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THE ROLE OF TECHNOLOGY IN SHAPING THE ENERGY FUTURE IN RUSSIA

The paper is a sub-report of The FINENTEC project (The Competitive Edge of the Finnish Energy Technology). The Russian energy sector is from the Finnish perspective near by and a potentially huge market for energy technology. The transformation of this market is analysed here by an independent Russian expert.

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ABSTRACT: In the recent years of economic transition, lack of investment and dire financial constraints of the energy utilities have limited maintenance and replacement of the energy equipment in Russia. This, in its turn, has put the whole future of the national energy equipment manufacturing and new technology development in danger. In this study we address problems and changes in technology development and energy equipment manufacturing in Russia. The paper includes analysis of the electricity demand and energy market structure in Russia as well as needs to rationalise electricity generation, the existing public policies and influence of these factors on the further development of energy technologies and equipment manufacturing. Description of the major technologies and products is presented together with an overview of the major companies, operating in the field. A potential for the different technologies and fuel is analysed from the point of view of equipment availability and opportunities for international companies to fill in the gap, that will appear due to the above said structural changes. According to our forecast, gas-fired technologies and equipment are likely to lead the investment league in the beginning of the new millenium.

KEY WORDS: Russia, energy sector, technology development and equipment manufacturing

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TIIVISTELMÄ: Siirtymäkauden aikana investointien puute ja energialaitosten vaikea taloudellinen tilanne Venäjällä ovat rajoittaneet energiantuotannossa käytettävien koneistojen huoltoa ja saneerausta. Tämä on vuorostaan vaarantanut energia-alan konerakennusteollisuuden ja uusien teknologioiden kehitystä. Tässä tutkielmassa tarkastellaan energia-alan tutkimus- ja kehitystoimintaa sekä laitevalmistusta Venäjällä. Samalla analysoidaan sähköenergian kysyntää ja energiamarkkinoiden rakennetta Venäjällä, energiatuotannon tehostamisen tarpeita ja valtion energiapolitiikkaa sekä näiden tekijöiden vaikutusta alan T&K -toimintaan ja laitevalmistukseen. Lisäksi kuvataan Venäjällä käytettävää tekniikkaa ja laitevalmistajia. Eri teknologioiden ja polttoaineiden potentiaalia analysoidaan laitteiston saatavuuden kannalta, mukaan lukien ulkomaalaiset teknologiat, jotka saavat paikkansa Venäjän markkinoilta rakenteellisten muutosten seurauksena. Ennusteemme mukaan kaasupohjaiset teknologiat ja laitteet tulevat johtamaan investointeja ensi vuosituhannen alussa.

AVAINSANAT: Venäjä, energiasektori, teknologia, laitevalmistus

YHTEENVETO

Energiasektori on Venäjän elinkeinoelämän tärkeimpiä osa-alueita, joka tuottaa lähes puolet maan valuuttatuloista. Noin 30% Venäjän teollisuustuotannosta liittyy energia-alaan. Energiasektorin toimivuus suuressa osin määrää koko Venäjän talouden kehitystä.

Neuvostovallan aikana melkein kaikki energiakoneet ja -laitteet valmistettiin Neuvostoliitossa tai itä-blokin maissa. Ajan kuluessa koneistot ovat vanhentuneet. Siirtymäkauden aikana investointien puute ja energialaitosten vaikea taloudellinen tilanne Venäjällä ovat rajoittaneet koneistojen huoltoa ja saneerausta. Tämä on vuorostaan vaarantanut energia-alan konerakennusteollisuuden ja uusien teknologioiden kehitystä.

Millä tavoin energiasektori ratkaisee tämän ongelman? Kuinka suuri osa energiakoneteollisuuden markkinoista siirtyy ulkomaalaisille? Millä tavoin tämä vaikuttaa tulevaisuudessa käytettäviin teknologioihin ja polttoaineisiin? Näitä kysymyksiä pohditaan tässä tutkielmassa. Samalla esitellään niitä vaikeuksia ja esteitä, joihin Venäjä törmää siirtyessään neuvostoajan ylikunniahimoisesta, suureellisesta ajattelusta markkinataloudelle ominaiseen ajattelutapaan. Siirtymäkausi Venäjällä kestää kauan ja sen hinta tulee olemaan kova.

Luvussa 1 kuvataan energiasektoriin kohdistuvia poliittisia, taloudellisia ja sosiaalisia muutoksia, jotka ovat ominaisia tämän päivän Venäjälle. Energiasektorin kehitys heijastaa myös tutkimus- ja kehitystoiminnan ja laitevalmistuksen sopeutumista uusiin markkinavaatimuksiin.

Realistinen lähestymistapa päätöksentekoon ja investointiprojektien toteutettavuusselvitykset otetaan yhä laajemmin käyttöön Venäjällä. Vanhat käsitykset täydellisestä teknisestä ja tuotannollisesta riippumattomuudesta ovat väistymässä kaupallisen, markkinakeskeisen ajattelun tieltä.

Luvussa 2 käsitellään energiasektorin teknisen kehitystoiminnan ja laitevalmistuksen nykytilaa ja tulevaisuudennäkymiä tuotannon, kysynnän, omistuksen yms. lähtökohdista. Samalla tarkistellaan viranomaisten tukea tutkimus- ja kehitystoiminnalle.

Luvussa 3 esitellään energia-alan kehitys- ja tutkimustoimintaa Venäjällä ja sen prioriteetteja. Samalla annetaan lyhyt kuvaus tutkimuslaitoksista ja tutkittavasta tekniikasta.

Luvussa 4 kuvataan energia-alan laitevalmistusta, mm. markkinatilanteeseen vaikuttavia tekijöitä, alan päätoimijoita sekä sen tulevaisuudennäkymiä ja markkinaosuuksien uudelleenjakamista.

Luku 5 sisältää yhteenvedon energia-alan tutkimus- ja kehitystoiminnan ja laitevalmistuksen kehityksestä Venäjällä. Venäjän markkinoiden avautumisen ja kasvavan kilpailun seurauksena tulevaisuuden polttoainevalikoima tulee muuttumaan. Lähivuosien aikana taloudellinen tilanne ei salli hallituksen esittää aktiivista roolia elinkeinoelämän ohjauksessa. Talouden kehitys tulee määräytymään kysyntälähtöisessä kilpailussa eri tekniikoiden ja laitteiden välillä. Kasvava kilpailu paikallisten ja kansainvälisten laitevalmistajien välillä sekä paikallisen rahoituksen ja investointien vähyys auttavat ulkomaalaisia yrityksiä voittamaan uusia projekteja. Paikalliset laitevalmistajat sen sijaan tulevat dominoimaan huolto-, kunnostus- ja saneerausmarkkinoita.

Tämän tutkielman valmistelua on vaikeuttanut luotettavien tilastotietojen puute. Tästä syystä kaikki tutkielmassa esitetyt kuvat ja taulukot perustuvat riippumattoman tutkimuksen tuloksiin ja arviointeihin. Kuvissa ja taulukoissa käytettävä numerotieto edustaa tekijän omaa näkemystä asioista.

SUMMARY [1]

The energy sector is the major sector of the Russian economy that generates nearly half of its hard currency revenues and 30% of the total industrial output. Thus, functioning of this sector to a great extent determines the overall economic success of Russia.

In the Soviet era, nearly 100% of the energy sector equipment was produced by Soviet and Eastern bloc manufacturers. As the time went by, the installed equipment base has become worn out and out-dated. In the recent years of economic transition, lack of investment and dire financial constraints of the energy utilities have limited maintenance and replacement of the energy equipment in Russia. This, in its turn, has put the whole future of the national energy equipment manufacturing and new technology development in danger.

How the energy sector will cope with this problem? What shares of the local energy utilities equipment market will be gained by foreign companies? How this will affect the future fuel and energy technology mix? These questions as well as obstacles and hardships of the transition from an over-ambitious grandeur approach of the Soviet times to market economy thinking are addressed in this paper. It is shown, that the transition will take a long time and expected loss during this period will be tremendous.

Chapter I is devoted to the description of the energy sector as a major single sector at the forefront of the political, economic and social changes undergone by Russia in the present time. Changes in the energy sector are also reflected in and driven by the adjustment in technology development and equipment manufacturing to the new market requirements.

Such novelties as a realistic approach to decision making and feasibility assessment of investments and development projects are being introduced and are gaining ground in the Russian market. A pragmatic approach is widely used as a new method of project valuation. The old ideas of full technological and manufacturing independence are slowly fading away and are being replaced by commercial, market oriented thinking.

In Chapter 2 we discuss the overall perspective of the technology development and equipment manufacturing in the energy sector and address its present condition in terms of production output, market, ownership etc., its organisation and related public policy issues.

Chapter 3 is devoted to the discussion of current energy technology development in Russia, including analysis of the development trends. A brief description of the major research facilities and alternative technologies is also presented.

Chapter 4 concentrates on the energy sector equipment manufacturing. The present state of this sub-sector, factors that affect the market situation, major players as well as development trends are identified and discussed. Redistribution of the market shares after opening-up of the Russian

1 I would like to express my acknowledgements for help and valuable support provided in technical issues by Mr. Michael Nerovny, Chief Engineer of the SolidEnergoProject Company, St. Petersburg, Russia.

market in the early stages of the economic transformation is described. Some conclusions concerning future development of the sector are also presented.

In Chapter 5 we summarise the information and analysis on the further development of energy technologies and equipment manufacturing in Russia. Due to openness to the world economy and increasing competition, the fuel mix in Russia will be re-shaped in the nearest future. For the next few years, financial constraints will not allow the weak government to play an active role in economic issues and power will pass to the market demand driven competition of technologies and equipment. Increased competition between local and international producers as well as scarcity of local finance and investment resources will lead to the success of international companies in winning green field projects, as the local producers will dominate the replacement, rehabilitation and modernisation markets.

One of the major difficulties in preparation of the present paper was the lack of reliable statistics and data related to the sector's operation. For this reason, the author has compiled market statistics graphs and tables on the basis of independent private research and estimates. These figures represent the author's view and should be duly judged.

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1. ECONOMIC TRANSITION AND ENERGY TECHNOLOGY DEVELOPMENT AND EQUIPMENT MANUFACTURING IN RUSSIA

In 1990-1991, Russia entered into a period of transition to the market economy. The changes brought by this process have affected the whole Russian society and economy, including the equipment manufacturing and technology development. In this Chapter, we shall give a general overview of the energy sector in Russia, which will serve as a framework for a detailed analysis of equipment manufacturing and technology development in the proceeding chapters.

Energy equipment manufacturing and technology development is largely determined by the inherited capital from the Soviet period. It is, thus, necessary to start with an analysis of how the inherited capital of the Soviet period has been affected by the economic transition in Russia. This analysis constitutes a basis for evaluation of the future prospects of energy equipment manufacturing and technology development in Russia.

Inherited Capital of the Soviet Period

Since the very beginning of Soviet era, the energy sector has traditionally been at the top of the political and public agenda in Russia. For the Soviet state, development of energy technologies and equipment manufacturing was always one of the highest investment priorities. In the 20-60ies, the national achievements in the energy sector were discussed and admired all over the country. A large amount of investments was committed to build a base for powerful energy technology research and development as well as equipment manufacturing industry. The full self-sufficiency principle, proclaimed by the Communist Party, was the main driving force for that process.

There were several stages of the development. The first was started by Lenin immediately after the October Revolution in 1917 and was driven by hydropower plant construction and development. In 1930-1950ies under Stalin's rule, the focus shifted to coal, which became the main source of energy and dominated the fuel mix. At that time also the energy systems of Russia were finally unified, thousands kilometres of transmission lines were constructed. It was the time, when many far-reaching decisions concerning the further energy system structure were made, sometimes with disastrous consequences[2]. In the next decades, development of one of the largest nuclear power sectors in the world became the priority for the Soviet leadership, setting another example of grandeur thinking and planning.

In the Soviet period, energy policy issues were always political and, thus, were decided upon by the Communist party "nomenklatura". Driven by political incentives, those decisions were in most cases either unprofessional or unfeasible in the common economic sense. This has led to great structural distortions in the sector, enormous continuous losses and mismanagement of resources. Correction of this distortions and mistakes, sustainable energy sector development is one of the major challenges for the Russian economy. The sector's exceptional position in the country's economy adds to its importance for the whole Russian society, as well as for the global market. Energy sector restructuring will also require greatest ever investments to unable transition to the market economy, including complete revision and rethinking of the

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2 In the 1950-ies, when the centralisation and unification of the electricity supply in Russia was carried out by the Soviet government, nearly 5 000 hydropower plants were shut down and their consumers were switched to the Unified Energy System's grid.

strategy, policies and practices. To carry out a process of such a profound nature, work input of several generations and strong commitment of the whole society to implement the task will be needed.

On the equipment manufacturing side, the best investment resources were traditionally put into energy sector machine-building and technology development. The policy of full technological independence from the world dominated the Soviet energy technology development for decades. The results of this policy have been both positive and negative. The positive side of this is a very extensive base for fundamental research, technology development, engineering and equipment manufacturing, inherited from the Soviet times. The negative side deals with operational difficulties, that have resulted from poor management, mistakes in geographical positioning of the technology development and manufacturing facilities. The same grandeur, over-ambitious approach to the new product development led to the creation of the world's most concentrated manufacturing facilities, very narrow specialisation of the production units, creation of the world's largest turbines and boilers, etc. As the world market as well as the Russian customers tend to favour smaller, more consumer oriented solutions in power generation, this approach represents a major challenge for the technology development and equipment manufacturing companies in Russia. Conversion of the practices and facilities to smaller unit production will require substantial investment from the main stream technology development and manufacturing companies in order to survive in the long term.

