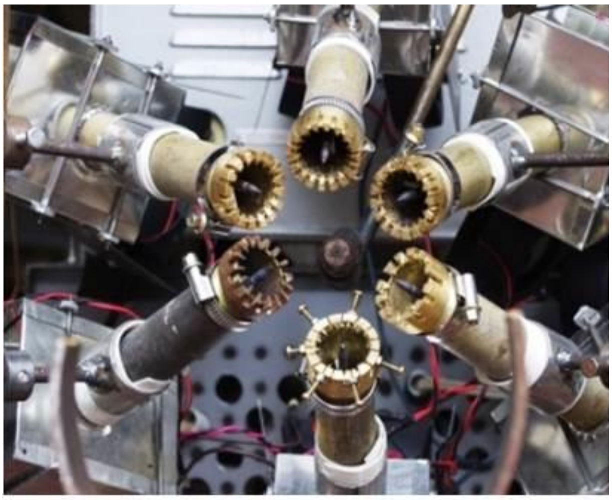

Fig. 6. Electric plasma generator

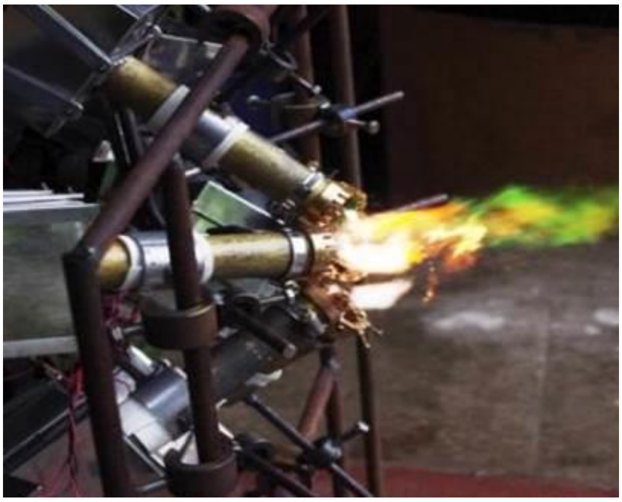

Fig. 7. Burning of liquid organic wastes

Low-carbon multicomponent fuel

Another approach to the reduction of costs for motor and stove fuel is the production of composite multicomponent fuel. Hydrocarbon fuel content (diesel fuel or mazut) amounts to 80% of multicomponent diesel fuel. The working model of equipment for multicomponent fuel production with 2 t/h capacity is installed at the biofuel laboratory at VIESH (Fig. 8) [1, 9]. Comparison of characteristics of diesel, mazut and multicomponent motor fuel in Tables 2 and 3 are presented.

The use of multicomponent fuel in tractors, ships, automobiles, locomotives and stationary diesel engines leads to a reduction of harmful emissions into the atmosphere by 30-40%. In stove multicomponent fuel carbon fuel content is 50-60% which halves heating costs.

Fig. 8. Equipment for multicomponent fuel production with 2 t/h capacity at the Bioenergy Department of VIESH

Table 2

Comparison of the characteristics of diesel, and multicomponent motor fuel

№	Fuel characteristics	Summer diesel fuel	Multicomponent motor fuel with 80% diesel content
1.	Lowest combustion, kj/kg	42 776	44 327
2.	Mass fraction of sulfur, %	0.13	0.038
3.	Kinematic coefficient of viscosity, cSt at 20 °C	4.8	3.9
4.	Flash temperature in a closed cup, °C	75	73
5.	Cetanel number	50	61 (standart Euro-4)
6.	Industrial purity class	12	over 17
7.	Fuel storage time, years	-	1

Table 3

Comparison of characteristics of mazut and multicomponent motor fuel

№	Fuel characteristics	High-sulphur mazut	Multicomponent fuel with 80% mazut content
1.	Lowest combustion, kj/kg	41 816	44 101
2.	Mass fraction of sulfur, %	1.71	0.87
3.	Kinematic coefficient of viscosity, cSt at 20 °C	7.3	5.9
4.	Flash temperature in a closed cup, °C	93	97
5.	Fuel storage time, years	-	1

Non-carbon silicon fuel for energy generation

By analogy with hydrocarbon energy, this trend can be termed silicon energetics. Let us consider four known methods of using silicon for energy generation [11].

1. Silicon combustion in air:

$$Si + O_2 = SiO_2. \quad (1)$$

2. Silicon catalytic combustion in water:

$$Si + 2H_2O = SiO_2 + 2H_2. \quad (2)$$

$$2H_2 + O_2 = 2H_2O. \quad (3)$$

3. Silicon catalytic combustion in nitrogen:

$$Si + 2N_2 = SiN_4. \quad (4)$$

4. Physicochemical reactions in molten sodium silicate:

$$sNa_{2r}\,SiO_{(2r+s)} \Rightarrow Na^{+} + Si_mO_n. \quad (5)$$

Comparison of calorific efficiency of silicon and hydrocarbons is given in Table 4.

Initial and final products of silicon energetics are not radioactive, do not pollute the environment and do not generate greenhouse gases. In combustion in air, silicon as a fuel is twice as effective as coal and is almost equal to natural gas. If associated with nitrogen in oxygen-free energetics, silicon as fuel is twice as effective as coal. Nitrogen content in the atmosphere greatly exceeds all other gases. Thermal energy of high-temperature physical-chemical reactions in heterogeneous media of high-modulus silicate solutions, for example sodium silicate exceeds the calorific value of hydrogen fuel with the same mass by a thousand times. Electrochemical current source with molten electrolyte with nonstoichiometric composition on the basis of sodium silicate with megawatt capacity has calculated price of electricity of 80 Euro/MWh.

Another promising non-carbon fuel is nanometric particle nickel powder producing huge amounts of thermal energy as the result of cold fusion with hydrogen [12]:

Alternative non-carbon source of thermal energy
Temperature 150-500 ^{o}C
Pressure $2{\cdot}10^5$-$20{\cdot}10^5$ Pa

↓↓

One gram of nanometric
particle nickel powder + Hydrogen ⇒
⇒ Coopper + 517 t of oil equivallents

Table 4

Comparison of calorific efficiency of silicon and hydrocarbons

Reaction number	Fuel	Calorific efficiency
1	Silicon	858.294 kJ/mol
2	Silicon	858.294 kJ/mol
2 ÷ 3	Silicon	1.144 MJ/mol
4	Silicon	753.624 kJ/mol
-	Methane	879.228 kJ/mol
-	Coal	393.5592 kJ/mol
3	Hydrogen	285.95844 kJ/mol
5	Sodium silicate	35.587 GJ/mol
-	Heavy oil	35.587 MJ/mol

Biofuels for transport industries

A vision of the possible solution in the sphere of biofuels production and utilization is based on the recent trends in power and transport industries.

A transport system without engine and chemical battery is under development.

Resonant single-conductor electric power transmission systems (Fig. 9, 10) [13] would offer global opportunities for developing non-contact high-frequency electric transport. The well-known non-contact method for transmitting electric power to a vehicle through an air-core transformer (using the electromagnetic induction method and conventional single-phase power transmission lines) has basic limitations on the transmitted power level, the transmission efficiency and the line length; therefore, it is not currently used.

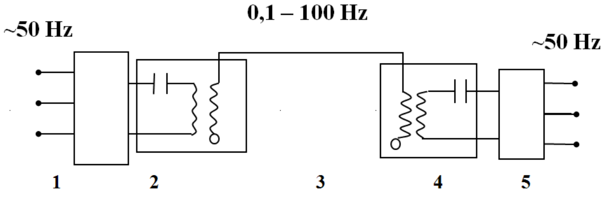

Fig. 9. Resonant system for electric power transmission:
1 – converter; 2, 4 – resonant high-frequency Tesla transformers; 3 – single-conductor high-voltage line connecting the transformers; 5 – inverter

Experimental models of non-contact electric vehicle and tractor in Fig. 11 and 12 are presented.

It is possible to imagine that in the future large, green cities, full of flowers, without exhaust

Fig. 10. 20 kW, 5 kHz resonant electric power transmission system

Fig. 11. Non-contact high frequency electric vehicle

Fig. 12. A model of an electric tractor, using non-contact trolley

gases and smog. A cable transmission line will be laid in this city under each driving lane along main roads, and each vehicle has an electric motor and a non-contact trolley in addition to the combustion engine. The traffic along major highways between cities can be organized in the same way, including possible use of automated vehicles controlled by robots and computers.

The use of an electric non-contact drive in the agricultural industry opens the prospects for substantial fuel saving and developing robots controlled by computers with satellite navigation, intended for tillage, cultivation and harvesting agricultural products. In this case the agricultural plants will be transformed into field factories organized according to the principles of automated industrial enterprises. Thus, three present-day electrification problems can be solved: energy saving, reducing harmful gas emission and automation of agricultural production process.

Agriculture for the Arctic zone

The most efficient way of solving the problem of Russia's food security is based on techniques aimed at the setting-up of fractal innovative biotechnological cluster platforms, intended for the accomplishment of different-scale projects for the production of organo-functional food and formation of a network of different scale automated production complexes. The technological and economic advantages of the new approach to the solution of the problem of food safety in Russia, primarily the problems of food supply to the regions of Siberia, the Far East and the Arctic zone, have been considered. Advanced biotechnologies leading to accelerated growing of agricultural plants with the use of synergoponics, new technological equipment for industrial production of organo-functional food, as well as innovative methods of quality control and safety of produced goods on the basis of biotesting, have been developed and implemented [14].

Fuel-free energy generation

Each technological mode and corresponding energy source is characterized by the phases of development, in turn flourishing and then declining. The Twentieth Century was the period of maximum development and use of hydrocarbon energy, which by the end of the Twenty-first Century may be replaced by fuel-free power generation on the basis of renewable energy sources. The decline in the development of hydrocarbon energy will stem not from depletion of hydrocarbons reserves but from the development of new energy technologies and emergence of new energy transporters allowing reduced costs of energy resources, raised energy use efficiency and diminished negative impacts on environment [11].