The Soviet policy of full self-sustainability has brought some good results too, as the smaller unit manufacturing and technology development companies were developed for the other purposes (jet, marine engine manufacturing, turbines for gas pumping compressors etc.). These companies are the main competitors for the main stream energy technology and equipment manufacturers. Small equipment producers will certainly benefit from the new market trends, that will add to their operations in the traditional markets.

Changes Brought by the Economic Transition

The scale of changes, brought by the economic transition in energy technology development and equipment manufacturing, can not be underestimated. The energy sector is still a core of the Russian economy. In 1997, it provided 28,5% of Russia's total industrial output and 46 % of total exports.

The nature of the said changes in Russia has been reflected by reshaping of the fuel mix into a more rational and feasible one. The market is making its way in Russia by introducing cost advantage instead of political decision as one of the main driving forces of energy generation and supply markets. This, in turn, finds its reflection in the energy producing companies demand for the new technologies and equipment.

Fuel Mix

Different fuels have, at different times, dominated the fuel mix in Russia. The hydropower was dominant in the 1920'ies and early 1930'ies. In mid 1930'ies-1950'ies coal captured the bulk of electricity generation and industrial energy investment. From 1970's till 1980's the nuclear power and large hydropower projects gained vast ground in Russia. The beginning of "perestroika" brought diminishing investments in the new power plant construction. The process of new construction nearly stopped in the 1990's, when the country entered a period of economic and financial instability and privatisation.

Today, it is the turn of gas to lead energy investments. It is expected that gas-fired power generation will gain its share from the oil, coal and, in the longer term, even from the nuclear power generation. Availability of the fuel on the local market as well as the availability of a wide range of local, competitively priced technologies and equipment coupled with safety and reliability of gas supplies and relative cost advantage of the gas-fired electricity generation are the main factors to support this trend in the nearest future. Nevertheless, coal is also expected to preserve most of its positions due to the introduction of the new clean coal systems and relative price advantage of the coal based power generation for the many Russian regions.

There is uncertainty as to the final shape of the fuel mix, where the impact of the new technologies and concerns about the environment will be decisive in the long term. The potential for development of the new technologies based on different fuels is extensive. The rate of development of the technologies will be influenced substantially by the investment ability of the Russian government, major producers and consumers.

Market Demand

The fact that, nowadays, energy technology development and equipment manufacturing are driven by the market demand is one of the main achievements of the Russian economic transition. Participation of the state in steering the sector's development is being reduced to a level, close to the one in the normally functioning market economies. Thus, for the nearest future, it is the support to extensive fundamental research in the sector, that remains one of the main concerns for the government. Another major problem still left is the governmental control over electricity tariffs, through which the government tries to balance the low purchasing power of the consumers with the enormous investment needs of the energy utilities. However, these are the issues, that are best regulated by the open market.

In the years of transition, the demand side of the market has changed completely: privately owned energy utilities and companies have substituted the state as the major customer. That change yet needs to find due reflection in the practices and approaches in technology development and equipment manufacturing companies. Those, who will adapt their strategies and approaches to the new requirements soonest, will be the most probable winners in the long term.

Growth in demand for energy technologies development and new equipment is driven by the overall demand for energy. This demand, in its turn, projects social, economic and industrial activities of the society. At the moment, Russia is undergoing a tremendous structural change that, in the end, will significantly alter its economic, social and institutional structures. The level, at which those structures will stabilise, will finally determine the future structures of the society and economy and, thus, the demand for energy. The outcome of this process is still unclear and can not be reliably quantified.

Problems Brought by the Period of Transition

The current volume of production is supported by the presently installed equipment. Built in the Soviet times, the equipment is economically inefficient, largely worn-out and out-dated.

Supporting the current volume of production in the energy sector requires an enormous amount of investment in rehabilitation, replacement of the equipment by the new, efficient and competitive one. This need itself represents a challenge for Russia as the necessary and long postponed investment in the energy sector constitutes a large portion of the country's GDP[3]. Another problem, related to the above, is that the postponed investment in the energy sector means low demand for new technologies and equipment for the local producers. This, in its turn, may endanger the long term survival of the Russian technology development and equipment manufacturing sector.

The problem of equipment replacement and introduction of the new energy efficient, environmentally friendly and safe technologies in a situation, when the local producers of such equipment have collapsed, will have no short term solution and will undoubtedly lead to a supply crisis. This may, consequently, lead to an increase in energy prices and an overall decline in competitiveness of the Russian economy in the world market. Thus, it is of great importance, that the growth of the Russian economy should start before the state of energy sector becomes too critical. Only an increase in energy demand, based on the economic growth, will allow to solve the investment dilemma described above.

Due to the large proportion of the equipment and power plants that must be fully replaced for environmental and efficiency reasons, a substantial amount of the new construction will be needed to substitute these capacities in the energy balance of the country. The other argument for the increase of the new construction in the future is the tendency to correct the geographical location distortions and excess centralisation of the Soviet period in order to bring electricity generation closer to consumer. Environmental pollution concerns and cost advantages of different fuels for different geographic locations will be instrumental in decision-making on new power plant construction.

Major Factors That will Influence the Future Development

It is still an open and widely debated issue, whether the achieved level of the electric energy production will in the long term be sustainable for the Russian economy, taking into consideration its growth perspectives. There is a number of uncertainty factors, that are to be taken into account in this respect, such as energy efficiency and productivity increase gains, that may be achieved by an investment and public policy means.

Energy Efficiency

Energy intensity of an economy at a given time reflects the interaction of technology, social structures and relative prices. Energy efficiency strategies are not only inherently friendly to the environment and safe. These strategies also offer a potential to substantially slow down the energy demand growth in a way, that allows society to gain considerable flexibility in choosing how to cope with challenges, imposed by the environment and decrease of the production output. Theoretically, the potential for cost-effective energy savings is very large. But in practice, it has proved difficult to capture the full potential, owing to a wide range of well-known institutional obstacles.

Higher energy prices are often seen as a primary driving force of the energy savings. Unfortunately, there is no proof found in Russia, that increased energy prices will lead to the corresponding energy savings. On the contrary, increasing prices have been echoed mostly by the increase of accounts receivable in energy utilities balance sheets and in the corresponding increases in proportion of energy payments settled by barter transactions.

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[3] According to various sources, the annual investment needs vary from 10 to 30% of the country's GDP.

Notwithstanding the above facts, the energy efficiency gains in Russia have already led to a substantial softening of the energy supply crisis. This has happened due to the decommissioning of a large part of inefficient equipment in the Russian industry. Most of this equipment is not likely to be taken into operation ever again. This illustrates one of the outcomes of the current industrial restructuring, driven by the market demand, not by the political directives.
It is important to keep in mind, that the installed equipment in the Russian industry is already largely worn out and out-dated. Energy intensity of an industry is determined by the level and quality of the capital equipment in use. Thus, as the industry in order to compete in the open market will invest in the new modern technologies, energy intensity gains will result. This is inevitable for the survival of the industry in Russia. Those, who will not invest and develop, will be sooner or later driven out of the market and energy intensity will improve further. Though obvious, the impact of the mentioned factors is very hard to calculate.

Productivity

There are undoubtedly major advances to be made in productivity. These advances will occur through technological, managerial and communication changes, as well as through changes in the market structures.

New educational programmes for academic institutions in Russia already include basics of the market economy and modern management techniques, that will undoubtedly reflect in the results of the Russian companies as soon as the change of generations in management will gain the full speed.

Using open tenders to replace or rehabilitate the installed equipment will certainly produce results in the longer term as the achieved productivity gains will accumulate.

Development of the New Technologies

Traditionally highly valued fundamental research in Russia nowadays faces exceptional difficulties in developing its concepts into designs and further into production. Introduction of the new technologies into practice is hindered by the lack of investment and insufficient demand by the energy utilities for the new technologies. Other significant limitations of fundamental research in Russia arise from the worn-out, technically out-dated equipment of the research facilities, lack of resources to invest in modern computer hardware and software. It is clear, that these difficulties will be reflected in the future fuel mix in Russia. Only very few local technologies are likely to be introduced into practice, giving up their positions to the technologies developed internationally.

The present situation in the market, when the demand for new equipment is very low, has forced Russian technology development companies to concentrate mostly on modernisation and rehabilitation solutions for the already existing equipment. The manufacturing industry focuses on supply of spare parts for the installed equipment. This situation leads to the deterioration of the production facilities and decrease in long term competitiveness of the local manufacturers. This undoubtedly will make it even more difficult for the local technology development and manufacturing companies to compete with the international suppliers. The only sensitive competitive advantage, that the local companies can benefit from, will be the lower cost of production and various governmental support programmes.

Openness of the Market

Due to the increasing openness of Russia to the world market, it is reasonable to assume, that in the medium term a sound part of existing and new construction will use western technological solutions and equipment as an alternative to the local products. On the other hand, lower costs of the local manufacturing will still allow Russian equipment to dominate the market in the short term. The products of joint ventures with the foreign companies will play a greater role in the Russian market as well.
Possible technological advances in the future can also play an important role, especially in the final shaping of the fuel mix structure in Russia. It is clear, that advances in facilitating international investment and participation in the energy sector will make the most advanced foreign technologies available and, as a consequence, will allow to benefit from them in the longer term.

It is also clear, that international companies and technologies will tend to use the increasing openness of the Russian energy market and their competitive advantages to participate in shaping the energy future in Russia. It is expected to take place primarily in the new construction projects. Making use of such instruments, as "joint implementation projects" indicated in the Kyoto Protocol, will facilitate participation of foreign energy companies in the replacement of the out-dated equipment and modernisation of the existing power plants, using energy-efficient and environmentally friendly technologies. It is also quite obvious, that such projects will be mostly based on foreign technologies and equipment.

Public Policy

The government of Russia is trying to support research and influence the trends of technology development. Due to political lobbies and interest groups, this process lacks concentration and aims at providing little funding for many technology development projects, instead of getting a few top priority projects done in a proper way. The process of economic transformation makes market demand the main force in shaping technology development companies in Russia.

The role of government is limited to participation in the tariff policy that looks like an attempt to balance the investment requirements of the energy utilities with the diminishing purchasing power of the consumers. This policy can not be sustainable in the long term as it has proven to be impossible to solve electricity pricing dilemma only by governmental intervention. By setting price limitations, the government takes on the burden of subsidising the energy utilities to cover part of the energy price, which the consumers can not afford to pay. The wiser approach would be to open the electricity generation markets for the competition that will make it easier to pick up winners that will provide the cheaper electricity. Some steps in this direction have already been made by the previous governments but the major decisions still wait to be done.

2. GENERAL OUTLOOK ON RUSSIAN ENERGY SECTOR TECHNOLOGY, SECTOR STRUCTURE AND PUBLIC POLICY

2.1 Overview

Development of high value added sectors is one of the main long term priorities for the Russian economy, as it is the only way to increase the GDP and per capita income to the level of the developed countries. A large amount of capital and investment, inherited from the Soviet times, gives energy equipment manufacturing and technology development companies a competitive advantage in the new open energy technology and equipment market in Russia. Understanding how this advantage will be used by the Russian companies is a difficult issue. It is clear, that the companies' success will hugely depend on the local market demand for their services and products. This is why, it is important to examine energy technology and equipment manufacturing from the point of view of market demand for their products. But before we proceed to the analysis of factors shaping the market demand for energy equipment and technologies in Russia, it is worth to give a brief outlook of the present state of these sub-sectors.

Energy Technology and Equipment Manufacturing in Transition

Before the beginning of the economic transformation in Russia, the volume of production in energy equipment manufacturing and technology development was about 2 to 3% of the total industrial output. At present, it constitutes an average of 1-1,5% of the total production. Thus, the relative share of these sub-sectors has been substantially reduced. This has resulted from a very low demand for technologies and equipment as well as from the inability of the companies to adjust their product range or to control pricing for their products. Out of approximately 50 companies operating in the field of energy technology and equipment manufacturing, 9 engage also in research and development[4]. Currently, about 100 000 people are employed in the field, compared to 200 000 in 1990.

As a result of the policies by the Soviet government, - oriented to energy supply self-sufficiency and independence in terms of energy equipment supplies, - an extensive energy equipment production and technology development capacity was created in Russia before 1990. There was a stable demand for energy equipment and technologies, supported by the governmental investments in the energy sector. Till 1990, a large part of the energy equipment production was exported from Russia abroad. Large exports may give a wrong impression of a high international competitiveness of the said equipment. It was not usually the case. Most of the exports went to the developing countries, which used to finance these purchases through increasing of their debt to the Soviet Union. Abolition of this practice in the today's Russia has entailed a dramatic decrease in exports. Nevertheless, some large equipment manufactur-

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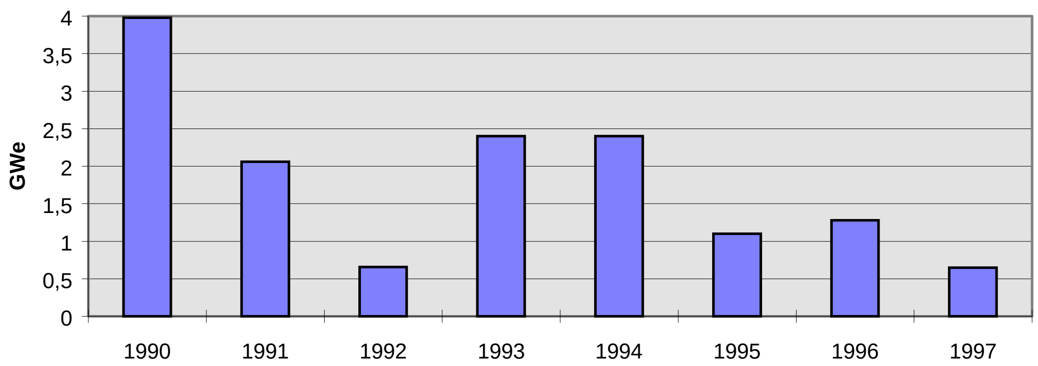
[4] This figure includes only independent technology development companies specialising in technology development and equipment design for electricity generation. The figure does not include academic institutions engaged in fundamental research as well as multi-industry companies which are involved, for example, also in jet engine design and development. The total number of such institutions is approximately 200. Insufficiency of reliable information and multi-sector orientation of many institutions makes their verification a very complicated task.

ers still try to lobby the continuation of such practices in their projects with India, Iran, China etc.
Since 1991, transformation of the Russian economy has lead to a substantial decrease in energy demand and new energy construction (see Table 2.1.2 and Graph 2.1.1. respectively). Severe financial constraints have put a serious limitation on the energy utilities' investments in rehabilitation and replacement of the worn-out and out-dated equipment. That, in its turn, has led to a substantial stagnation and output decline in the technology development and equipment manufacturing. Exports faded due to the requirements by the manufacturing companies to pay for the supplies in the standard terms.

During the last five-year plan periods in the Soviet Union, the total power plant start-ups represented 50 to 52 Gwe. Production of the equipment was substantially higher, as it also covered the needs for replacement and rehabilitation of the national energy sector and the export needs. Annual volume of production of steam turbines was 12 to 15 GWe, hydraulic turbines - from 2 to 4 Gwe. These volumes of production were also supported by an extensive research and technology development activities funded by the Soviet state in all major areas of the modern technology development. Important technological breakthroughs in this field were the glory of the Soviet state. Unfortunately, very few of these achievements have proved to be long term sustainable or have been successfully put into practice.

Graph 2.1.1 New Generating Capacity Annual Start-up in Russia, GWe.



Source: Ministry of Economy (1998).

Nowadays, the volume of production has fallen to 10 to 25% of the pre-transition levels. As a consequence, the industry is losing qualified personnel, which can not be supported by these volumes of production. This will inevitably affect the long term sustainability and competitiveness of the industry.

Demand For Energy - A Key Factor That Influences Development

Energy demand and consumption are the main driving forces for energy equipment manufacturing and technology development. It is important to specify the difference between energy demand and factual consumption. Transition period in Russia is characterised, among the other things, by large electricity payment arrays. Electricity supplies to some indepted customers are already cut off and this practice is likely to gain wider ground the nearest future. The payment difficulties are inflicted by the process of adjustment of the privatised companies to the market requirements. Many of such companies do not find a sufficient demand for their products in the market and, to keep their facilities afloat in expectation of the demand increase, consume more electric energy than they can afford to pay for. The recent wave of bankruptcies[5] will certainly lead to the shut-down of many companies and substantial decrease in the electric energy consumption.

In other words, the present level of the electric energy consumption does not reflect the real energy demand, as the substantial part of the consumed energy is not used for production and can not be paid for or settled otherwise. Over the years to come, the economic and institutional adjustment underway will most probably lead to a further decrease in the electricity demand for industrial production in Russia.

Total energy consumption by industries in 1997 and its share in comparison to the consumption in 1990 and 1996 are given in the table below.

Table 2.1.1 Energy Consumption Dynamics.

Industry, consumers	1997, TWh	1997/1990, %	1997/1996, %
Total consumption (used output)	641,6	72,4	98,1
Industrial sector	325,1	61,4	98,9
Transport and telecommunications	61,1	62,0	92,9
Agriculture	41,7	58,4	86,6
Non-industrial sector	104,24	109,4	103,1
Public consumption	101,07	131,0	99,7

Source: RAO UES (1998).

The above table shows the dynamics of consumption (used output) in 1990-1997 in the major sectors of the Russian economy in percentage to the 1990 level. It can be clearly seen, that in 1997, acceleration of the consumption decline of 1992-1995 changed towards stabilisation and first signs of growth. The exception was public consumption, which grew consistently during those years.

This change in electricity consumption found its reflection in the annual output results of energy technology development and equipment manufacturing. In the table below we present the output figures for St. Petersburg, which alongside Moscow, is one of the main centres of energy equipment manufacturing and technology development. These figures prove the

5 In less than a year, from late summer 1998 till now, over 5000 bankruptcy cases were filed in Russia compared to 1000 in the previous five year period.

statement, that electricity consumption stabilisation has led to the stabilisation of production in these sectors.

Table 2.1.2 Energy Sector Equipment Manufacturing and Technology.
Development Sub-sector's Output in St.Petersburg.

Energy Sector's Sub-sectors	Total Production Output, billion roubles (without VAT)[6]		
	1995	1996	1997
Equipment manufacturing	1320,4	2046,1	2051,2
Research and Technology Development	281,7	569	697,8
Total	1602,1	2615,1	2749

Source: GosKomStat (1998).

The crisis of August, 1998 has revised the trend once again. Alongside with the substantial fall of production in some industries, it has also led to the substitution of imported goods by the domestic ones and thus facilitated growth in the domestic consumer products industries. This will inevitably cause further changes in the structure of energy consumption. At the time the present report was prepared the information concerning these influence was not yet available.

Over the years, stabilization of production will be followed by an increase in energy consumption, echoed by the energy utilities' demand for technologies and equipment. Unfortunately, this correlation will not be that straight-forward. The main problem lies in the field of pricing of the technologies and equipment and corresponding adjustments of the energy tariffs. The prices for castings, metals and other supplies for equipment manufacturers are on the world market level. This will certainly be reflected in pricing of their goods as well.

However, the purchasing power of utilities is low, as, due to the fixed electricity tariffs, their revenues decrease in pace with inflation and devaluation. Thus, the major obstacle becomes the governmental regulation of tariffs, which during the recent crisis, has proven to be a political, not economic tool. In other words, the energy tariffs still remain on the pre-crisis level, which, in many terms, means a four-fold decrease of their real value. The purchasing power of the energy utilities as the main client for the discussed sub-sectors has diminished substantially, putting on hold many investment and renovation projects.

Nevertheless, the analysis of the impact of the crisis on the overall competitiveness of the local producers shows, that the crisis has definitely strengthened their position in replacement market of the existing equipment and has increased their chances to preserve a share of the new power plant construction market as well. This has become possible mainly due to the substantial decrease of the local costs of production.

Unfortunately, the tariff regulation policy of the Russian government has cut down the investment resources of the energy utilities, that now can only afford to attend their urgent maintenance needs. Rehabilitation and maintenance of the installed generating equipment will

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6 The USD/rouble exchange rate at the end of 1995 was 4667 roubles, at the end of 1996 it was 5554 roubles and at the end of 1997 - 5942 roubles. The figures in the table are presented as to before the denomination. After the denomination, the value of rouble dropped 1000 times.

support day-to-day operations of the equipment manufacturers, but it will also channel their scarce resources away from the new technology development.

At the same time, foreign competitors of the Russian energy equipment manufacturers will invest in more efficient and environmentally friendly technologies. The gap between these companies and their approaches will grow consistently and, at some point, for many producers it will become impossible to overcome. These processes will lay ground for the major redistribution of the market shares in Russia in the longer term, leaving only few of the most successful local manufacturers in the market.

Fuel Mix Change - Another Factor Affecting the Long Term Development

To identify, what technology development and equipment manufacturing companies will have a better chance to survive and what sectors will the market shares redistribution affect most, we shall analyse the development trends of the rational fuel mix and power generation structure in Russia, taking into consideration the inherited capital and experience acquired in the different spheres of manufacturing and technology development.

Changes due to the Replacement of the Worn-out and Out-dated Equipment

Let us first address the present electricity generation structure and the fuel mix in Russia, presented in the table below.

Table 2.1.3 The Electric Energy Installed Capacity and Production in 1997.

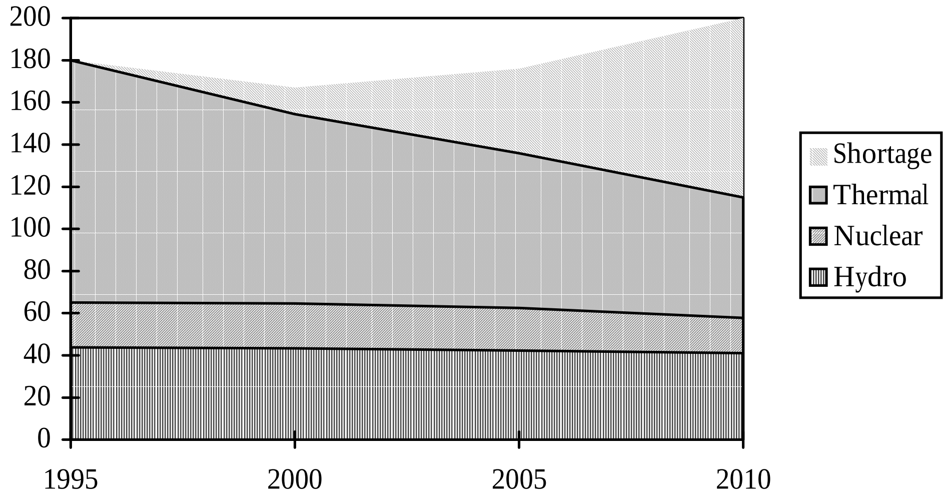
Type of Power Plant	Installed Capacity		Electricity	Production
	GWe	%	TWh	%
1. Thermal	150,2	69,8	557,7	66,9
2. Hydropower	43,8	20,3	168	20,1
3. Nuclear	21,2	9,9	108,3	13
Total	215,2	100	834	100

Source: MinTopEnergo (1998).

According to the statistics, in the course of the last seven years the total installed electricity generation capacity in Russia has increased by 3 GWe. However, the total real capacity has been constantly decreasing because of the fast decay of the previously installed equipment. In case this trends will not revert in the nearest future, the delayed electricity supply crisis will occur. It is currently delayed by the permanent decrease in demand, but any stabilisation on the demand side will inevitably lead to shortages. The development of this trend is easy to follow in the Graph 2.1.2, shown below .

The lifetime of the main power plant equipment in Russia is designed to be 100 000 hours of operation or approximately 30 years. The safety and reliability of the electric energy supply requires maintenance of the equipment as well as provision of the reserve capacities. On the other hand, we know that the major part of the installed power plant equipment has already reached the end of its lifetime span and, thus, needs to be replaced or fully modernised. Annual deterioration of the generating equipment is estimated to be from 5 to 6 GWe. If we take into consideration, that implementation of a new power plant construction project takes up to 8 years, we find that Russian energy sector is already in a very critical situation. It is clear, that the energy supply crisis will inevitably follow, if urgent measures will not be taken as soon as possible. The probability, that the Russian government or utilities will undertake any urgent measures in the nearest future is very low. As a consequence, the most probable outcome will be an energy consumption driven self-adjustment of the sector. Some ideas on the possible outcomes may be found in the present paper.

Graph 2.1.2 Change in the Installed Electricity Generation Capacity, Gwe.



Source: RAO UES (1998).

According to the data of the Unified Energy Systems of Russia, 80 GWe of the generating capacity will reach the end of its lifetime by the year 2005. This implicates the replacement of one third of the total generating capacity. By 2010, 50% of the thermal hydropower plants and up to 100% of the nuclear power plants will have to be replaced.

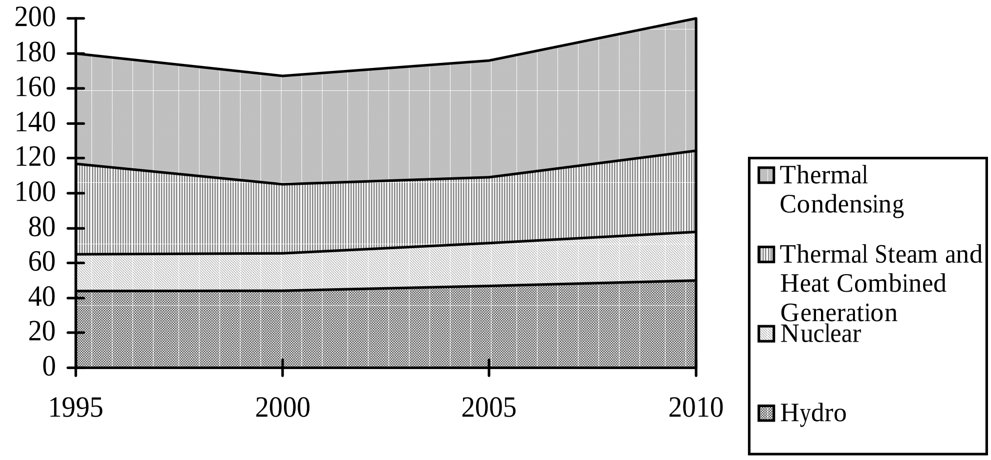
Insufficiency of the installed generation capacity can be explained by two factors: deterioration of the installed equipment and stabilisation of the demand. To eliminate or, at least to postpone, the shortage of the electric energy, an intensive energy saving programme has to be implemented alongside with investments for the rehabilitation of the installed capacities as well as for the completion of the on-going and new construction projects.