Currently the fuel energy generating industry provides 87.1% of the energy consumed worldwide. Local and foreign experts estimate that by the end of this century over 80% of the global energy consumption will be provided by non-fuel energy technologies: hydrological, biological, solar, wind and geothermal energy plants alongside hydrogen energy. The advanced Russian technologies for solar energy, include chlorine-free technologies for solar-grade silicon production, the technologies for silicon solar modules with 20% efficiency at 60-fold concentration of solar radiation, the technologies of assembling solar modules with 40-50 years' service life and the technologies for concentrator solar modules [1, 11].

The energy model of the future world offered by VIESH in 2004 is based on round-the-clock electric power generation by solar power plants and on energy systems and networks on the basis of Nikola Tesla technologies [11, 13]. In Russia, new energy technologies have been developed allowing the creation of a global solar energy system within the framework of an international project involving energy companies concerned, the International Energy Foundation, IRENA, UNESCO, the UN and other national and international organizations and financial institutions. The development of solar energetics silicon will make it possible to reduce the negative impact of hydrocarbon energy on climate, environment and human health, as well as to reduce greenhouse gases emission down to a safe level.

Such a global solar energy system would need to generate electrical power of 20 000 TWh per year which would be equivalent to current global energy consumption. The global solar energy system (Fig. 13) comprises three solar power plants (SPP) installed in deserts of Australia, Africa and Latin America and connected to one another and to national energy systems of all the countries all over the world with waveguide resonant lines for electric power transmission on the basis of Nikola Tesla technologies.

Parameters of each solar power plant [11]:

size	200×200 km^2;
electric capacity	2.5 TW;
efficiency	25%;
servicelife	50 years.

Computer simulation of the global power system parameters with due account taken of meteorological data on solar radiation for the whole

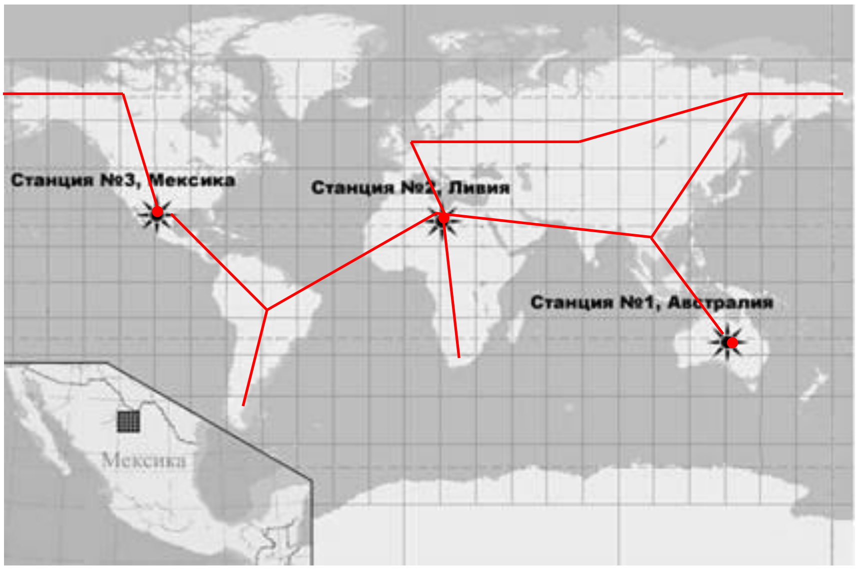

Fig. 13. Mega project global solar power system

Fig. 14. Experimental model of a non-tracking solar concentrator module with 800 W peak capacity. The photoreceiver area is reduced by a factor of three in comparison with solar power plants without concentrators

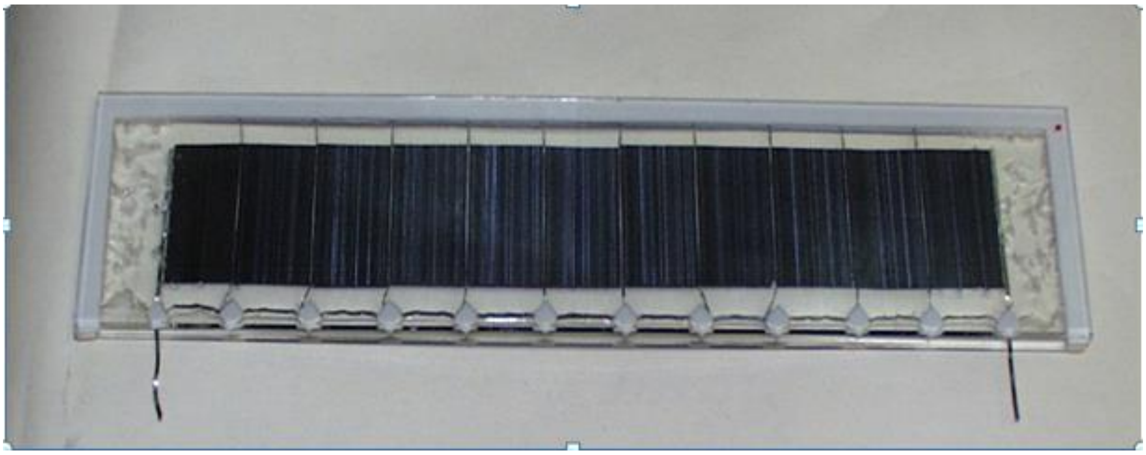

Fig. 15. High voltage PV module

Fig. 16. Solar power plant with 1 150 W capacity and with 40-50 years of service life

observation period at proposed SPP location confirmed uniform year-round electricity production irrespective of season, equivalent to the amount of global consumption [11].

Modern solar energy is mainly based on planar low-voltage silicon solar modules without concentrators with 15% efficiency and overall production of modules generating 30 GW/year with the rate of production of silicon for solar panels of around 200 kt/year. Silicon content in the Earth core exceeds the content of all other elements with the exception of oxygen, which is why it is silicon, that will remain the basic material for solar energy in future. SPP with 2.5 TW capacity at 100 concentration would require 300 kt of silicon, which is comparable to current volume of silicon production for electronics and photovoltaics. A stationary PV concentrator module installed at a VIESH test site in Fig. 14 is shown.

SPP with cylindrical concentrators and a photoreceiver on the basis of a high voltage solar module (HVSM) with 20% efficiency and 50-60 concentration is under development. The area of photoreceivers with HVSM with concentrators will be reduced 50-60 times. High voltage solar module has operating voltage 1000 V and the size 0.7 m·0.07 m (20 000 V/m^2) (Fig. 15).

A solar power plant consisting of solar modules without concentrators with an estimated 40-50 years' service life (VIESH technology patent) and capable of generating 1 150 W peak capacity installed at the VIESH testing site in Fig. 16 is shown.

Conclusions

1. The current situation in the field of fuel and energy is characterized by unstable prices for fossil fuels and ever growing technogenic pressure on environment. These factors determine the main political, economic, legislative and technological trends. In the scientific and technological sphere this stimulates the search for new possibilities for biofuels production, notably, the use of bioresources that do not unbalance the structure of agricultural production traditionally oriented towards meeting the demand for food products. In recent years, due to the considerable increase in the use of biomass for energy purposes, serious problems have emerged related to deforestation and transfer of considerable parts of agricultural products from the food and forage industries to the energy production area. Also the intensive wood procurement for biodiesel production leads to failure of ecosystems.

2. The rate of biomass generated by algae exceeds many times the most productive land plants and, moreover, algae produce more useful products per unit area. Biofuels made of algae oil are termed third generation biofuels. The problem of using algae oil for energy purposes has two principal aspects determining the scale of use and applications: the search for species of oil-containing algae most suitable for cultivation, and development of optimal cultivation technology. In recent years the idea of a two-phase technology for microalgae cultivation for biodiesel production, combining closed (photo bioreactor) and open (basins and ponds) methods of cultivation has been developed. In this case closed photo bioreactors can be effectively and economically used for production of high-quality inoculum - cell suspension used as feedstock for cell culture cultivation with further introduction to nursery ponds for open cultivation. It can be concluded, that at the present stage of the world economic and technological development there are great opportunities for microalgae use as alternative vegetable raw materials for biodiesel production.

3. An innovative approach to the reduction of costs for motor and stove fuel is the production of composite multicomponent fuel with diesel oil content 80% for motor fuel and 64% for in stove fuel. Plasma technologies for solid domestic waste processing into electric energy and the technologies for liquid organic waste processing based on supercritical water oxidation of organic substances into liquids for thermal and power plants with 1 MW capacity are under development.

4. Comparison of parameters of a classical electric power supply system with an electric power supply system using single-wire wave-guide lines with high frequency, proposed by N. Tesla 100 years ago show, that in such characteristics as current density and line losses, energy transmission distance, transmission capacity, the possibility of cable and wireless power transmission the Tesla electrical systems exceeds the classical energy supply systems. In future electrified mobile robots with external wireless power supply will make it possible to organize agricultural production on the principles of «Industrial Factories on Fields» with full automation of technological processes.

5. The energy model of the future world based on direct solar energy conversion and transcontinental terawatt power transmission with the use of resonant wave-guide technology, development by N. Tesla, is proposed. The advanced Russian technologies for solar energy include chlorine-free technologies for solar-grade silicon production, technologies for silicon high voltage solar modules with 20% efficiency at 60-fold concentration of solar radiation, technologies for assembling solar modules with 40-50 years' service life, and concentrator solar modules and non-carbon fuel technologies.