This represents a major challenge for the energy technology development companies and equipment manufacturers. The technologies and equipment that will be most suitable and cost effective to satisfy these needs will dramatically alter the future fuel mix in Russia. It is still too early to estimate the outcome of this process, although some ideas concerning this will be presented in the Chapters 3 and 4 of the present paper.

Changes Due to Rationalising of the Power Generation Structure

It is widely accepted, that the present geographic location and technologies applied in the Russian power plants do not meet modern requirements for productivity, cost efficiency and reduction of environmental pollution. One of the most reasonable analysis of this issue is given in the recommendations for a rational structure of the electric energy generation, which is presented on the Graph 2.1.3. This recommendations were prepared in 1994-1995 by the joint Russian-American commission, headed by the Russian Prime Minister Mr Victor Chernomyrdin and the American Vice President Mr Albert Gore.

Graph 2.1.3 Rational Structure of the Electric Energy Generation.



Source: The Report by the Chernomyrdin-Gore Commission (1995).

The following conclusions concerning development of the electric power generation and the rational location of the generating facilities in Russia were made by the Commission:

- Combined heat and electricity is more effective than separate heat generation in the boiler houses.
- Rehabilitation of the thermal power plants is more effective than new construction for the forecasted period of time.
- Construction of the new gas-fired combined cycle power plants is more effective than rehabilitation of the condensing thermal power plants.
- Gas-fired combined cycle power plants are more effective than nuclear and condensing thermal power plants.
- Nuclear power plants with reactors of the third generation are more effective in the European part of Russia and the Far East than condensing thermal power plants, in the Urals they are equally efficient and in Siberia condensing thermal power plants are more efficient.

2.2 Public Policy and Regulation

Regulation of the Sector

Besides the legislation, covering all the major issues of the energy sector functioning, the sector is controlled and regulated by a hierarchy of state organs. The levels of the state control are shown below.

- *The Ministry for Fuel and Energy of the Russian Federation*. The ministry oversees all aspects of the national oil, gas and energy sector, supervises exports and transportation. It is also responsible for tariff policy, but in case of electricity wholesale market this function is delegated to the Federal Energy Commission. It also manages the state investment programs, decides on the development priorities and supports fundamental research.
- *The Ministry for Nuclear Energy of the Russian Federation.* The ministry oversees all activities concerning the nuclear power sector development in Russia. This includes development of technologies, decision making, funding and management of the new construction projects. Elaboration and implementation of the governmental programs related to the development of the nuclear power sector in Russia.
- *Federal Energy Commission.* FEC supervises functioning of the Federal Wholesale Electric Power Market (FOREM) as well as energy tariffs on the federal level. Regulation of energy tariffs in the regional energy systems is delegated to the regional commissions.
- *Regional Energy Commissions (RECs).* RECs supervise the tariffs for electric power in administrative regions of the Russian Federation.
- *Regional/Municipal Authorities*. Regional governments and municipalities are responsible for overseeing certain issues of tariff policies on the municipal level in accordance with the decisions by a respective Regional Energy Commission.

Public Policy

Ministry for Fuel and Energy of the Russian Federation plays the main strategic role in the management of the energy sector in Russia. Its main focus is:

1. Creation of the most favourable conditions for the development of international competitiveness for the Russian-made equipment and technologies. This includes strategic management through law making, funding of the target technology development programmes and tariff regulations for energy and natural resources; development of the technical level of equipment, compliance of the Russian technologies and processes with the international standards, environmental impact, overall safety of technologies and equipment etc.
2. Strategic development of technologies, which can provide long term sustainability of the Russian energy sector. That includes funding of the fundamental research, funding and support for the strategically important research companies, focusing governmental support on priority technologies, etc.
3. Prognosis and analysis of the development in the energy sector, including elaboration of development programmes, analysis of different development scenarios and preparation of legislative initiatives.

Analysis of the present situation in the energy sector, performed by the Ministry for Fuel and Energy, has indicated the following goals for technology and research development in Russia:

- to increase efficiency of electricity and heat production from organic fuels, especially, from the natural gas,
- to improve safety of the energy production, transportation and supply,
- to decrease environmental pollution, caused by the energy projects,
- to improve nuclear safety,
- to develop clean coal energy technologies and equipment,
- to introduce environmental impact supervision on the federal and regional levels,

- to elaborate new prognosis techniques of future production and technology development trends,
- to develop new materials,
- to study hydrodynamics and gas dynamics, heat and mass vaporisation in the combustion processes of the energy equipment,
- to develop thermonuclear fusion power generating equipment for the industrial purposes.

The national development programmes by the Ministry for Fuel and Energy and the Ministry for Nuclear Energy are the main framework for governmental financing of the research and technology development in Russia. These programmes are classified into four groups in accordance with their orientation and importance:

Federal Programmes

These are the research and technology development programmes of strategic importance, initiated by the Ministry for Fuel and Energy and funded exclusively from the state budget.

Inter-sector Programmes

These programmes are developed in co-operation with the leading companies in the respective industries. Funding of these programmes in agreed by the participants, usually incorporating inputs from non-budgetary funds of the Ministry for Fuel and Energy and the other ministries as well as inputs from the companies interested in the outcome of the research.

Sector Programmes

These programmes are initiated by authorities responsible for the regulation of a certain industry as well as by the interested companies and their clients, including international investors.

Regional Programmes

These programme are developed by regional authorities, companies, local governmental bodies and are aimed at problems of a particular region. These programmes support the priority goals, set by the Ministry for the Fuel and Energy. Regional programmes are rarely funded from the state or local budgets. Usually financing of those programmes is agreed by the interested companies and clients.

Annually, about 10% of the research budget of the Ministry for Fuel and Energy is earmarked to support new technology development as part of the fundamental research.

Nowadays, there are several national research programmes, supported by the Russian government, such as "Fuel and Energy", "Nuclear Power in Russia", "Natural Resources of the Russian Federation", "Environmentally Friendly Energy" etc. These programmes as well as regulation of custom tariffs for imported equipment and technologies are seen as the main means of governmental participation in steering energy technology development and equipment manufacturing. Unfortunately, lack of consent between the government and the parliament on many issues concerning the future of the Russian energy sector, usually leads to poor financing and implementation of the national development programmes. Thus, the national development programmes in their present form do not yield the expected results and are a rather inefficient tool of state support for research and development.

2.3 Major Customers And Their Sources of Financing

Major Local Customers

After the end of the Soviet era and consequent privatisation and economic changes, the energy sector has retained much of it integrity. The main customers for the energy technology development and equipment manufacturing companies are:

- The Unified Energy System of Russia (the RAO UES) is a nation-wide operator, which possesses the inter-regional electric transmission grids and manages operation and development of the national energy system. The RAO UES owns majority of the large electricity generating power plants (typically with generating capacity exceeding 1000 MWe),
- 72 regional energy utilities, the "energos", which generate and provide heat and electricity to customers in all regions of the Russian Federation. The RAO UES has control or significant share of equity in many regional energos. These utilities own and run the majority of the small size electric power and heat generating power plants,
- 3 regional energy utilities are independent from the RAO UES, namely the Tatenergo, the Irkutskenergo (no shares owned by the RAO UES) and the Bashkirenergo (the RAO UES owns 17% of votes). These utilities own and run electric energy and heat generating power plants with capacity under 1000 MWe.
- 34 large electric power stations, operating as independent units in the electric power market.
- A number of smaller power stations owned by industrial enterprises and serving mainly their production needs.
- A number of regional heat generating facilities that are owned by municipal authorities or belong to the large industrial companies located in the region.

The Unified Energy System of Russia (the RAO UES) has an effective monopoly over the domestic electricity generation and transmission. Thus, it is a major single customer for the technology development and equipment manufacturing companies in Russia. Regional energy utilities, most of which are majority owned by the RAO UES, represent the other major group of customers. Nowadays, they gain more and more power and influence in certain areas such as investments in new medium size power plants, renovation and rehabilitation of their own generating and transmission facilities.

The group of municipal, regional authorities and large industrial companies represent another developing group of customers that own and will be interested in constructing smaller size electricity and heat generating power plants.

Even though the Russian legislation allows independent private electricity production, very few activity has been seen in this area so far. Investment constraints and government tariff regulations are probably the most serious obstacles for development of competition in the power generation.

As independent energy producers are only entering the market, their influence on the demand for power technology development and equipment manufacturing at present in minor. For this reason, we will concentrate our further analysis on the ability of the main customer group - the energy utilities led by the RAO UES of Russia to invest in replacement, rehabilitation and new power plant construction.

Tariff and revenue structure of utilities

One of the factors that still determines greatly the ability of the energy utilities to spend money for the new purchases is the present energy tariff structure that is decided upon by the Federal and Regional Energy Commissions. Transition to the open wholesale electricity markets already underway in Russia will certainly alter the tariff structure. The changes will be dictated by the wholesale competition on the market.

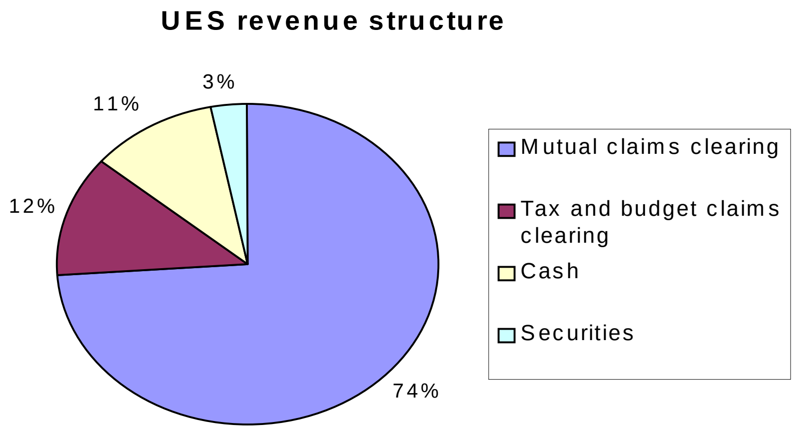
To analyse the impact of the present tariff structure on the development of the energy sector and the demand for technologies and equipment, one should start with the RAO UES of Russia, as it is by far the major single customer for the technology development and equipment manufacturing. Despite the specifics of the RAO UES's product (managerial services and operation of the united energy system), the structure of its tariffs and revenues outlines the overall situation in the electricity generation and transmission sector.

Table 2.3.1 The RAO UES's service tariff structure.

Category	Share in total tariff
Investment component	52.4%
Networks maintenance	8.6%
The CDU, other service and administrative costs	7.8%
Depreciation	8.3%
Research and development	1.5%
Taxes	15.8%
Other expenses	5.6%

Source: RAO UES (1997).

A large share of investment component in tariffs reveals one of the core problems of the industry. Instead of using market-driven investment mechanism, providing fair rate of return on capital and attracting investment funds from the financial market, the RAO UES incorporates investment programmes into its tariff structure



or technology and

Source: RAO UES (1998).

As shown above, cash settlements make only a minor share in the RAO UES's revenues, which is typical of the energy sector as a whole. A low cash share is accompanied by large arrears and mutual debts, making the energy sector an industry with relatively poor finances. This certainly poses limitations on the choice of supplies, as payments for equipment purchases and renovation are possible mostly in the barter form. This fact certainly represents the major short term competitive advantage for the Russian electrical equipment and technology producers versus their competitors from the other countries. It allows to win supply contracts for Russian equipment for the energy utilities not on the basis of the terms and price competition but because of the ability to accept barter payments in metals, electricity and other possible components and supplies. However, as barter trade does not include cash in the transaction, long term competitiveness of companies, engaging in such deals, will deteriorate because of the limited ability to renew equipment through barter transactions and relatively heavy cost structure compared to the cash dominated competitors.

It is evident, that excessive political regulation of the electricity prices does not facilitate the development of the energy sector and related industries in Russia. At the same time, a weak position of the anti-monopoly authorities makes freeing of the electricity tariffs a very dangerous issue as many regional electricity utilities (the "energos") will try to use their almost monopoly positions to charge extraordinarily high prices. In other words, introduction of a free electricity market has to be supported by the institutional development and will probably be a gradual process, that will require a complete renovation of the energy sector governance and legislation. Thus, the local demand for energy technology and equipment in Russia will for a long period of time be influenced by the distortions brought about by the governmental intervention in the energy prices and further high energy price fluctuations that will follow the final transition to the open electricity market.

3. TECHNOLOGY DEVELOPMENT IN THE ENERGY SECTOR

3.1 Overview

Economic transformation in Russia has initiated a tremendous structural change in research and development in the energy sector. Majority of the scientific research and engineering companies in Russia were privatised in 1992-1996. RAO Unified Energy Systems of Russia and RAO Gazprom have, however, succeeded to keep their blocking amount of shares in the most important R&D companies.

In 1992, before the beginning of privatisation, there were 238 scientific research and technology development companies in the energy sector[7], usually called the "institutes". The institutes employed more than 104 000 engineers. Typically, these institutes were R&D centres, that included design bureaux, laboratories and experimental facilities. Some of them (the larger ones) had pilot production facilities, used to produce samples of the new products. Others were located in the premises of large equipment manufacturers and produced and tested samples, using the manufacturers' machinery. The latter solution was more flexible, providing an instant feedback for designers from the production staff. This facilitated substantially the process of introduction of the new designs into manufacturing.

As the privatisation started, the sector experienced a large outflow of skilled and the most active part of the personnel. Substantial reduction of the state budget funding for R&D and low open market demand for their services resulted in salary arrays and deterioration of employment conditions. An important factor in the loss of the younger and more active part of the personnel was the appearance of the new attractive opportunities in the private sector. Since then, the amount of R&D personnel has decreased by more than 50%. Another medium term problem is rapid ageing of the remaining staff, as only a small number of young graduates wishes to join R&D companies. In 1997, an average age of the personnel in the sector was 48.2 years. This makes it difficult to pass knowledge and experience over to the new generations of engineers. Thus, one of the most important and precious values of the sector, the inherited capital, is being unfortunately lost.

Increasing international competition and information technology breakthroughs in the energy technology have created another challenge for research and development in the Russian energy sector. Pressure for faster replacement of the installed equipment, metering and experimental facilities, for investments in the latest computer technologies and hardware is growing. These investments are urgently needed to fill in the gap in development and application of the new technologies between the most technologically advanced countries and Russia. Unfortunately, at a time, when companies and governments in the European countries, the US and Japan invest substantial financial resources in new energy technology research, dire financial constraints in Russia do not allow to replace the worn-out equipment and facilities. This already has become an obstacle for the future development of the new technologies and research in Russia. It may also alter the future structure of the energy equipment manufacturing, as the energy utilities will increase their purchases of the up-to-date equipment[8] from abroad.

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7 The figures are given for the whole energy sector. In the Soviet Union, majority of the institutes specialised in numerous research fields at the same time, which makes it impossible to identify the share of the electricity generation R&D in the total number.

8 An illustration of this process is the North Western Power Plant in St.Petersburg, which is now constructed

Weakened ability of the energy utilities to finance research for their needs as well as insufficient governmental support for fundamental and strategically important research in the energy sector has caused a drop of R&D sales. According to the State Statistics Bureau (GosKomStat) of Russia, in 1997, sales in the energy research and development amounted to only 43% of the pre-reform level.

The main sources of income in the energy technology development are the following:

- state budget financing,
- non-budget funds (1,5% of the net costs of the companies),
- client financing (Gazprom, the Unified Energy Systems of Russia, local utilities etc.),
- own financing of the research institutions.

After the collapse of Soviet Union, the traditional patterns of labour division in the technology development had to change. Many technology development companies found themselves outside the borders of the Russian Federation. Further introduction of custom controls and VAT in the former Soviet republics made R&D co-operation in many cases impossible. To make it worse, parts of documentation and designs for many particular projects were divided between different institutions in accordance with their specialisation. Left abroad, this documentation was very difficult and expensive to obtain. The whole structure of the R&D sector has changed dramatically.

Nearly all major technology development companies in Russia suffered from the above said problems. In the former Soviet Union such important R&D institutes as "Teploproekt" (heat engineering), "Gidroproekt" (hydropower engineering), "Energosetproekt" (heating networks engineering) and "Atomenergoproekt" (nuclear power engineering) had their branches all over the country and, thus, have lost in their research capacity substantially after the collapse of the Soviet Union. At present, these institutes are majority owned by RAO UES of Russia. The only exemption is "Atomenergoproekt", that operates under the Ministry for Nuclear Energy.

Before 1990, there were also many smaller sub-sector oriented institutes, specialising in specific problems, like design of the small capacity boilers etc. Since the disintegration of the Soviet Union, some of these research facilities have ceased operation due to financial reasons. Many earn their living by leasing their office premises and running some other business ventures.

Below we present a description of the leading and the most important R&D companies, which is characteristic of the present state of the technology development sector in today's Russia.

Thermal Power Plant Design

The thermal power plant design in Russia is led by the "Teploelektroproekt Institute". Its Moscow and St.Petersburg branches design mainly thermal condensing and combined heat-electric power plants. The Rostov branch specialise in gas turbine power generation and the Ivanovo branch - in new technologies.

Other important thermal power plant design facilities are based in St.Petersburg - "Energoprom" and "Promenergoproekt" specialise in combined heat-electric power plants and boiler

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to use modern gas turbine combined-cycle technology.

houses for industrial and municipal use, and "Teploproekt" institute specialises in district heating network design.

Fundamental research in thermal power is carried out by "Kontloturbinny Institute (Boiler and Turbine Institute) and Teplotehnichesky Institut (Heat Engineering Institute) in St. Petersburg.

Hydropower Plant Design

Before 1990, all the hydropower plant related engineering was concentrated in "Gidroproekt" institute with its multiple branches all over the Soviet Union. Out of 11 branches in Moscow, St. Petersburg, Alma-Aty, Baku, Yerevan, Tbilisi, Kharkov etc., only few were left in Russia after the collapse of the Soviet Union.

Design of the hydropower plant constructions is carried out by the Hydraulic Engineering Institute in St. Petersburg and its multiple branches.

Nuclear Power Plant Design

Nuclear power plant design is carried out by the "Atomenergoproekt Institute" in Moscow and St. Petersburg. Fundamental research is carried out by institutes, supervised by the Russian Academy of Science, such as the Institute for Physics and Technology in St.Petersburg.

Transmission Grid Design

Transmission grid and transformer units are designed by the "Energosetproekt", Moscow, and its multiple branches all over the country. The two leading institutes in Moscow and St. Petersburg prepare standard designs, that are afterwards applied for regional needs by the local design facilities. The fundamental research in the field is carried out by the Energy Institute, in Moscow and Novosibirsk, and by the Direct Current Institute in St. Petersburg and their branches. Another large scientific research centre is located in Beskudnikovo. Experimental facilities, laboratories and tester stands of those institutes allow to carry out extensive research in the field.

3.2 Energy Technologies and Research in Russia. Overview, Development Trends

As it was already mentioned in Paragraph 3.1, RAO Unified Energy Systems of Russia is a leading technology development holding company in the power generation sector. At the same time it is the main customer for technology development companies. This situation has guaranteed RAO UES of Russia affordable prices for the technology development services. In the long run, however, this can endanger the competitiveness of the R&D companies, as they do not compete freely in the market and have a costs based price structure, that may not reflect their real development needs for the longer term.

Nevertheless, as RAO UES of Russia is the main customer in the Russian energy technology development market, it is important to start our analysis of this market's future development by addressing the top development priorities, set by RAO UES for itself. According to RAO UES's development department, the company puts a special emphasis on developing the following issues:

1. Technological refurbishment and reconstruction of power stations using combined cycle units for gas-fired power plants and introducing clean coal technologies for coal-fired power plants. By 2010 it is planned to put into operation about 30 GWe of combined cycle gas turbine units[9] and over 10 GWe of effective environmentally friendly power units for coal-fired power plants, including power units with supercritical parameters, fluidised bed combustion, coal gasification, etc.

2. Gas-coal fuel strategy. The gas-coal fuel strategy is a promising trend of forming a reliable fuel balance for thermal power plants. In accordance with this strategy, the share of gas will grow from 62 to 66 %, the share of oil fuel will fall from 9 to 5 % and the share of coal will remain at the level of 27-28 % in the fuel balance.[10]

3. Maximum introduction of hydropower into the fuel mix. Timely technological refurbishment of the hydropower plants that have exhausted their resource (about 25 GWe by 2010) will allow to preserve the present power generation volume of the hydropower plants. Putting into operation 14 hydropower plants in Siberia, the Far East, North Caucasus and Karelia is one of the most effective ways of getting extra capacities to produce cheap electricity of 9 GWe and 35 TWh.

4. Maximum introduction of nuclear power into the fuel mix. The main strategy of the nuclear power development programme is to provide safety of operation of the nuclear power plants, to prolong operation of the decommissioned power units, to start-up power units in the nuclear power plants under construction and to substitute the decommissioned nuclear capacities.

Besides RAO UES of Russia, another influential party in the Russian technology development market is the Ministry for Fuel and Energy, that sets priorities and finances technology development programmes on a vast scale. Governmental priorities in this field were already addressed in the previous Chapters. Here we will combine the two approaches (by RAO UES of Russia and the Russian government) to analyse the development trends of the major technologies.

Two fuel based power generation technologies, that stand out as important in achieving environmental benefits at competitive costs, have been identified by the Russian government and RAO UES as the top energy policy priorities[11] for the future. They are namely:

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[9] The most distinguished of the gas-fired combined cycle thermal power plant projects by RAO UES of Russia is the North Western Thermal Power Plant in St.Petersburg. The modern combined cycle gas-fired power generation technologies, based on a combination of western (Siemens) and local (LMZ) equipment are used in this project. The plant includes 2 power units of 450 MW (it is planned to install two more units of the same capacity later). The first power unit was to be put in operation in 1997-1998. Unfortunately, the project has been delayed and none of the units is operating by now. This project may serve as an example of how adjust the plans of RAO UES of Russia and the National Technology Development Programmes to reality. In other words, all plans in Russia tend to be implemented for much longer periods of time than originally expected.

[10] It is still unclear by what means RAO UES of Russia plans to achieve these targets.

[11] It is planned to increase the share of hydropower and to keep the share of nuclear power in the power balance of the country by finalising the on-going construction of the hydropower plants and rehabilitation of the existing nuclear power plants. For the time being, construction of the new nuclear power plants seems to be very unrealistic to the reasons addressed further in this Chapter.

advanced gas turbine/steam turbine combined cycles;

- clean coal systems.

These technologies make it possible to provide electricity with low levels of local air pollutants and are based on the cheap local resources.

Gas-fired technologies

These technologies have advantages in terms of lower emissions, flexible power plant operation with smaller staff and lower running costs. The electricity provided is cheaper. But there are also disadvantages.

An important aspect of the increasing reliance of the power sector on gas is that the technology used is effectively monovalent. In other words, the power generating companies, due to technical reasons specific to this technology, will tend to use more gas to provide peak and reserve capacities than to diversify their generating capacity by the introduction of the coal-fired or other solutions. The increasing use of gas, in other words, reduces the flexibility of fuel use and possibly exposes the generator to greater risks of supply disruption and price variation. Without the opportunity to store fuel at the power plant, gas supply disruption is much more likely to have a direct impact on electricity supplies, thus affecting an important factor of economic production. A gas price shock could have the effect of a double economic blow. As well as hitting gas consumers directly, it would also increase electricity prices.[12]

There are the following priority projects in gas-fired power generation presently under development in Russia:

- development of a range of gas-fired power generating units starting from 3 up to 250 MWe as well as standardised power plant designs on the basis of those units,
- development of a whole range of gas-fired power generating units on the basis of aircraft jet turbine engines,
- increase of combined gas-fired power generation effectiveness by increasing the upper temperatures of the combustion cycle up to 1500-1600°C.

In Russia nowadays a wide range of competing gas-fired power generation technologies are elaborated. They include application of marine turbines and diesel engines, aircraft jet engines, industrial compressor driving gas turbine units for the power generation purposes. Unstable market conditions, lack of demand, prevailing barter transactions will certainly influence the survival of these solutions. All of them are only half way ready. Only few manufacturers have succeeded to find customers and put their products into operation. One of the successful examples of such conversion is a Nevsky Zavod made gas turbine power generation unit of 12 MW, operating in Rio Chica, Argentina.

Another successful gas-fired power generation unit was brought to the market by Rybinsk Motors, a Russian airplane jet engine manufacturer. Gas turbine unit GTD-110 has the capacity of 110 MWe and can be used as a driving engine for the gas/steam combined cycle equipment. This equipment will be used in new power plants, although it is also possible to use it as a re-

12 Although it is projected, that gas supplies will remain reasonably stable in the short term, there are some doubts concerning the longer term development of the gas-fired power generation because of the increasing difficulties in developing new gas fields in Russia.

placement unit in the old power plants, allowing 10 to 20% gas fuel savings in the power generation process. RAO Unified Energy Systems of Russia and some other regional utilities consider this unit to be a valuable alternative for the replacement of the worn-out equipment. This will, however, require extensive construction and assembling works at the site.

Clean Coal Systems

Coal-fired power generation is assumed to continue, due to the very low cost of electricity, produced by these plants - lower, than in the gas-fired combined cycle plants. However, it is not likely, that many new conventional coal-fired plants will be built in the future. It is also planned to combust lignite, dirty coals, waste tip coals, other wastes and even some biomass in the new clean coal systems, such as atmospheric and pressurised fluidised bed power and/or steam generation plant.

There is a range of new design solutions, which are developed in the framework of the National Scientific Research Programme "Environmentally Friendly Energy". The programme is meant to promote development and introduction of new solid fuel combustion technologies into industrial production. This programme is financed from the state budget and is currently pursued at a slow pace, due to the scarcity of the available funding. Some design solutions supported by the programme are:

- 800 MWe brown coal-fired power generation unit with gradual combustion of preheated coal dust and fabric filters for ash and sulphur dioxide collection,
- 300 MWe coal-integrated gasification/combined cycle power generating unit
- 300 MWe coal-fired power generating unit using anthracite and bituminous low quality coals as a fuel combusted in a furnace with circulating fluidised bed. The electric wave filter with alternate voltage for ash and sulphur dioxide collection will be used in this unit.

It is planned to develop 300 and 500 MWe clean brown coal-fired power generating units, which will have a full range of pollution reduction equipment in full compliance with the international standards. Introduction of the new rehabilitation and equipment design solutions in thermal condensing power plants will also increase the efficiency of those plants up to 45%.