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Corresponding author:
Academician **Dmitry Strebkov**
All-Russian Scientific-Research Institute for Electrification of Agriculture,
1-st Veshnyakovsky proezd, 2, 109456, Moscow, Russia.
Tel.: (+7-499) 171-16-74.
E-mail: viesh@dol.ru

ЭКОЛОГИЧЕСКИ ЧИСТЫЕ ИСТОЧНИКИ ЭНЕРГИИ И ТЕХНОЛОГИИ

Д.С. Стребков
Всероссийский научно-исследовательский институт электрификации сельского хозяйства (ФГБНУ ВИЭСХ), Москва, Россия

Текущая ситуация в области топлива и энергетики характеризуется нестабильностью цен на ископаемое топливо и постоянно растущей техногенной нагрузкой на окружающую среду. Эти факторы определяют основные политические, экономические, законодательные и технологические тенденции. В научно-технологической сфере это стимулирует поиск новых возможностей для производства биотоплива, в частности, использование биоресурсов, которые не вносят существенный дисбаланс в структуру производства сельскохозяйственной продукции, традиционно ориентированной на удовлетворение спроса на продукты питания. В последние годы в связи со значительным увеличением использования биомассы для энергетических целей возникают серьезные проблемы, связанные с вырубкой лесов и передачей значительной части сельскохозяйственных продуктов для энергетической отрасли. Интенсивная заготовка древесины для производства биодизельного топлива приводит к выходу из строя экосистем.

Биотопливо из масла водорослей называется биотопливом третьего поколения. Можно сделать вывод, что на современном этапе мирового экономического и технологического развития имеются большие возможности использования микроводорослей в качестве альтернативного растительного сырья для производства биодизеля. Инновационный подход к сокращению затрат на моторное и печное топлива состоит в производстве композиционных многокомпонентных топлив при работе на дизельном топливе с содержанием углеводорода 80% для моторного топлива и 64% для печного топлива. Плазменные технологии для переработки твердых бытовых отходов в электрическую энергию и технологии для переработки жидких органических отходов на основе сверхкритического водного окисления органических веществ в жидкости для тепловых и электростанций 1 МВт находятся в стадии разработки.

Результаты сравнения параметров классической системы электроснабжения с системой электроснабжения с помощью однопроводниковых волноводных линий с высокой частотой, предложенных Н. Тесла 100 лет назад, показывают, что по таким характеристикам, как плотность тока и потери в линии, дальность передачи энергии, мощность передачи, возможность кабельного и беспроводного питания, электрические системы Тесла превышают классические системы энергоснабжения. Использование в будущем электрифицированных мобильных роботов с беспроводным питанием от внешнего источника позволит организовать сельскохозяйственное производство на принципах "промышленной фабрики на полях" при полной автоматизации технологических процессов.

Предлагается энергетическая модель будущего мира на основе прямого преобразования солнечной энергии и трансконтинентальных тераваттных линий передачи с использованием резонансной технологии Н. Тесла. Передовые российские технологии для солнечной энергетики включают бесхлорную технологию солнечного кремния, технологии кремниевых высоковольтных фотоэлектрических модулей с 20%-й эффективностью в 60-кратной концентрации солнечного излучения, технологии сборки солнечных модулей со сроком службы 40-50 лет, технологии концентраторных солнечных модулей и безуглеродного топлива.

Ключевые слова: биотопливо, продовольственная безопасность, быстрый пиролиз, горение в СВЧ-плазме, плазменная обработка, безуглеродное топливо, низкоуглеродное топливо, электротехника Тесла, солнечные энергосистемы.

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Сведения об авторе:

Стребков Дмитрий Семенович - Академик РАН, научный руководитель Всероссийского института электрификации сельского хозяйства (ФГБНУ ВИЭСХ), Москва, Россия,
e-mail: viesh@dol.ru

THE METHOD OF RELIABLE ESTIMATION AND FORECASTING OF CAPACITY OF ALTERNATIVE ENERGY GENERATING EQUIPMENT

P. Kuntsevich
All-Russian Scientific-Research Institute for Electrification of Agriculture, Moscow, Russia

The method of forecasting capacity of alternative energy generating equipment, based on the theory of sets, the theory of probability and mathematical statistics, has been suggested. The formula for calculating current capacity of energy generating equipment (EGE), considering its reliability, technological energy losses and the level of organization of technical measures is given. The method allows to exclude subjective factor in assessing efficiency of the EGE use.

Keywords: *energy source, method, probability, event factor, forecasting, capacity, reliability, efficiency.*

While assessing technical potential of energy sources, generated by irregular natural phenomena (ESINP) – solar radiation, wind, sea waves, tides, etc., they usually do not consider energy generating equipment downtime caused by failures, planned preventive maintenance and technological factors [1, 2].

Thereby, the forecasted EGE capacity and that obtained in operation are not adequate [3], which puts in doubt conclusions when assessing technical potential of ESINP and the project feasibility. Empirical formulas suggested *apriori* for calculation of equipment downtime, comprise a subjective factor, and consideration of influence of EGE reliability is not correct [4].

For objective assessment of indicators of efficiency of investment projects in the field of the ESINP use, or for EGE certification, the author of the present article offers the rigorous method (not relying on empiricism) of forecasting of EGE capacity – the method of probability of events factors, making it possible to assess and forecast EGE efficiency to a high degree of accuracy.

The suggested method is based on the mathematical model of an event in space of events: “probability – energy parameter – time” within design-basis time interval T_p, expressed through elemental events whose number $I = T_p/\tau$ is determined by monitoring standard where τ – is monitoring period. In long-term monitoring of energy parameter (EP) of the flow $e(t)$ complete space of events is relatively accurately described by probability density function $f(e(t))$.

Considering the function $f(e(t))$ in 3D coordinate system, the author established strict relation of the number of failures of EGE $b(t_э)$ to probabilities of events factors [5], which is expressed by the following formula:

$$b(t_э) = \frac{\omega(t_э) T_p F_2 F_3 / F_4}{1 + \omega(t_э)\eta F_2 F_3 / F_4}\ , \qquad (1)$$

where $t_э$ – current operation time, T_p – baseline time period, η – average time of organizational downtime accounting for failure, F_2 – probability of purpose factor; F_3 – factor probability with which EGE is able to perform the purpose function and technical measures (TM) are admitted; F_4 – probability of factor of favorable conditions for TM. Failure frequency $\omega(t_э)$ is related to failure-free operation probability by the formula [5]:

$$\omega(t_э) = -j(t_э) P_o \cdot \frac{ln(P_o)}{T_o} \times \times exp\left[-ln(P_o) j(t_э) \frac{T_p - T_o}{T_o}\right], \qquad (2)$$

where $j(t_э)$ – failure intensity in relative units; P_o – possibility of failure-free operation; T_o – time segment corresponding to P_o. The function $j(t_э)$ approximates statistical curve of operational failures intensity.

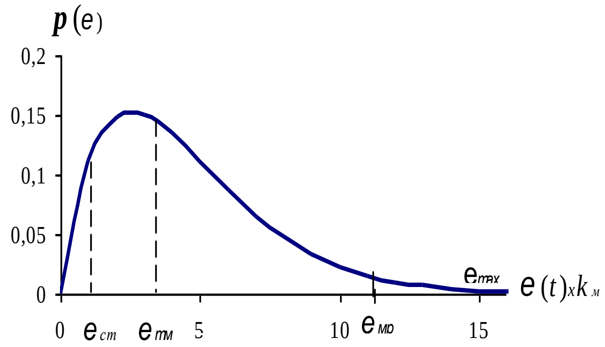

Fig. 1. The function of EP probability density

Here and below EGE downtime is accumulation of time in baseline period T_p during which EGE capacity $N_{EGE}(e) = 0$ due to objective factors of downtime: energy, technical, organizational, technological. Time spent on technical measures (TM) are determined by the following factors: restoration, maintenance, expectation of favorable conditions for TM.

In relation to wind energy equipment, probability of event factors is expressed through probability density of EP of air flow (wind) in correspondence with the following equations:

$$F_1 = \int_{e=0}^{e_{cm}} f(e)dt\,;\quad F_2 = \int_{e=e_{cm}}^{e_{\text{мр}}} f(e)dt\,;$$

$$F_3 = \int_{e=e_{cm}}^{e_{m\text{м}}} f(e)dt\,;\quad F_4 = \int_{e=0}^{e_{m\text{м}}} f(e)dt\,;$$

$$F_5 = \int_{e=e_{m\text{м}}}^{e_{max}} f(e)dt\,, \qquad (3)$$

where e_{cm} and $e_{\text{мр}}$ – boundary values of EP; e_{max}– maximal possible value of EP; $e_{m\text{м}}$ – maximal value of energy downtime by safety conditions for TM; F_1 – probability of downtime because of low energy of EP; F_5 – probability of expectation factor of favorable conditions for TM (Fig. 1, where $k_{\text{м}}$ – scale coefficient).

We relate all types of downtime with the baseline time period T_p and with the probability of event P_k, expressed through downtime factors and time factors in correspondence with the mathematical model of events [5]:

$$T_j = T_pP_k = T_p\beta\tau_kP_{ck}, \qquad (4)$$

where T_j– event duration; P_{ck} – probability of events conjunction.

Table 1

Events	**Time factor τ_k**	**Probability P_k**	**Duration T_k**
Energy downtime	$\tau_{\text{э}}=1$	$P_{\text{э}} = \beta(1–F_2)$	$T^{\text{Э}}_{\text{П}} = \beta T_p(1–F_2)$
Failure	$\tau=T_p/I$	$P=1–P_o$	$t_{\text{ОТК}} \to 0$
Organizational measures	$\tau_o = \eta\cdot b(t)/T_p$	$P_o = \eta\cdot b(t)/T_p$	$T^{\text{О}}_{\text{П}} = \eta\cdot b(t)$
Maintenance	$\tau_{mo}=D\,T^{\text{ТО}}_k/T_p$	$P_{mo}= \tau_{mo}\beta F_2F_3/F_4$	$T^{\text{ТО}}_{\text{П}} = \tau_{mo}\beta T_pF_2F_3/F_4$
Expectation in maintenance	$\tau_{mo}=D\,T^{\text{ТО}}_k/T_p$	$P^{\text{ТО}}_{\text{ож}} = \tau_{mo}\beta F_5/F_4$	$T^{\text{ТО}}_{\text{ож}} = \tau_{mo}T_p\beta F_5/F_4$
Restoration	$\tau_{\text{в}}=b(t)\ T^{\text{В}}_k/T_p$	$P_{\text{в}}= \tau_{\text{в}}\beta F_2F_3/F_4$	$T^{\text{В}}_{\text{П}} = \tau_{\text{в}}T_pF_2F_3/F_4$
Expectation in restoration	$\tau_{\text{в}}=b(t)\ T^{\text{В}}_k/T_p$	$P^{\text{В}}_{\text{ож}} = \tau_{\text{в}}\beta F_5/F_4$	$T^{\text{В}}_{\text{ож}} = \tau_{\text{в}}T_p\beta F_5/F_4$
Active mode of operation		$P_{ap} =1–(P_{\text{э}}+P_o+P_{TM}+P_{\text{ож}})$	$T_{ap} = T_pP_{ap}$

The formulas presented in Table 1 determine time factors τ_k, probability P_k and events duration T_k, where k – event index. In Table 1 the following designations are accepted: η – average time of organizational downtime, D – the number of prevention measures for the calculation period; $T^{\text{ТО}}_k$ и $T^{\text{В}}_k$ – calendar time expenditure for maintenance and restoration; $\beta = (T_p–\eta\cdot b(t))\ /\ T_p$– relative reduction of estimated time T_p.