Despite the urgent need to reduce environmental pollution and increase efficiency of the power generation, marginal electricity production cost in the coal-fired power plants will keep those in operation for several years to come. Further improvement of the economic situation in Russia will bring along wider introduction of gas-fired combined cycle plants.

Coal-integrated gasification/combined cycle power generating technology will have little chances in the market in the decades immediately ahead, in case investment decisions by the utilities will be made strictly out of price considerations. This, in its turn, will heavily effect technology development and manufacturing companies, as it is hard to expect that the state will bear the full costs and invest in their survival. It is likely, that in this particular technology the sub-sector will loose substantial share of its market to successful joint ventures, new entries or international competitors.

Nuclear Power

Bringing about major expansion of nuclear power over the next century would require winning public confidence that nuclear power is safe and that radioactive wastes can be successfully managed. New nuclear fusion technology is probably needed both to restore public and

financiers' confidence in the nuclear power. Nevertheless, in Russia belief in nuclear power among the key industry and political decision makers is very strong. There is a powerful industrial lobby supporting decisions in favour of the nuclear energy development by the government and the parliament of Russia.
New controversial nuclear construction projects in Iran and China are used to arouse political interest to support Russian-made technologies and supplies. Those projects are, however, likely to face opposition from and be hindered by the international community, worried about the long term political consequences of providing these countries with the additional possibilities to produce materials for nuclear weapons.

Political lobbying for nuclear energy in Russia does not, however, facilitate new research in the field, as the main emphasis is to support existing production and existing design solutions, many of which are already seriously out-dated.

One of the outcomes of such policy is the new "National Programme for the Nuclear Power Generation Development for 1998-2005 and for the Period till 2010", recently adopted by the government of the Russian Federation. According to the Programme, the total installed capacity of the nuclear power plants in Russia will increase up to 27,6-29,2 GWe and annual electricity production will grow up to 170 TWh. At the first stage, it is planned to finalise the construction of the second reactor of the Kalinin Power Plant and the fifth reactor of the Kursk Power Plant as well as to construct the first reactor of a new power plant in Rostov. After these reactors will be put into operation, it is planned to start the construction of a new type of reactors (VVER-640, VVER-1000, BN-800). The construction of the following new nuclear power plants is scheduled to start after 2003:

- Novo-Voronezh-2 (two reactors á 1000 MWe),
- Leningrad-2 (one 640 MWe reactor),
- Kola-2 (three reactors á 640 MWe),
- Beloyarsk (one 800 MWe reactor),
- Yuzhno-Uralsk (three reactors á 640 MWe),
- Voronezh with combined electricity and heat production (electricity capacity of 140 MWe and heat generation capacity of 2500 MWe).

It has been decided, that until 2005 all the operating reactors built in 1971-1975 will continue electricity generation with the assumption, that the on-going investments in their safety improvement and maintenance will be duly executed.

An analysis of the financing side of the aforementioned National Programme leaves no doubt that it is a product of a powerful industrial lobby and it will follow the path of the previous nuclear sector programme of 1992 to the full collapse. It is planned, that 50% of the funding will be provided from the state budget and 50% by the Russian Agency for Nuclear Energy "Rosenergoatom". However, given huge domestic and international debts of the Russian state, it is highly unlikely, that either of these sources will become practically available in the nearest future.

It is also planned to develop new safer nuclear reactors in the framework of the National Programme "Environmentally Friendly Energy" in the beginning of the next millenium. However, the political clout around the "Environmentally Friendly Energy Programme" is to a large extent fading out and, as a consequence, the probability that new nuclear technologies will be developed in Russia in the foreseeable future is very small.

Electric Energy Transmission

As one can see from the guidelines of RAO UES of Russia, construction of the new transmission lines and development of the related technologies is one of the priorities, that will facilitate introduction of the wholesale electricity market. In Russia, development of the electricity transmission technologies is going in the following directions:

- development of the extra- and ultra-high voltage transmission lines and new equipment for them,
- elaboration of modelling systems and tools for large, complex electricity networks (grids) planning,
- further development of the electric generator limiting states theory and its applications,
- development of electric motors that will allow motor speed regulation based on sophisticated movement theories,
- creation of new electric converters, semiconductor devices for the commutation of the mega-ampere currents.

Another very important task is to increase safety, reliability and manageability of the supplies in the Unified Energy Systems of Russia.

The role of fundamental science and research in achieving these goals is crucial. It is assumed that research activities will be supported by the national programmes and RAO Unified Energy Systems. The cash constraints have effected research in these fields by limiting the scale and the scope of the projects.

District Heating Systems

Another important target for urgent improvements, that rely on technology development, are municipal heat distribution networks. Most of them are in a very poor condition. Almost 20% of heat is lost during transportation, which causes 25 Mtoe losses annually. These tremendous losses in the supply networks do not only put a heavy financial burden on municipal authorities, but also set limitations on urban development and further housing construction.

The existing equipment of boiler houses, fired by solid fuels, has to be replaced by fluidised bed and circulating fluidised bed furnaces as well as by water-coal suspension furnaces.

A full range of the emission gas cleaning equipment shall be designed and put into operation. Decentralisation of the heat supplies shall be supported by the development of small heat generating units, involving many companies and design facilities. Among the leaders in this field one can name "CKTI", St.Petersburg, which has presented many interesting innovations and designs.

Unreliable supplies and pricing problems in the municipal and energy utilities have created a vast potential market for small capacity boiler houses, either automatic or with minor manual controls. The demand is driven by private and industrial consumption, which has emerged after the beginning of privatisation of the industrial enterprises and housing in 1992. Thus, the best local and international technologies are expected to win this market in the medium term. In the short term, the penetration of these technologies will be limited by the financing abilities of the potential consumers.

Fundamental Research

Fundamental research in electricity generation is aimed at increasing the effectiveness of gas-fired power generation units. Introduction of a high-tech unified steam-gas turbine, using steam-gas mixture as a working fluid for a unified generating unit, is seen as one of the top priorities in the fundamental research and technology development.

Another priority is the development of magnetohydrodynamic and magnetofluid-dynamic generators. However, international co-operation and co-ordination is needed to generate achievements in this field.

A very serious attention is paid to the development of high temperature fuel cells technologies. These technologies are believed to provide efficient and environmentally friendly energy production in the future.

Some other high priority research fields, based on extensive experience and research facilities in Russia are:

- low-temperature plasma research.
- superconductivity,
- development of the new effective gas cleaning systems.

Poor condition of the fundamental research facilities in Russia as well as fast ageing of their staff creates a long term survival problem for many of them. As the significant technological breakthroughs require continuity, extensive education and effort, the probability of the new achievements in Russia reduces considerably as the time goes on.

Renewable and Other Energy Technologies

Intermittent renewable electric technologies (wind, photovoltaic, and solar thermal-electric power) can make major contributions. The cost for wind electric power has dropped substantially and is, for the first time, comparable to the cost of electricity from coal. Similarly, there has been substantial progress in solar thermal-electric technology, which, with further development, has good prospects of being fully competitive with coal power in areas of good insulation by 2020. Until recently, photovoltaic technology has not been as close to commercialisation for large scale electricity generation as wind and solar thermal-electric technologies. But, as in the case of biomass technology, successful development of these technologies could be a long term R&D target.

Advanced biomass energy technologies can provide modern energy services with very low local pollutant emissions, can help stimulate rural development, and can offer substantial greenhouse benefits. A problem in Russia will be also the generation of the biomass itself as the agricultural sector is very inefficient and underdeveloped.

In Russia, development framework for these energy technologies includes:

1. Transfer of small power and heat generation plants from liquid oil and hard oil fuels to gas fuels such as natural gas, gas from gasification processes of biomass and other as well as to fossil fuels.
2. Development of samples for full-scale equipment production for renewable and

other energy technologies for industrial and municipal use, such as:

- wind energy based small, medium and large capacity power generation units,
- hydropower generation units for small hydropower plants, that will be used for the reconstruction of destroyed and conserved small hydropower plants with high- (more than 30 metres), medium- (10-30 metres) and small-head (2-10 metres) power generation units,
- hydropower generation units for 2 to 30 metres head without dam, floating and submersible units exploiting flows over 1,5 m/sec,
- air- and water-heating units for boiler houses using solar energy collectors,
- solar and photoelectric power generation units for industrial and municipal purposes,
- biomass gasification and power generation units using farm, agriculture waste as well as municipal sewage waters,
- gasification units using timber, wood-processing industry waste and fossil fuels as well as cellulose and paper industry wastes,
- geothermal energy based power generation units for district and industrial heat and electricity generation purposes, small (from 1 to 30 kW), medium (from 30 to 500 kW) and large (from 500 kW to 10 MW) capacity thermo-compressors exploiting environmental energy (soil, water and air) as well as air-conditioning heat, heat of gas and fluids in technological cycles of various industrial processes.

2. Development of modern automatic and control systems, providing automatic operation of power generation.

3. Development of power generation units for fuel cells (especially phosphoric oxide based) with capacity from 5 kW to 10 MW.

4. Development of energy accumulation systems for self-contained power generation units as well as for energy system switched power generation units.

5. Creation of power generation units using a range of renewable energy sources as well as units, that combine traditional and renewable sources, such as wind-diesel power generation units.

6. Further advances in the elaboration of safety systems for self-contained power generation units and supply systems.

Wind Energy

Wind power generating units may be classified into four groups in accordance with their capacity range:

- under 1 kW,
- from 1 to 30 kW,
- from 30 to 100 kW,
- over 100 kW.

The first range up to 1 kW is used for household, navigation systems, buoy, radio station electricity supplies. In Russia, such units are produced in small series of approximately 500 units a year by four producers. Their technical level is rather high and price is substantially lower than that of the imported analogues. The total market for this range in Russia is estimated to be 5000 units a year.

Units with capacity from 1 kW to 30kW cover the electricity needs of single houses, geological expeditions, etc. Units with capacity from 20 to 30 kW can provide full electric energy supply for small remote settlements. From this range only units of 4 kW are produced in series of 150-500 units by NPO "Vetroen", and small numbers of 1,1 to 10 kW units are produced by a Russian-Dutch joint venture "LMV. Vetroenergetika". A range of experimental pilot plants with capacities of 2;3;4;6;8;16 and 30 kW is also produced. The combination of 8;16 and 30 kW units and small diesel engines is practically the only way to provide electric energy for small settlements in the Far North of Russia. The potential market for such units is estimated to be from 40 to 60 thousand units a year.

Wind power generation units with capacities from 30 to 100 kW can become the basic electric energy supply solution for self-contained supplies of small and medium sized settlements (from 10 to 100 inhabitants) in Russia. At present, an pilot plant with capacity of 60 kW is already under construction in PO "Almaz-zoloto" and a unit of 100 kW - in the Ufa Aviation Institute.

Units with capacity over100 kW are produced according to designs by different design bureaux. In 1994, in the Vorkuta Wind Power Generation Plant two units were put into operation with capacities of 250 kW each. These units were produced by NPO "Yuzhnoe", Ukraine, and NPO "Vetroen", Russia. The Kalmyk Wind Power Generation Plant uses a 1 MW unit, designed by "Raduga" design bureau.

The main producers of wind power generation units are NPO "Vetroen" and the Tula Combine Plant.

The main development trends, set by the Ministry for Fuel and Energy of Russia for wind generation units production and technology development are:

- full-scale production of wind power generation units with capacities from 1 kW to 10kW for self-contained electricity supply of private farms and houses,
- full-scale production of 16;30;60 and 100 kW units for self-contained supply of farms, settlements in rural areas, especially as a wind/diesel power generation combination,
- design and introduction of large energy system wind power generation units, applying Russian made and imported technologies and equipment.

Solar Energy

The following three solar energy based power generation technologies are best developed in Russia:

- photoelectric
- solar energy/steam turbine
- Sterling engine technologies.

One of the most successfully developed is power generation in photoelectric units, using solar silicon elements, which transform solar radiation into electric energy.

At present, a wide range of power generation units on a basis of solar elements for consumer electric appliances, street lightning, telecommunication, etc. purposes is designed in Russia. Unfortunately, none of those has been put into production. The main demand in Russia for solar energy systems is focused on photoelectric stations with capacities from 0,1 to 100 kW for operation in automatic mode in parallel with wind and other power generation units. The main obstacle for their industrial development is the poor availability of the raw materials, solar quality silicon in particular.

High quality solar collectors are produced by the Kovrovo Mechanical Works, PO "Machinostroitel" and "Mitra" in Moscow. The market consumption potential is estimated to be 250 thousand square metres a year. The main obstacle for development is the high production cost of the solar collectors in Russia.

A wide range of various solar energy using appliances is being developed at the moment, including water heating and hot water supply systems, air heating units, etc.

The Stavropol Solar Power Plant, constructed in the framework of the National Program "Environmentally Clean Energy", is designed to be the testing field for the majority of design solutions and technologies.

It is projected, that in the future, the Southern parts of Russia will be an area, where combined solar and steam turbine units will be used for heat and power generation, making use of small gas fields and high solar energy potential of this region.

The relative cost of development and production of the solar energy systems in Russia will be a major obstacle for the industrial use of technologies developed at the moment. Even though, it is most probably, that the market will be dominated by imported units. It is also likely, however, that some of the interesting technical solutions will be used for joint projects or will be purchased by the international market leaders.

Hydropower

In modern Russia, a few effort is put into elaboration and design of the new hydropower equipment and technologies for large hydropower stations. This happens partly due to the lack of investment resources for renovation and rehabilitation of the existing power plants. Thus, there is also no demand for new technologies. Technical characteristics of the Russian made hydropower turbines are among the best in the world. The main drawback is, as usual, the control and automation systems.

The fact, that hydropower equipment in the majority of the Russian power plants is outdated will, at some point, inevitably lead to an increase in demand for the new technologies. It is also envisaged, that the lack of investment resources will delay construction of the new plants and rehabilitation of the old ones and, thus, will put an additional pressure on the existing equipment and machinery.

One of the incentives for research and development has been the process of decentralisation in Russia. Autonomous regions need small to medium size plants for local energy production, which drives also R&D in this direction.

At the moment, there are over 50 micro hydropower plants (capacities from 1 to 10kW) and over 300 small hydropower plants (capacities from 100 kW to 10 MW) in operation in Russia. Annually they produce approximately 2 TWh of electric energy.

Technologies and equipment for those plants are provided by about 10 Russian companies. The most successful of them are MNTO "Inset", St. Petersburg, and "Soyuzhydropostavka", Moscow.
A new module approach to the construction of micro and small hydropower plants was elaborated by the "Gidroproekt" institute, St.Petersburg, and "Soyuzhydropostavka", Moscow, which have designed unified modular solutions for new hydropower plant construction.

Biomass

There are more than 10 large biomass-fired power generation plants in Russia, that process cattle and poultry farm waste. The first Russian biomass gasification plant "KOBOS-1", processing biogas with heat generating capacity of 3500-6000 ccal/nm^3 was introduced in 1991.

In 1992, biomass gasification plant designs for medium sized farms (developed by VIESH, Ekoross Centre, AKH named after Pamfilov) and for small farms (by VIESH, Ekoross Centre) were brought to the market. These units are designed to use all types of farm waste.

In the framework of the National Programme "Environmentally Clean Energy", the following technologies and full scale production designs are being developed:

- a unit with heat generation capacity from 1,3 to 5 MW and 70% efficiency to process raw materials, such as timber cut in large pieces with up to 60% of moisture content (system "Les"),
- a cyclone type unit handling polyfractional raw materials with heat generating capacity from 100 kW to 3MW and 70% efficiency. Raw material moisture content up to 60% ("Cyclone" system).
- an externally heated gasification unit for the high temperature gas production from biomass wastes with heat generating capacity of 1 MW and 65% efficiency. Raw material moisture content up to 60% ("Thermolisator" system).

Other prospective projects include development of small gasification units, processing timber industry waste (16 kW and 4 kW capacity) and heat-electric unit applying biogas (capacity 100 kW, 16 kW and 4 kW).

The first Russian made biomass gasification power plant with 1 MW capacity using saw mill waste has been in operation for 20 years in Kharovsk in the Vologda region.

Geothermal Energy

Exploitation of geothermal energy resources is a regional issue in Russia. It is important for such regions as the Krasnodar Region and the Stavropol Region in the Northern Caucasus and in the Far East of Russia (the Kamchatsky Peninsula and the Sakhalin Island). In the Kamchatsky Peninsula and the Sakhalin Island there are two electricity generating power plants, which use the geothermal resources of those regions. A wide range of power generating equipment for these purposes is designed and produced by two Russian companies: the Kaluga Turbine Plant and NTP "Turbokon" The electric energy generating units are of 0,5; 1,7; 2,5; 6; 12; 20,0 and 25 MW capacity. Usually, the capacities of geothermal heat generating units range in between 2,5 and 20 MW. The two aforementioned manufacturers also produce self-contained module thermal-electric power plants for geothermal power use with electricity generating capacity of 1,7 MW and heat generating capacity of 20 MW.

There is also another design by the Siberian Energy Research Institute for a power generating unit, making use of the open geothermal fields. Development of technologies in this field is constrained by the lack of demand from utilities and other consumers, high research investments and high costs of experimental production.

Low-grade Heat Energy

The possible sources of low grade heat are free air (with average temperatures from 5 to 15°C), ventilated air (with average temperatures from 15 to 20°C), ground waters (with average temperatures from 10 to 15°C), surface waters (10-17°C), process waters (25 to 40°C), geothermal waters (40-65°C), hot fluids (40-70°C), etc.

Thermocompressors are used to heat water in the swimming pools, to provide water heating and to supply hot water for housing and industrial facilities. In the developed countries wide use of thermocompressors allows large energy savings.

In Russia, thermocompressors of the following types are designed and produced:

- NT 100 (0,1 Gcal/hour),
- NT 400 (0,3-0,5 Gcal/hour),
- NT 3000 (2,5-3,0 Gcal/hour),
- NT 10000 (8-9,3 Gcal/hour).

The cost of heat energy produced by these thermocompressors is 2 to 4 times lower than in the conventional heat production.

A self-contained thermocompressors ATNU-10 use ground heat as the source of energy and have heat generating capacity of 10,3 kW. Those compressors provide heat for individual country houses and small farms. The units can be used all year round either to supply heat or cooled air for harvesting and storing of vegetables.

Another thermocompressor unit TUGV-200 with heat generating capacity of 2 kW is designed to provide hot water supply of individual houses using the heat of the ventilation air.

From 1986 till 1993, approximately 300 thermocompressors of the THU-14 type, using the heat of fresh milk for heating of farm houses were put into operation. Heat generating capacity of those units was 10 kW. However, the long period of economic stagnation and lack of investment has deteriorated demand for those units, which, in its turn, has led to a loss of gains and potential in this sphere.

Russian technology design has always been based on the existing manufacturing facilities and their capabilities. During economic transformation no new equipment was purchased, many companies have lost their customers and either gone bankrupt or substantially reduced their production. This has had its negative impact also on the development of thermocompressor technologies.

The future of these technologies depends on the development of the new effective and environmentally friendly coolants, effective compressors and safe and reliable automatic controls. Advances in these fields rely heavily on the technical and experimental facilities as well as on investment in research. It is hard to believe, that the private sector in Russia will be capable of supporting this kind of investments. The government also lacks the resources to fund these research programme. This will undoubtedly result in deterioration of the facilities and substantial losses in the competition with western companies in the longer term.

4. ENERGY EQUIPMENT MANUFACTURING

4.1 Overview

Russian energy equipment manufacturers produce equipment for steam, hydro, gas, coal and nuclear power plants, gas pumping stations, compressors, blowers, superchargers, recovery and electric equipment for chemical and oil refining industry, ferrous and non-ferrous metallurgy, machine-building as well as boiler house equipment for electricity and heat generation, diesel engines and diesel generators, crushing and face equipment for coal mining and etc. A detailed description of the product range is presented in section 4.2. of this paper.

Let as have a look at the factors, which determine development of this market and its structure in Russia nowadays.

In the previous chapters we have already addressed the issues of delayed demand for renovation and new construction of the power plants in Russia. The tendencies of the market development forecast changes in the fuel mix in favour of gas, clean coal and renewables as well as growth of demand for smaller, user-oriented power and heat generating units.

It the Soviet era, investments were channelled mainly into large power generation units. Now those units have turned into a heavy structural burden for many manufacturers. With the economic transition, sector restructuring will bring a completely new product range for major Russian manufacturers. However, this need for restructuring finds no support in the public policies.

As the demand for new energy equipment by the utilities is low, only a fraction of production capacities is now in operation, for example:

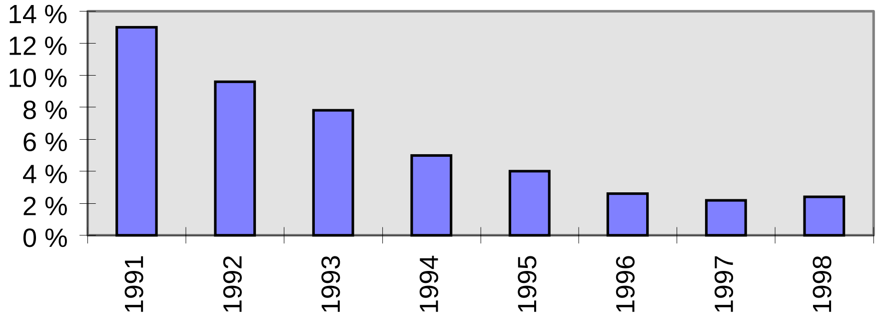
- Steam turbine production - 15%,
- Gas turbine production - 10%,
- Hydraulic turbine production - 30%,
- Steam boilers with capacity up to 10 tonnes of steam/hour - 25%,
- Steam boilers with capacity over 10 tonnes of steam/hour - 35%,
- Diesel engines and diesel-generators - 9.6%.

Intensive international competition in the world market forces Russian producers to focus on the needs of the domestic market. Graph 4.1.1 shows changes in the share of Russian-made equipment in the world market.

World energy equipment manufacturing is highly concentrated with a small number of multinational companies leading the list. These companies are Siemens, Germany, ABB, Sweden/Switzerland, and General Electric, the USA. The French, Japanese and other producers occupy the rest of the market, leaving a tiny 2% share for the Russian companies. The key reason for this is the current lack of governmental financial support for export contracts and inability of the Russian suppliers to offer competitive equipment quality at competitive prices.

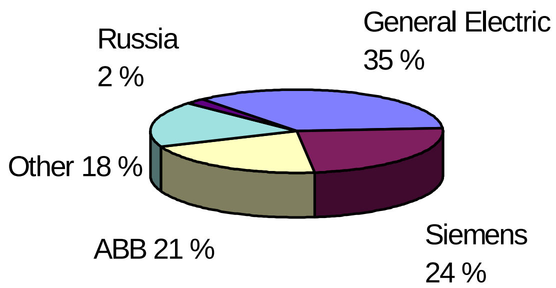
The other problem associated with the above, is that the majority of the Russian suppliers is not able to finance their export production costs themselves and their opportunity to obtain commercial credits on reasonable terms is also very low.

Graph 4.1.1 Changes in the Share of the Russian Energy Equipment in the World Market During the Economic Transformation.



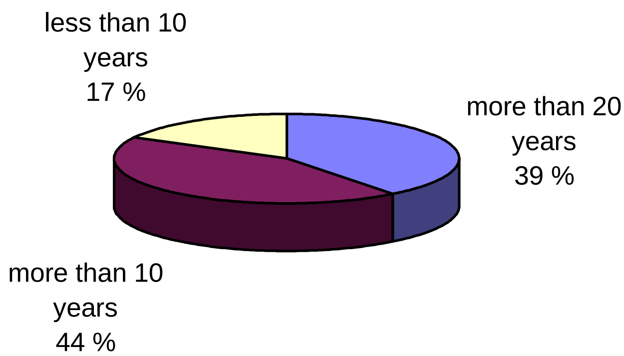
Source: Author's Own Compilation.

Graph 4.1.2 World Market Shares in 1997.



Source: Author's Own Compilation.[13]

Graph 4.1.3 Proportion of the Out-dated Equipment in the Total Installed Equipment in Russia



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[13] This graph is an author's approximation of leading multinational companies market shares compiled from various sources. The main purpose of this graph is to present an idea of international market concentration and shares distribution in order to show the Russian manufacturers position discussed.

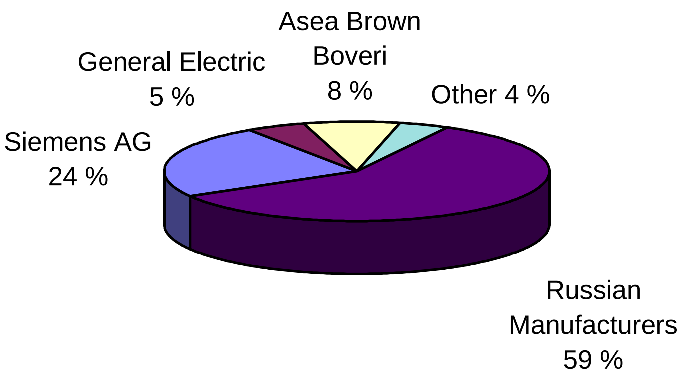
Source: Report of Ministry of Economics of the Russian Federation (1998).

The present state and future development of equipment manufacturing and technology development in the energy sector is very negatively influenced by the fact, that technological equipment in the industry is not renewed in accordance with the market competition demand. Only minor investments are made in maintenance and updating of the equipment at the moment. Especially critical is the situation in the computer hardware and software equipment systems, used in the energy equipment manufacturing. The installed equipment is deteriorating fast due to the little investment in its maintenance and replacement.

The already low annual rate of the machinery and equipment replacement has decreased during the economic transition period 4 times and is now a mere 4%. The proportion of the already out-dated equipment has considerably increased in this period

Due to the factors described above, i.e. decrease in the market demand, little investment in the new technologies development, world-wide shift in the market demand towards smaller production units with the focus on gas-fired technologies and poor condition of the production facilities, the Russian manufacturers are losing market shares not only internationally but domestically as well.

Graph 4.1.4 Division of the Russian Energy Equipment Market.



Source: Author's Own Compilation.[14]

Loss of the domestic market share by the Russian manufacturers has happened also due to the fact, that such supplementary activities as service, training etc., provided by foreign suppliers, were poorly developed by the Russian manufacturers. Another serious drawback of the Russian manufacturers, in comparison to the foreign ones, was the lack of modern, effective automatic controls systems. Development of the computer software and hardware in Russia has started later, than in many other countries. This has delayed the introduction of computer systems in the manufacturing and product designs. However, the momentum gained due to the Soviet era investment is not completely lost.