Using the formulas (1) – (4) and Table 1, the author has obtained the reliable formula for forecasting EGE capacity W_{EGE} with due

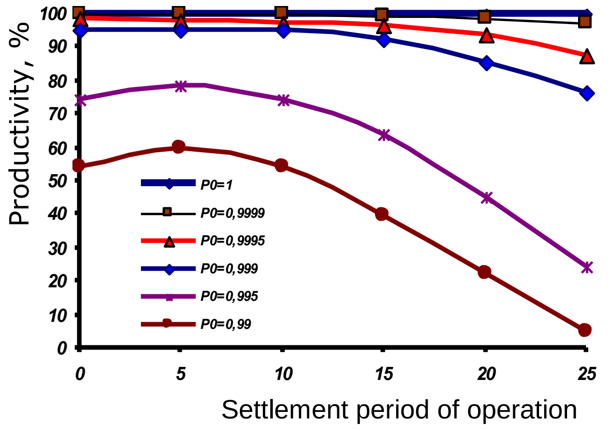

Fig. 2. Dynamics of capacity of the wind energy plant UE-550-41

consideration of failures and planned preventive measures [6].

$$W_{\text{ГЭО}} = W_1 + W_2 =$$

$$= T_p \int_{e_i = e_{CT}}^{e_{TM}} N_{\text{ГЭО}}(e)(\beta F_3 - P_{TM}) f(e) de +$$

$$+ T_p \int_{e_i = e_{TM}}^{e_{MP}} N_{\text{ГЭО}}(e) \cdot (\beta F_5 - P_{TM}) f(e) de. \qquad (5)$$

The formula (5) confirms that EGE real capacity for the baseline period cannot exceed the value expressed (5). The suggested method makes it possible to forecast technological losses W_{mx}. In this case $W_{EGE} = W_1 + W_2 - W_{mx}$. Therefore, the calculated value of capacity of failure-free ESINP source, expressed by the formula [7]:

$$W_0 = T_p \int_{e_i = e_{CT}}^{e_{MP}} N_{\text{ГЭО}}(e_i) f(e) de. \qquad (6)$$

In comparison with capacity of the real source (Fig. 2) it is overestimated by the value [6]:

$$\Delta W = T_p \int_{e_i = e_{CT}}^{e_{TM}} N_{\text{ГЭО}}(e_i)(P_0 F_3 - P_{TM}) f(e) de +$$

$$+ T_p \int_{e_i = e_{TM}}^{e_{MP}} N_{\text{ГЭО}}(e_i) \cdot (P_0 F_5 - P_{TM}) f(e) de. \qquad (7)$$

The calculation results are confirmed by operational tests of wind energy plants built in Russia.

Conclusions and recommendations

1. The suggested method predetermines the reliability of long-term forecast and allows to exclude errors in assessment of return on investment at the initial stage of a project.
2. During EGE certification it is necessary to take into account EGE reliability and downtime, considering factors described in the present article.
3. It is necessary to reconsider the methods of calculating technical potential of ESINP energy, taking into account controlled parameters of EGE reliability.

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Corresponding author:
PhD (Engineering) **Petr Kuntsevich**
All-Russian Scientific-Research Institute for Electrification of Agriculture,
1-st Veshnyakovsky proezd, 2, 109456, Moscow, Russia
Tel.: (+7-499) 171-19-20.
E-mail: viesh@dol.ru

МЕТОД ДОСТОВЕРНОЙ ОЦЕНКИ И ПРОГНОЗИРОВАНИЯ ПРОИЗВОДИТЕЛЬНОСТИ ГЕНЕРИРУЮЩЕГО ОБОРУДОВАНИЯ АЛЬТЕРНАТИВНОЙ ЭНЕРГЕТИКИ

П.А. Кунцевич
Всеросийский научно-исследовательский институт электрификации сельского хозяйства (ФГБНУ ВИЭСХ), Москва, Россия

Предложен метод прогнозирования производительности генерирующего энергетического оборудования (ГЭО) альтернативной энергетики, основанный на теории множеств, теории вероятности и математической статистике. Приводится формула для расчёта текущей производительности ГЭО, учитывающая надёжность ГЭО, технологические потери энергии и уровень организации технических мероприятий. Метод позволяет исключить субъективный фактор в оценке эффективности использования ГЭО.

Ключевые слова: источник энергии, метод, вероятность, факторы событий, прогнозирование, производительность, надёжность, эффективность.

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Сведения об авторе:
Кунцевич Пётр Антонович – канд. техн. наук, ФГБНУ ВИЭСХ, Москва, Россия,
e-mail: viesh@dol.ru

THE TECHNICAL AND ECONOMICAL EVALUATION OF EFFICIENCY OF THE BIOTECHNICAL SYSTEMS (BTS) OF ANIMAL BREEDING

S. Kartashov, Ye. Reznik, A. Musin
All-Russian Scientific-Research Institute for Electrification of Agriculture, Moscow, Russia

The methods of constructing the mathematical model of efficiency of fattening pigs, showing live-weight gain in the course of feeding, are considered. As initial data, rations and feeding norms recommended by specialists, are used. The calculation algorithm is developed that shows how to increase live-weight in the course of feeding.

Keywords: *biotechnical system, operational efficiency, planned effect, technological effect.*

Forecasting of efficiency of technological processes is necessary at all stages of equipment life. Changing of external environment and attempts to improve the end result of a production cycle at less cost require corresponding adjustment of equipment operation. In order to select the optimal technological solution, operational evaluation of expected results is necessary. Operational evaluation makes it possible to achieve BTS inherent economic potential in the process of its use.

BTS operational efficiency is determined by comparison of actual effect with planned effect which is considered as basic. The mathematical model of planned effect is built through the analysis of BTS work in standard conditions when the system parameters and characteristics conform to norms. As initial data, values recommended by standards and technological requirements written in conformity certificates, are assumed. In order to build the mathematical model of the end result of the technological process, it is necessary to express the data in the form of mathematical symbols and dependencies. As a rule, standard data are presented in a tabulated form.

Let us consider the process of building the model of planned effect at the example of the technological process of pig feeding on the basis of initial data presented in the conformity certificate. Pig feeding rate [3] is shown in Table 1.

Table 1. Pig feeding rate in meat fattening (RFID project)

Liveweight, kg	Average daily gain, g	Daily requirement per head					
		Fodder units, g	Protein, g	Common salt, g	Calcium, g	Phosphorus, g	Carotene, g
14-20	300-350	1.3-1,5	165-190	12	9	7	5
20-30	300-400	1.4-1.5	175-215	14	10	8	5
30-40	300-450	1.5-1.8	180-225	15	12	9	7
40-50	450-500	2.0-2.3	220-235	20	14	10	8
50-60	450-500	2.1-2.4	240-275	22	15	11	10
60-70	500-600	2.6-3.0	260-330	25	16	12	12
70-80	600-700	3.2-3.7	320-390	32	18	13	15
80-90	600-700	3.3-3.8	330-410	32	19	14	15

The characteristics of pigs being fattened built on the basis of the data shown in Table 1, are presented. Below their analytical expressions used in further calculations, are given. For their determination the program of building characteristics of a living object of BTS is used [2, 4].

From Table 1 the coordinates of three points of the characteristic were selected whose values were substituted in specially defined EXCEL table cells. The values of target values of coefficients appeared in the defined cells on the screen display.

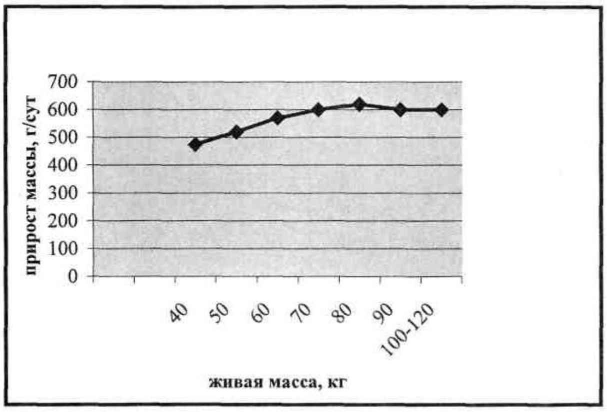

Fig. 1. Dependence of daily weight gain on liveweight

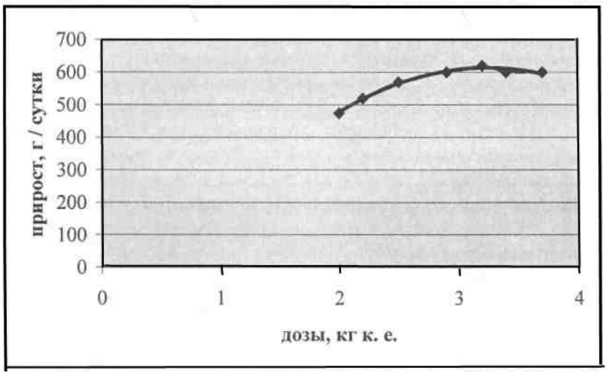

Fig. 2. Dependence of daily weight gain on fodder dosage

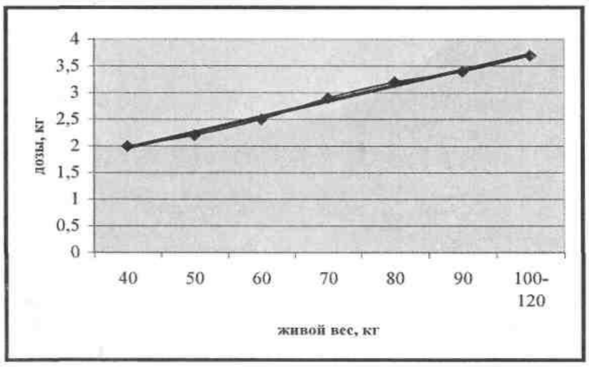

Fig. 3. Dependence of fodder dosage on liveweight

At Fig 1, 2, 3 the results of calculation with the use of this program are demonstrated. Below the mathematical models obtained by this method are presented.

Approximate analytical expression of dependence of daily weight gain on fodder dosage is as follows: $m = -0.0771*M^{\wedge}2+12,875*M+83.33$. Approximate analytical expression $m = -94.608*d^{\wedge}2+612.794*d-372.16$. Approximate analytical expression $d = 0.028*v + 0.88$.

The monitoring of the technological process is most convenient if planned efficiency is presented in the form of the dependence of liveweight on the number of weeks that have passed since the beginning of young pigs fattening. In this case in order to determine current operational efficiency it is necessary to define animals liveweight for the number of weeks passed since the beginning of feeding, and compare these values with the planned ones.

Let us designate initial weight of a young pig as M_0.

We shall consider weight gain for a week invariant. In this case weight gain for the 1st week is as follows:

$$m_1 = a_1* d_1^{\wedge}2 +b_1* d_1 + c_1, \qquad (1)$$

where a_1, b_1, c_1 – coefficients of the productivity function for the 1st week of feeding; d_1 – fodder dosage for the 1st week of feeding.

The animal weigh in the end of the 1st week is

$$M_1 = M_0 + m_1 = M_0 + a_1* d_1^{\wedge}2 +b_1* d_1 + c_1.$$

Weight gain for the 2nd week

$$m_2 = a_2 * d_2^{\wedge}2 + b_2 * d_2 + c_2.$$

The animal weight at the end the 2nd week is

$$M_1 + m_2 = M_0 + a_1* d_1^{\wedge}2 + b_1* d_1 + c_1 + a_2 * d_2^{\wedge}2 + +b_2 * d_2 + c_2.$$

Weight gain for the i-week is

$$m_i = a_i* d_i^{\wedge}2 + b_i* d_i.$$

The animal weight at the end of i-week is

$$M_i = M_0+ \sum_{i=l}^{i} (a_i*d_i^{\wedge}2 + b_i*d_i + c_i).$$

Weight at the end of feeding cycle for n weeks

$$M_n = M_0 + \sum_{i=l}^{i=n} (a_i*d_i{}^{A}2 + b_i*d_i + c_i). \qquad (2)$$

Weight gain for the whole feeding cycle for n weeks

$$\Delta M_n = \sum_{i=l}^{i=n} (a_i*d_i{}^{A}2 + b_i*d_i + c_i). \qquad (3)$$

The expression (2) is the target dependence of liveweight on the number of weeks passed since the beginning of fattening. The calculation according to the formula is complicated by the fact that each term of the expression is changing in the process of feeding. Therefore, the mathematical model must be supplemented by dependencies reflecting these changes. For this purpose data from Table 1 must be used.

At Fig. 4 a fragment of the algorithm of calculation made in the EXEL language, is shown. The step duration is one week. It is considered that for this period of time daily weight gain remains invariant. It is changed in the following week depending on fodder dosage and liveweight. Calculation continues till liveweight at which feeding should come to the end, is obtained.

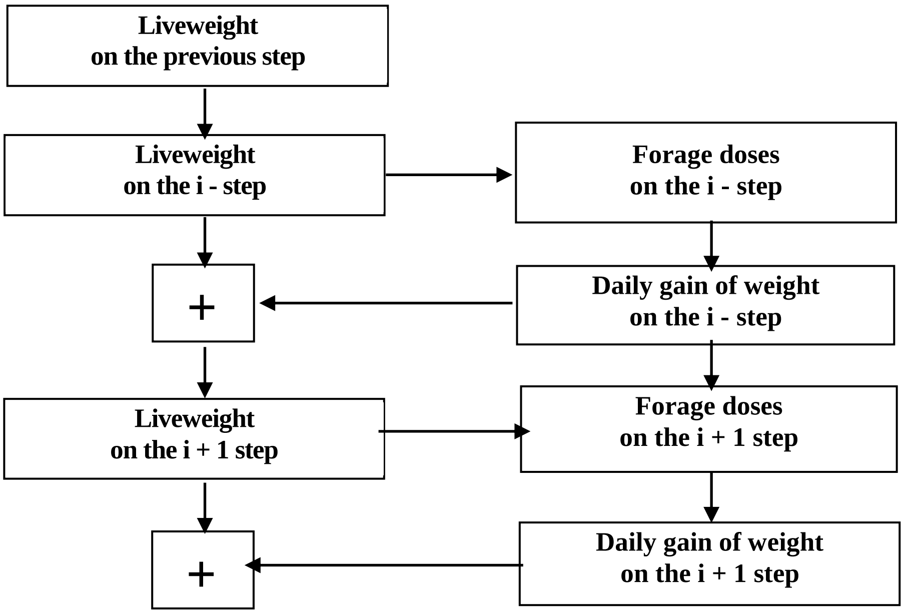

Fig.4. The algorithm of program for the calculation of planned effect

Table 2. Calculation of pigs liveweight in meat fattening

Weeks	Live-weight, kg	Fodder dose, kg	Daily weight gain
0	17	1,4	335.46
1	19.348	1.4761	346,53
2	21.774	1.5547	357.96
3	24.28	1.6359	369,77
4	26.868	1.7197	381.96
5	29.542	1.8064	394.56
…	…	…	…
20	82.051	3.5076	642.02
21	86.545	3.6533	663.2
22	91.187	3.8037	685.07
23	95.983	3.959	707.67
24	100.94	4.1195	731.02
25	106.05	4.2853	755.13

The feeding parameters for initial data specified in accordance with feeding rates specified in the project, have been calculated (Table 1). The left part of the Table presents planned conditions of BTS functioning (without regard to factors involved in its operation).

In real conditions, because of effect of uncontrolled factors, technological indicators are lowered. One of the major factors affecting the end result, is error in fodder dosage. It is explained not only by imperfection of a dosage device but also by other causes. As I.I. Girutzky research [1] has shown, 20% allowance in dosing liquid fodder is included in the process of fodder preparation when it is mixed with water. Water surplus leads to lowering of fodder nutritional value.

In Table 2 the results of the calculation of pigs liveweight are presented (mathematical expectation of dosage error being 10%). In this case, dependence of weight gain on fodder dosage should be corrected through multiplying it by 0.9.

$$m = 0.9 * (-94.608 * d^{2} + 612.794 * d - 372.16).$$

In Table 2 the calculation results considering correction are given. In the result, we shall obtain BTS actual efficiency when weight gain is lowered because of the dosing device error.

At Fig. 5 the diagram of planned and actual efficiency of feeding built on the basis of the data of Tables 1 and 2, is presented.

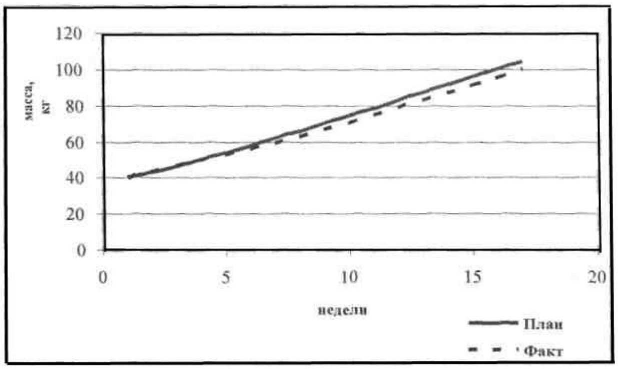

Fig. 5. Planned and actual efficiency of feeding

Table 3. Loss of productivity (dosing error being 10%)

Error - 10%		
Liveweight, kg	Weight gain, g	Loss of productivity, kg
17	315.1	0
19.206	325.06	0.1425
21.481	335.35	0.2927
23.829	345.98	0.451
26.251	356.96	0.6175
28.749	368.3	0.7925
…	…	…
77.393	591.02	4.6579
77.393	591.02	4.6579
81.53	610.08	5.0149
85.801	629.77	5.3867
90.209	650.11	5.7738
94.76	671.12	6.1768
99.458	692.82	6.5961

With due consideration of one of the factors – error of fodder dosing, loss of efficiency (difference between planned and actual liveweight) is inconsiderable. In real conditions animals are affected simultaneously by several factors. Their cumulative effect may considerably lower efficiency of feeding systems. Moreover, it is necessary to take into account that the combination of factors affecting the system is permanently changing in a random way. It is impossible to forecast these changes and calculate their effect on the end result of the technological process.

The microclimate parameters can be referred to factors markedly affecting pigs feeding efficiency. Regardless of the use of a wide range of various regulating devices, it is not possible to maintain air environment parameters of livestock houses within the specified range. In summer season temperature and humidity may exceed the norm for a long period.

At such periods livestock productivity is lowered. It should be added that the effect of these factors on animals depends on their breed and age as well. Therefore, it is possible to assess the effect of random uncontrolled factors only in the course of the technological progress.

Microclimate parameters can be classified as partially controlled factors. Though various devices are used for their regulation, it is not possible to provide complete compensation of the effect of weather conditions. Temperature, air humidity, content of harmful gas in livestock houses diverge from the specified values. Moreover, it is not possible to forecast the time of emergence of these factors and duration of their effect.

For example, in summer season hot calm weather may be settled for a long time. In spite of the ventilation system operation, air parameters in premises deviate from standard values. Animals lose appetite and weight gain is radically decreased. It should be noted that, depending on breed and age, productivity loss may vary. It is possible to assess the effect of such factors only having information on changed microclimate parameters in the technological process.

Information on current values of the technological process is necessary for decision- making concerning technical measures aimed at compensation of negative influence of random uncontrolled factors. Mathematical simulation allows to assess possible consequences of their negative effect, as well as of measures that can be taken to prevent product loss.

Conclusions

1. Conventional methods of efficiency assessment do not allow to assess technological efficiency of biotechnical systems considering increasing livestock productivity. They take into account only expenditures for technical devices. It is advisable to combine them with advanced calculation methods with the use of computers and mathematical simulation.

2. The peculiarities of an animal as an object of automated control involve high variability of its characteristics and parameters, therefore, for analysis it is necessary to use the dynamic mathematical model including the function of an animal productivity (dependence of productivity on an affecting factor). The methods and program for determination of this function with the use of computers on the basis of the specified coordinates of three points. The conformity certificate for livestock feeding and handling norms is used as initial data.

3. In the process of operation of the biotechnical system its parameters and characteristics affected by various factors, deviate from standard values specified at the designing stage, in accordance with law of randomness. These variations may considerably decrease efficiency of the system. Therefore, operative control of the technological process is required. It is especially important for the technological process of young stock breeding. The methods and the program for the determination of planned and actual pigs weight gain in the feeding technological process have been developed.

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Corresponding authors:

Ph D. (Engineering) **Stanislav Kartashov,**

D. Sc. (Engineering) **Yevgeny Reznik,**

D. Sc. (Engineering) **Askhat Musin**

All-Russian Scientific-Research Institute for Electrification of Agriculture,

1-st Veshnyakovsky proezd, 2, 109456, Moscow, Russia

Tel.: (+7-499) 171-18-81

E-mail: viesh@dol.ru

ТЕХНИКО-ЭКОНОМИЧЕСКАЯ ОЦЕНКА ЭФФЕКТИВНОСТИ БИОТЕХНИЧЕСКИХ СИСТЕМ (БТС) ЖИВОТНОВОДСТВА

С.Г. Карташов, Е.И. Резник, А.М. Мусин

Всероссийский-научно-исследовательский институт электрификации сельского хозяйства (ФГБНУ ВИЭСХ), Москва, Россия

Рассмотрено построения математической модели технологической эффективности откорма свиней, показывающей прирост живой массы в процессе откорма. В качестве исходных данных использованы рекомендуемые специалистами по кормлению рационы и нормы. Разработан алгоритм расчета, показывающий, как должна нарастать живая масса животных по ходу откорма.

Ключевые слова: биотехническая система, оперативная эффективность, плановый эффект, технологический эффект.

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Сведения об авторах:

Карташов Станислав Григорьевич – канд. техн. наук, ФГБНУ ВИЭСХ, Москва, Россия, e-mail: viesh@dol.ru

Резник Евгений Иванович - доктор техн. наук. ФГБНУ ВИЭСХ, e-mail: viesh@dol.ru

Мусин Асхат Миргалимович - доктор техн. наук, ФГБНУ ВИЭСХ.

AN ALTERNATIVE PROOF OF THE FUNDAMENTAL THOEREM OF ALGEBRA

L. Akopyan
All-Russian Scientific-Research Institute for Electrification of Agriculture, Moscow, Russia

We present an alternative proof to the Fundamental Theorem of Algebra (FTA) using a modified lianit algebra very closely resembling the algebra of complex numbers. This lianit algebra was specially constructed to be commutative, associative and distributive with respect to multiplication and addition operations. The multiplication operation differs from the multiplication of complex numbers by a mere sign. A distinctive feature of the algebra used lies in its unique property: the sum of elements of secondary lianit roots is a numeric solution (if it exists) to the original numeric polynomial. The presented proof complements the first proof of the FTA via the lianit algebras as a much finer proof in terms of methodological simplicity and the use of algebraic structures very much alike ordinary complex fields. The provided proof is yet another application of the general theorem of principal and secondary lianit roots, which establishes a direct correspondence between the complex roots of a polynomial and the secondary lianit solutions of its related pseudo-polynomials. We use this theorem twice: first we apply it in its most general setting, establishing the link between the secondary lianit roots of pseudo-polynomials and the numeric roots of related complex polynomials. The consequence of this theorem formulated as a generalized theorem of Cayley-Hamilton allows to perform an explicit calculation for the so-called "probing" and "associated" polynomials providing a shortcut in the proof. This latter technique inspired us to search for a shorter and more explicit proof of the FTA than our first proof was.

***Keywords**: pseudo-algebraic equations, lianit roots, associated polynomials, Fundamental Theorem of Algebra.*

Introduction

Since the discovery and classification of non-numeric solutions to Algebraic polynomials [1-4] (more correctly defined as algebraic pseudo-polynomials [5]) establishing a *sui generis* transition from the lianit sets to the field of complex numbers, the question of proving the fundamental theory of algebra (FTA) by the means of pure algebra has been ostensible. In the original research paper [6] the FTA was proven using a specific algebra already familiar with its very productive features in terms of deriving many applications (the solution to Cyclotomic equations, solutions of multivariate polynomial systems of equations, derivation of complete Galois terms of solvability by radicals, etc.). In this paper we present a simpler proof based on a lianit algebra that could be called the lianit "analogue" of the complex set: its properties of addition and multiplication are identical to those of the complex numbers with "up to a sign". This fact has inspired us to search for a proof for the existence of complex roots for polynomials of arbitrary degrees via an algebra that itself is not too from the field of complex numbers.

Proof to FTA

Consider the following lianit set

$$\begin{cases}\sigma_1+\sigma_2=(x_1,x_2)+(y_1,y_2)=(x_1+y_1,x_2+y_2)=\sigma_2+\sigma_1,\\ \sigma_1\cdot\sigma_2=(x_1,x_2)\cdot(y_1,y_2)=(x_1y_1+\ x_2y_2,x_1y_2+x_2y_1)=\sigma_2\,\sigma_1;\ \ k=(k,0).\end{cases}\qquad(1)$$

Algebra (1) is commutative, associative and distributive with respect to addition and multiplication, $e=(1,0)$ is the right identity element. The linear equation $x+a_0=0$ has a single principal lianit root: $\sigma_0=(-a_0,0)$. For any p and q, the trinomial $f^2(x)=x^2+px+q$, has two principal lianit roots. Indeed, the condition $f^2(\sigma)=(0,0)$ reads: $\sigma^2+\sigma\cdot p+q=(x_1^2+x_2^2,2x_1x_2)+$

$+(px_1, px_2) + (q, 0) = (x_1^2 + x_2^2 + px_1 + q, 2x_1x_2 + px_2) = (0, 0)$. At $x_2 \neq 0$ (the case $x_2 = 0$ is equivalent to searching for numeric roots), we obtain,

$$\sigma_1 = (x_1^1, x_2^1) = \left(-\frac{p}{2}, +\sqrt{\frac{p^2}{4} - q}\right); \ \sigma_2 = (x_1^2, x_2^2) = \left(-\frac{p}{2}, -\sqrt{\frac{p^2}{4} - q}\right). \quad (2)$$

A distinctive feature of the set (1) is that for any $f^n(x) = x^n + a_1x^{n-1} + a_2x^{n-2} + \cdots + a_{n-1}x + a_n$ the sum of elements of all possible secondary lianit roots $\sigma_\ell = (x_1^\ell, x_2^\ell)$, i.e. $x_{0\ell} = x_1^\ell + x_2^\ell$, is a numeric solution to $f^n(x)$. Indeed, it is easy to show, that $\sigma^n = [f_1^n(x_1, x_2), f_2^n(x_1, x_2)]$ is given by the rule.

If n is even, then

$$f_1^n(x_1, x_2) = C_n^n \cdot x_1^n + C_{n-2}^n \cdot x_1^{n-2}x_2^2 + \cdots + C_0^n \cdot x_2^n;$$
$$f_2^n(x_1, x_2) = C_{n-1}^n \cdot x_1^{n-1} \cdot x_2 + C_{n-3}^n \cdot x_1^{n-3}x_2^3 + \cdots + C_1^n \cdot x_1 \cdot x_2^{n-1}.$$

If n is odd, then (3)

$$f_1^n(x_1, x_2) = C_n^n \cdot x_1^n + C_{n-2}^n \cdot x_1^{n-2}x_2^2 + \cdots + C_1^n \cdot x_1 \cdot x_2^{n-1};$$
$$f_2^n(x_1, x_2) = C_{n-1}^n \cdot x_1^{n-1} \cdot x_2 + C_{n-3}^n \cdot x_1^{n-3}x_2^3 + \cdots + C_0^n \cdot x_2^n.$$

where C_i^n are the binomial coefficients. Compiling the system $f^n(\sigma) = \sigma^n + a_1\sigma^{n-1} + a_2\sigma^{n-2} + \cdots + a_{n-1}\sigma + a_n = (0, 0)$ and summing up both of the equations, we arrive at: $(x_1 + x_2)^n + a_1(x_1 + x_2)^{n-1} + a_2(x_1 + x_2)^{n-2} + \cdots + a_{n-1}(x_1 + x_2) + a_n = 0$ (under the assumption that the secondary roots $\sigma_\ell = (x_1^\ell, x_2^\ell)$ exist). At $n = 2$, from (2), it follows that they do exist, therefore at $n > 2$, the putative secondary lianit roots must have the following structure: $\sigma_\ell = (x_1^\ell, x_2^\ell) = \left[\frac{x_{0i}+x_{0j}}{2}, \pm\left(\frac{x_{0i}-x_{0j}}{2}\right)\right]$, where x_{0i}, x_{0j} are the putative numeric roots of the original polynomial $f^n(x)$. Thus, we are to prove that any $f^n(x) = x^n + a_1x^{n-1} + a_2x^{n-2} + \cdots + a_{n-1}x + a_n$, defined over the lianit set (1), holds secondary roots of specific form $\sigma_\ell = (x_1^\ell, x_2^\ell) = \left[\frac{x_{0i}+x_{0j}}{2}, \pm\frac{x_{0i}-x_{0j}}{2}\right]$, which is, evidently equivalent to existence of numeric roots x_{0i} $(i = 1, 2, \ldots, n)$. We prove this assuming the opposite. Let, in the general case, the original polynomial $f^n(x) = x^n + a_1x^{n-1} + a_2x^{n-2} + \cdots + a_{n-1}x + a_n$ does not hold any numeric roots x_{0i}. Then the system on secondary lianit solutions $f^n(\sigma) = \sigma^n + a_1\sigma^{n-1} + a_2\sigma^{n-2} + \cdots + a_{n-1}\sigma + a_n = (0, 0)$ is either trivially inconsistent or is consistent formally after the exclusion of one of the variables which we, without any loss of generality, assume to be x_2. The resulting system reads,

$$\begin{cases} F_1(x_1) = z_1(x_1) \cdot F_{01}(x_1), \\ F_2(x_1) = z_1(x_1) \cdot F_{02}(x_1), \end{cases} \quad (4)$$

where $z_1(x_1)$ is the general associated polynomial of the system of equations $f^n(\sigma) = (0, 0)$. Since the original numerical polynomial $f^n(x) = x^n + a_1x^{n-1} + a_2x^{n-2} + \cdots + a_{n-1}x + a_n$, does not have any numeric roots, the obtained associated polynomial $z_1(x_1)$ cannot have any numeric roots either, meaning that $z_1(x_1)$ cannot have any divisors (see, for example, [7]). Let $f_0^m(x) = x^m + b_1x^{m-1} + b_2x^{m-2} + \cdots + b_{m-1}x + b_m$ is any other "probe" polynomial with an associated polynomial $u_1(x_1)$ emerging from the system $f_0^m(\sigma) = (0, 0)$. Then the system on secondary lianit solutions for the polynomial $G^{m+n}(x) = f^n(x) \cdot f_0^m(x)$ is also bound to either trivial inconsistency or formal consistency with some associated polynomial of the form $z_2(x_1)$. Since the set of two-element lianits (1) is distributive with respect to multiplication and $z_1(x_1)$, $u_1(x_1)$ cannot not have any divisors, $z_2(x_1)$ emerging from the system $G^{m+n}(\sigma) = (0,0)$ cannot have any other divisors but $z_1(x_1)$, $u_1(x_1)$, namely, $z_2(x_1) \equiv z_1(x_1) \cdot u_1(x_1)$. As a probing polynomial $f_0^m(x)$ we now take $f_0^n(x) = x^n + x_0 \cdot a_1 x^{n-1} + {} + x_0^2 \cdot a_2 x^{n-2} + \cdots + x_0^{n-1} \cdot a_{n-1} x + x_0^n \cdot a_n$, $(x_0 \neq 0, m = n)$. Using the formulas (22) it is simple enough to construct the corresponding system $f^n(\sigma) = (0,0)$, $f_0^n(\sigma) = (0,0)$, $G^{2n}(\sigma) = (0,0)$. Assuming that n is even and reducing the second equation of the system $f^n(\sigma) = (0,0)$ by $x_2 \neq 0$ [bypassing the purely formal search for secondary roots of trivial nature $\sigma_\ell = (x_1^\ell, x_2^\ell) = (x_1^\ell, 0)$], with respect to x_2 we obtain,

$$\begin{cases} x_2^n + 0 \cdot x_2^{n-1} + \alpha_2(x_1, a_1, \dots) x_2^{n-2} + 0 \cdot x_2^{n-3} + \alpha_4(x_1, a_1, \dots) x_2^{n-4} + \cdots \\ \qquad + (x_1^n + a_1 x_1^{n-1} + a_2\, x_1^{n-2} + \cdots + a_{n-1} x_1 + a_n) \\ (n x_1 + a_1) x_2^{n-2} + 0 \cdot x_2^{n-3} + \beta_2(x_1, a_1, \dots) x_2^{(n-4)} + \cdots \\ \qquad + [n x_1^{n-1} + a_1 (n-1) x_1^{n-2} + a_2 (n-2) x_1^{n-3} + \cdots + a_{n-1}]. \end{cases} \tag{5}$$

The principal matrix solution of the first equation of the system (5) reads,

$$\sigma_{n\times n} = \begin{pmatrix} 0, & 1, & 0, & \cdots & \cdots & \cdots & 0 \\ 0, & 0, & 1, & 0, & \cdots & \cdots & 0 \\ 0, & 0, & 0, & 1, & 0, & \cdots & 0 \\ \cdots & \cdots & \cdots & & & \cdots & \cdots \\ 0, & 0, & 0, & \cdots & \cdots & 0, & 1 \\ -f_1^n(x_1), & 0, & -\alpha_{n-2}(x_1, a_1, \dots), & 0 & \cdots & -\alpha_2(x_1, a_1, \dots), & 0 \end{pmatrix} \tag{6}$$

Substituting the matrix solution (6) into the second equation of (5) leads to a matrix along the main diagonal of which appear rational polynomials of degree $(n-1)$, and the remaining elements of the same matrix are either null or fractional rational polynomials with various degrees. The associated polynomial $z_1(x_1)$ of the system (5), as is known, coincides with the determinant of the resulting matrix. Evidently, $z_1(x_1)$ will be of the degree $n(n-1)$[1]. An analogous result is obtained in case of odd degree n of the original polynomial $f^n(x)$ [in that case it is advisable to substitute the matrix root of the second equation of the system $f^n(\sigma) = (0,0)$ in the first]. To resume, for arbitrary n, the systems of equations on putative secondary lianit roots, namely, $f^n(\sigma) = (0,0)$, $f_0^n(\sigma) = (0,0)$, $G^{2n}(\sigma) = (0,0)$, should always be formally consistent through the scheme (4) and their respective associated polynomials are $z_1^{n(n-1)}(x_1)$, $u_1^{n(n-1)}(x_1)$, $z_2^{2n(2n-1)}(x_1)$. If the original polynomial $f^n(x) = x^n + a_1 x^{n-1} + a_2 x^{n-2} + \cdots + a_{n-1} x + a_n$, does not hold any numeric roots x_{0i} there are no roots $x_0 \cdot x_{0i}$ $(x_0 \neq 0)$ for the polynomial $f_0^n(x) = x^n + x_0 \cdot a_1 x^{n-1} + x_0^2 \cdot a_2 x^{n-2} + \cdots + x_0^{n-1} \cdot a_{n-1} x + x_0^n \cdot a_n$ as well. Hence, the general associated polynomial of the system of secondary lianit solutions for $G^{2n}(x) = f^n(x) \cdot f_0^n(x)$ [that is $G^{2n}(\sigma) = (0,0)$], with respect to x_1, must assume the form: $z_2(x_1) = z_1^{n(n-1)}(x_1) \cdot u_1^{n(n-1)}(x_1)$ and thus have the degree $2n(n-1)$. But we just showed that the degree of $z_2(x_1)$ is equal to $2n\,(2n-1)$, as the degree of $G^{2n}(x) = f^n(x) \cdot f_0^n(x)$ is $2n$. Moreover, along with divisors $z_1(x_1)$, $u_1(x_1)$, the polynomial

[1] All the summands in the determinant of that matrix are rational polynomials of degree $n(n-1)$.

$z_2^{2n(2n-1)}(x_1)$ has always some new divisor $z_0^n(x_1)$ appearing doubly [$z_0^n(x_1)$ did not emerge in the original systems of equations $f^n(\sigma)=(0,0)$, $f_0^n(\sigma)=(0,0)$]. To verify the unambiguous existence of $z_0^n(x_1)\cdot z_0^n(x_1)$ if we substitute $x_2=\pm\left(\frac{1-x_0}{1+x_0}\right)\cdot x_1$ in the system $G^{2n}(\sigma)=(0,0)$. Then, the condition $G^{2n}(\sigma)=(0,0)$ renders into a consistent system with an associated polynomial $z_0^n(x_1)$,

$$\begin{cases} F_1^{2n}(x_1)=\left[x_1^n+\left(\frac{1+x_0}{2}\right)a_1x_1^{n-1}+\left(\frac{1+x_0}{2}\right)^2a_2x_1^{n-2}+\cdots\right.\\ \qquad\left.+\left(\frac{1+x_0}{2}\right)^{n-1}a_{n-1}x_1+\left(\frac{1+x_0}{2}\right)^n a_n\right]\cdot F_{01}^n(x_1),\\ F_2^{2n}(x_1)=\left[x_1^n+\left(\frac{1+x_0}{2}\right)a_1x_1^{n-1}+\left(\frac{1+x_0}{2}\right)^2a_2x_1^{n-2}+\cdots\right.\\ \qquad\left.+\left(\frac{1+x_0}{2}\right)^{n-1}a_{n-1}x_1+\left(\frac{1+x_0}{2}\right)^n a_n\right]\cdot F_{02}^n(x_1). \end{cases} \tag{7}$$

Since $2n(2n-1)-n(n-1)-n(n-1)-2n=2n(n-1)\neq 0$ [$z_0^n(x_1)$ appears doubly], the general associated polynomial of the system $G^{2n}(\sigma)=(0,0)$, i.e. $z_2^{2n(2n-1)}(x_1)$, in the reality contains a fourth divisor $v_1^{2n(n-1)}(x_1)$, which did not appear in the original systems $f^n(\sigma)=(0,0)$, $f_0^n(\sigma)=(0,0)$.

In other words: $z_2^{2n(2n-1)}(x_1)=z_1^{n(n-1)}(x_1)\cdot u_1^{n(n-1)}(x_1)\cdot[z_0^n(x_1)]^2\cdot v_1^{2n(n-1)}(x_1)$. The appearance of additional divisors $[z_0^n(x_1)]^2$, $v_1^{2n(n-1)}(x_1)$ in the transition from $f^n(x)$, $f_0^n(x)$ to $G^{2n}(x)=f^n(x)\cdot f_0^n(x)$ provides a conclusive proof that the general associated polynomial $z_2^{2n(2n-1)}(x_1)$ of the system $G^{2n}(\sigma)=(0,0)$ does have numeric roots x_1^ℓ [$\ell=1,2,\dots,2n(2n-$ $-1)$]. We thus arrive at the conclusion that over the set of two-element lianits (1), the polynomial $G^{2n}(x)=f^n(x)\cdot f_0^n(x)$ is bound to have [based on (2)] secondary lianit roots of specific structure: $\sigma_\ell=\left(x_1^\ell,\pm x_2^\ell\right)=\left[\frac{x_{0i}-x_{0j}}{2},\pm\left(\frac{x_{0i}-x_{0j}}{2}\right)\right]$. Each of the corresponding quadratic trinomials $f_\ell^2(x)=x^2+p_\ell x+q_\ell=x^2-2x_1^\ell\cdot x+\left[\left(x_1^\ell\right)^2-\left(x_2^\ell\right)^2\right]$, based on the theorem of principal lianit roots [1-3], are divisors of $G^{2n}(x)=f^n(x)\cdot f_0^n(x)$. Since any of $f_\ell^2(x)=x^2+p_\ell x+q_\ell$ holds two principal lianit roots $\sigma_\ell^1=\left(x_1^\ell,+x_2^\ell\right)$, $\sigma_\ell^2=\left(x_1^\ell,-x_2^\ell\right)$ from the set (1), the degrees of the consequent associated polynomials are determined as $n_0=C_2^{2n}\cdot n_2=\frac{N(N-1)}{2}\cdot 2=N(N-1)$ [$n_2=2$, N – is the degree of the original $f^n(x)$, $f_0^n(x)$ и $G^{2n}(x)=f^n(x)\cdot f_0^n(x)$]. The structure of the secondary lianit roots $\sigma_\ell=\left(x_1^\ell,\pm x_2^\ell\right)$ of $f^n(x)$, $f_0^n(x)$ and $G^{2n}(x)=f^n(x)\cdot f_0^n(x)$, implies that each of the numeric roots x_1^ℓ of the general associated polynomial of the system $G^{2n}(\sigma)=(0,0)$, i.e. $z_2^{2n(2n-1)}(x_1)$, is once repeated. Consequently all the associated polynomials of the systems $f^n(\sigma)$, $f_0^n(\sigma)$, $G^{2n}(\sigma)=(0,0)$ must be perfect squares which is indeed the case when determining these polynomials via the method of principal lianit solutions i.e. $z_1^{n(n-1)}(x_1)==\left[z_{1,0}^{\frac{n(n-1)}{2}}(x_1)\right]^2$,

$u_1^{n(n-1)}(x_1) = \left[u_{1,0}^{\frac{n(n-1)}{2}}(x_1)\right]^2$, $v_1^{2n(n-1)}(x_1) = \left[v_{1,0}^{n(n-1)}(x_1)\right]^2$. Thus, the polynomial $G^{2n}(x) = f^n(x) \cdot f_0^n(x) = [f^n(x) = x^n + a_1 x^{n-1} + a_2 x^{n-2} + \cdots + a_{n-1}x + a_n] \cdot [f_0^n(x) = x^n + x_0 \cdot a_1 x^{n-1} + x_0^2 \cdot a_2 x^{n-2} + \cdots + x_0^{n-1} \cdot a_{n-1}x + x_0^n \cdot a_n]$ holds exactly $2n$ numeric roots: $x_{01}, x_{02}, \dots, x_{0n}, x_0 \cdot x_{01}, x_0 \cdot x_{02}, \dots, x_0 \cdot x_{0n}$.

The number of possible combinations of two roots from a set of $2n$ roots is $C_2^{2n} = (2n - -1) \cdot n$. Therefore, based on the structure of its secondary lianit roots, $\sigma_\ell = (x_1^\ell, x_2^\ell) = \left[\frac{x_{0i}+x_{0j}}{2}, \pm\left(\frac{x_{0i}-x_{0j}}{2}\right)\right]$, the degree of the associated polynomial as a function of the unknown $x_1^\ell = \frac{x_{0i}+x_{0j}}{2}$, calculates as $C_2^{2n} \cdot 2 = n(2n-1) \cdot 2 = 2n(2n-1)$. Combinations of the type $\{x_{0i}, x_{0j}\}$ and $\{x_0 \cdot x_{0i}, x_0 \cdot x_{0j}\}$ generate doubly appearing divisors, namely: $z_1^{n(n-1)}(x_1) = \left[z_{1,0}^{\frac{n(n-1)}{2}}(x_1)\right]^2$, $u_1^{n(n-1)}(x_1) = \left[u_{1,0}^{\frac{n(n-1)}{2}}(x_1)\right]^2$ [the number of corresponding combinations are $\frac{n(n-1)}{2}$, $\frac{n(n-1)}{2}$]. These are the general associated polynomials of the system of equations $f^n(\sigma) = (0,0)$, $f_0^n(\sigma) = (0,0)$. There are exactly n combinations of the type $\{x_{0i}, x_0 \cdot x_{0i}\}$ generating the associated polynomial from (7), i.e. $z_0^n(x_1) = x_1^n + \left(\frac{1+x_0}{2}\right) a_1 x_1^{n-1} + \left(\frac{1+x_0}{2}\right)^2 a_2 x_1^{n-2} + \cdots + \left(\frac{1+x_0}{2}\right)^{n-1} a_{n-1} x_1 + \left(\frac{1+x_0}{2}\right)^n a_n$ with numeric roots: $\frac{x_{01}+x_0 \cdot x_{01}}{2}$, $\frac{x_{02}+x_0 \cdot x_{02}}{2}$, ..., $\frac{x_{0n}+x_0 \cdot x_{0n}}{2}$. The remaining $2n(n-1)$ combinations of the type $\{x_{0i}, x_0 \cdot x_{0j}\}$, where $x_{0i} \neq x_{0j}$, generate the divisor $v_1^{2n(n-1)}(x_1) = \left[v_{1,0}^{n(n-1)}(x_1)\right]^2$. $v_1^{n(n-1)}(x_1)$ with numeric roots $x_1^\ell = \frac{x_{0i}+x_0 \cdot x_{0j}}{2}$ $[\ell = 1, 2, \dots, 2n(n-1); x_{0j} \neq x_{0i}]$.

Summary

To conclude we summarize the results of our work. We have provided a purely algebraic proof of the fundamental theorem of Algebra via a specially constructed lianit set. The importance of the presented proof is that it utilizes a lianit algebra with the same algebraic properties of multiplication and addition as the complex numbers. In this aspect the provided proof is a simple application of the theorem of principal and secondary lianit roots, which establishes a direct correspondence between the complex roots of a polynomial and its lianit solutions.

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Corresponding author:
"Ph.D (Theor. Phys.), Ph.D (Algebra) **Loran Akopyan**
All-Russian Scientific-Research Institute for Electrification of Agriculture,
1-st Veshnyakovsky proezd, 2, 109456, Moscow, Russia
Tel.: (+7-499) 171-19-20. E-mail: loran.akopyan@gmail.com

ВТОРОЕ ДОКАЗАТЕЛЬСТВО ОСНОВНОЙ ТЕОРЕМЫ АЛГЕБРЫ

Л.В. Акопян
Всероссийский-научно-исследовательский институт электрификации сельского хозяйства (ФГБНУ ВИЭСХ), Москва, Россия

Представлено второе, чисто алгебраическое, доказательство основной теоремы алгебры (ОТА) посредством видоизменённой лианитовой алгебры, весьма схожей с алгеброй комплексных чисел. Использованная алгебра лианитов была специально сконструирована для сохранения привычных свойств числовых алгебр: она коммутативна и ассоциативна по отношению к операциям сложения и умножения, операции сложения и умножения связаны между собой дистрибутивным свойством. Кроме того, операция умножения отличается от умножения комплексных чисел только знаком.

Дополнительной отличительной чертой этой алгебры является свойство: сумма элементов всевозможных побочных корней псевдоалгебраических уравнений является числовым корнем (если такие существуют) для соответствующего числового многочлена. Представленное доказательство ОТА методологически дополняет самое первое доказательство этой теоремы посредством лианитовых алгебр: как альтернативный способ доказательства ОТА оно изящнее, отличается методологической простотой и использованием алгебраических структур, весьма близких по свойствам с обычными числовыми алгебрами.

В ходе доказательства вводятся вспомогательные понятия «пробного» и «сопровождающего» многочлена, играющие важную роль в проведении доказательства ОТА. Второе доказательство ОТА, как и первое, оказывается следствием общей теоремы об основных и побочных лианитовых корнях, которая устанавливает прямую связь между комплексными корнями числовых многочленов с побочными лианитовыми корнями соответствующих псевдоалгебраических уравнений.

Эта теорема используется во втором доказательстве ОТА дважды: во-первых, она обеспечивает существование и вычисление комплексных корней по существованию побочных лианитовых корней соответствующих псевдомногочленов. Во-вторых, мы пользуемся следствием этой теоремы, сформулированной ранее, как обобщением теоремы Гамильтона-Кэли для основных и побочных матричных решений псевдоалгебраических уравнений. Это позволяет укоротить доказательства ОТА путем прямого расчета пробного и сопровождающего многочленов в общем случае. Именно эта техника и лежит в основе второго доказательства, что вдохновляет нас на поиск более короткого способа доказательства ОТА, эта техника основана на лианитовой алгебре, весьма схожей с алгеброй комплексных чисел.

Ключевые слова: псевдоалгебраические уравнения, лианитовые корни, сопровождающие многочлены, основная теорема алгебры.

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Сведения об авторе:
Акопян Лоран Ваганович – канд. физ.-мат. наук, ФГБНУ ВИЭСХ, г. Москва, Россия,
e-mail: loran.akopyan@gmail.com

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