All the described has found its reflection in the market share distribution, presented in Appendix 1 to the present paper. Analysis of the market shares in the product segments leads us to a conclusion, that co-operation with the international companies is vital for the survival of

[14] This and other similar market share estimates were prepared on a basis of various independent corporate sources. This data represents the author's point of view and is not supported by the sufficient official data.

the Russian producers. In the future, equipment supplies are likely to include a complex combination of equipment, manufactured by many companies from different countries.
The side effect of this will be the opportunity for new market entries by the engineering and investment companies, that will assist consumers - the energy utilities - on turn-key projects and investigate the range of design solutions.

4.2 Manufacturers and Product Ranges

Production of the energy equipment in Russia is concentrated in several focal points that will be described in detail further on. In the Soviet era, the central planning system allocated orders not only in Russia or the Soviet Union but also in the other countries of the Eastern bloc. The principle "one product - one producer" was widely applied. Due to this fact, subcontracting of some of the vital supplies still remains a problem for the Russian manufacturers as many suppliers have been left outside the unified customs and economic area.

Boilers

In the Russian Federation, boiler manufacturing companies produce boilers for electricity production, which range in capacity as follows:

- straight-through boilers from 1000 to 3950 t/hour,
- drum boilers with natural circulation from 219 to 670 t/hour.

The following steam characteristics are applied for boilers with capacity

- 210-820 t/hour - 13,8 MPa, 560 °C,
- 670 t/hour - 13,8 MPa, 545/545 °C,
- 1000, 1650, 2650, 3950 t/hour (used in generating units 300, 500, 800, 1200 MWe), 25 MPa, 545/542 °C.

Russian-made boilers can use various kinds of fuel - natural gas, residual oils and a wide range of solid fuels, including high-ash and high-moisture. All boilers are manufactured as gas-tight units with all-welded membrane panels, solid fuel-burning boilers with balanced draught.

The main boiler house equipment producers in Russia are:

- Taganrog Boiler Factory, Taganrog
- Podolsk Boiler Factory, Podolsk Moscow Region
- Belgorod Energy Machine Building Factory, Belgorod
- Sibenergomach, Novosibirsk
- Barnaul Boiler Factory, Barnaul.

The Taganrog Boiler Factory is the main producer of the large boilers in Russia. It produces boilers with capacity range of 165, 200, 300, 800, 1200 MW for condensing thermal power plants. Steam generating capacity of the 300, 800 and 1200 MW units is 100, 2650 and 3950 steam t/hour accordingly, steam pressure is 25Mpa, live steam and superheated vapour temperatures are 545 and 542°C. Pressure and temperatures of the smaller capacity units is 13,8 MPa, 545-560°C.

The Podolsk Boiler Factory produces steam generating units with capacity range of 800, 500, 300, 200MW and less. Steam rate of the 500 MW unit is 1600 ton/hour, steam pressure and temperature characteristics are corresponding to the ones of the units by the Taganrog Boiler Factory. Steam generating units of the both manufacturers can be fired by coal, fuel oil and gas. Efficiency of these steam generating units is close to 90%.

Steam generating units of Sibenergomach and the Barnaul Boiler Factory have lower steam rate, pressure and temperature characteristics, than the boilers of the aforementioned producers. Those producers manufacture steam and water heating units for district heating, waste-heat recovery boilers for energy production as well as boilers for metal and chemical industries. For fuel in these boilers, it is possible to use not only coal, fuel oil and gas, but also fossil fuels and various wastes (timber, other waste), biomass and hot gases of other production processes. Sibenergomach and the Barnaul Boiler Factory produce over 100 different types of boilers with the following parameters:

- steam rate up to 500 ton/hour,
- pressure up to 13,8 MPa,
- temperature up to 500°C
- efficiency up to 87-93%.

Two other sector companies "Baltiysky Zavod", St.Petersburg, and "SKB Kotlostroenia" produce boilers for vessels. Recently the companies have developed boiler house designs for municipal purposes. These boilers can be fired by gas, fuel oil and waste. There is also a number of small size vessel boilers fired by pressurised liquid fuel. These boilers can be used for small power generating units up to 25-40 MW of capacity per unit. The advantage of those boilers, compared to all the previously mentioned ones, is that they are delivered to the customers preassembled at the manufacturer's premises and do not require costly installation.

All the listed manufacturers still have the design and technology development units inside their companies and provide the whole range of services from design to installation of the units.

Russian-made boilers usually cause considerable environmental pollution. Also the operational flexibility of Russian boilers is lower, than that of the boilers by international producers.

Steam and Hydraulic Turbines

Steam turbine manufacturers in Russia produce condensing turbines for thermal power plants using organic fuels, extraction turbines for heating and industrial purposes, turbines for nuclear power plants.

For thermal power plants, the following range of condensing turbines is produced:

- turbines with capacity of 200 MW and entry steam conditions of 13 MPa, 540/540° C,
- turbines with capacity of 300, 500, and 800 MW and entry steam conditions of 24 MPa, 540/540° C.

In the Kostroma Power Plant, a 1200 MW steam turbine is used, which is the largest mono-axial turbine with supercritical steam pressure in the world.

For combined heat and electricity generation plants, steam extraction turbines with capacities up to 250-300 MW are manufactured.

For nuclear power plants, 1000 MW steam turbines with rotor rotational speed of 3000 rotations/minute are produced. A steam turbine of type K-1000-60/3000 produced by the Leningrad Metal Factory is the largest turbine in the world, operating on saturated steam with the rotor speed of 3000 rotations/minute.

Russian hydropower turbines manufacturers produce Kaplan, Francis, horizontal-flow and adjustable-blade Francis types of hydraulic turbines with different parameters, depending on the conditions and requirements of the particular hydropower plant. The combined pump and turbine units for water storage power plants are also produced in Russia.

The leader in steam and hydraulic turbine manufacturing is the Joint Stock Company the Leningrad Metal Factory. At the moment, this company is majority owned by the Energy Machine-Building Corporation, Moscow, which is the largest holding company in the energy equipment sector[15]. The Leningrad Metal Factory produces steam condensing and back-pressure turbines. The capacity of the condensing turbines (without regenerative bleed-off) is 50, 55 and 100 MW, steam pressure is 9,0 and 10,0 MPa. A range of turbines with regenerating bleed-off and heating is much wider:

- capacities of 200, 210, 215, 225, pressure 13 and 18 MPa,
- 300 MW, pressure 17 MPa,
- 300, 315, 325, 330 with pressure of 24 MPa,
- capacities 450,500,520, 600, 800, 850, 1000, 1100 and 1200 MW with different pressures, starting from 7 MPa for nuclear power plants and starting from 13, 17 and 24 MPa for thermal power plants.

The parameters of the back-pressure turbines are:

- in capacity - from 25 to 330 MW,
- pressure - from 3 to 24 MPa.

The Leningrad Metal Factory is the largest hydraulic turbine manufacturer in Russia. The company has produced the largest Francis turbines in Russia for the Krasnoyarsk Hydropower

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15 At the moment, the Leningrad Metal Factory has stopped its production and is amidst a hard power struggle between its employees, led by the General Manager, and the Energy Machine Building Corporation (EMK). The appointment of the General Manager by the employees is disputed by the EMK. On the other hand, there is a certain level of confusion related to the Energy Machine Building Corporation itself. The registered owner of the Leningrad Metal Factory is the Energy Machine Building Corporation, located in Moscow. This Corporation has, however, recently started bankruptcy procedures. The Corporation now involved in the power struggle in the Leningrad Metal Factory has been recently registered in the Arkhangelsk region. There is a controversial discussion of what is the background of each of the Corporations and what is the possible legacy of their claims. Nothing seems to be clear at the moment except the fact, that the struggle against the holding company has already spread to many other power machine-building companies, owned by the EMK (the EMK owns totally 26 power machine-building companies), which will have a negative effect on the sector development.

Plant and the Sayano-Sushenskoye Hydropower Plant with capacities of 500 and 740 MW and hydraulic heads of 98 and 198 metres correspondingly.

There are many other steam turbine manufacturers in Russia. They manufacture turbines to be used as driving units for compressors, marine engines etc. They are:

- Proletarsky Zavod, St.Petersburg,
- Nevsky Zavod, St. Petersburg,
- Kaluga Turbine Factory, Kaluga, etc.

These companies produce condensing and back-pressure turbines. The turbines range from 1 to 30 MW in capacity, the pressure is up to 9 MPa. Some of the turbines can be used as driving units for turbogenerators. For district heating purposes, the turbines can be equipped with heating steam extraction.

The largest steam and hydraulic turbine manufacturer in the CIS is the Industrial Association of Nuclear Turbine-building "Turboatom", located in Kharkov, Ukraine. The range of turbine types produced by this company is very similar to that of the Leningrad Metal Factory. Both of the companies also have well-developed design and research facilities.

Important competition aspect in the Russian market is that the initial pressure of 13,8 MPa, widely used in Russia, is not applied in the western countries. In the western equipment the after the boiler steam pressure is 16-19 MPa. This allows the western systems to utilise steam for further power and heat generation. Limitations for higher pressure parameters in the western equipment is imposed by the Russian GOST standards, according to which 13,8 MPa is the upper limit for the process steam pipelines.

The technical parameters of the Russian-made heat exchanging systems for regenerative bleed-off, valves, cooling systems and water supply systems of the turbine units are low. There are also significant drawbacks in controls and in automatics. These areas will require international co-operation with western producers to up-grade the existing technologies and standards. Introduction of the ISO standards in Russia will certainly help to develop this co-operation.

Gas Turbines

Until recently, manufacturing of gas-fired electricity generating units in Russia was limited to only two turbine types GT-25-700 and GT-100-3M. These turbines operate with low initial gas temperature (under 770°C) and do not have blade cooling. However recently, a new GTE-150 unit with initial temperature of 1100°C has been tested.

The largest gas turbine manufacturer in Russia is the Nevsky Zavod, St. Petersburg. This company has already manufactured 1200 turbines with capacities range of 10 to 25 MW to be used as drives for gas pumping stations. Nearly 70% of natural gas in the Soviet Union was pumped by the units by the Nevsky Zavod. A gas-fired power generating unit with capacity of 12 MW produced by this company is nowadays successfully operating in the Rio Chica Power Plant in Argentina.

Turbine and Motor Factory in Ekaterinburg also produces gas pumping station turbines with capacities of 12,5, 16 and 25 MW.

Large capacity gas turbines (100 and 150 MW) are produced by the Leningrad Metal Factory. Gas turbines for marine engine drives are produced by the Proletarsky Zavod, St. Petersburg, Russia, and by a factory of the Zarya Industrial Association, located in Nikolaev, Ukraine. The total amount of gas turbines produced by the Zarya Association for marine and compressor drive purposes is approximately equal to that of the Nevsky Zavod.
At the moment, Russian aircraft jet engine manufacturers look for new markets for their products. The companies Rybinsk Motors, Perm Motors, the SNTK named after N.D. Kusnetsov in co-operation with the Kirovsky Zavod, St.Petersburg, and the Leningrad Metal Factory have designed and produced first experimental gas turbine units for combined steam and electricity generation with capacities ranging between 45 and 250 MW as well as power generation units with capacity up to 450 MW. These works are performed in the framework of the National Technology Development Programme "Gas Energy".

Hydro- and Turbogenerators

Power machine-building companies in Russia manufacture turbogenerators with capacities from 2,5 to 1200 MW and hydrogenerators of various designs for different rotational speeds and of different configurations.

At the moment, there are many 800 MW water-cooled turbogenerators in operation in Russia. An extensive research to increase safety, to modernise the units and to apply new materials and technical solutions for the turbogenerators has been carried out. The analysis of the operation of these turbogenerators has given enough information, used to apply water-cooling for the smaller capacity turbogenerators.

A 220 MW turbogenerator with water-cooling has been tested. There are also 320 and 500 MW turbogenerators of these types ready for full-scale manufacturing.

The technical level of Russian-made hydrogenerators for the large hydropower plants is equal to that of the best corresponding equipment by western manufacturers. At the same time, automatics, excitation systems, diagnostics and controls leg behind. Introduction of a competitive Russian water storage plant is difficult due to the lack of starting and regulating systems.

The largest turbo- and hydrogenerators in Russia are produced by the Joint Stock Company Elektrosila, St. Petersburg. Until the end of 1998, this company also used to be part of the Energy Machine Building Corporation[16]. Elektrosila includes manufacturing, research and design facilities. The product range of Elektrosila includes unified turbogenerators from 63 to 1200 MW and other generators with excitation systems. Turbo- and hydrogenerators of smaller capacity (under 200 MW) are manufactured also by the following companies:

- Uralelektrotjazhmash, Ekaterinburg,
- Elsib (the former Sibelektromash), Novosibirsk,

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16 The big turmoil raised by the bankruptcy of the Energy Machine Building Corporation (EMK), Moscow, and transfer of the ownership of the companies to another Energy Machine Building Corporation based in the Arkhangelsk Region, has influenced Elektrosila as well. After announcement by the General Manager of the company, that Elektrosila will leave the EMK , he was dismissed by the EMK during an extraordinary shareholders meeting. The dispute is not yet settled and right now there are two operating General Managers in the company.

- Privod, Lysva (turbogenerators of 63, 32, 20, 12, 6, 4 and 2,5 MW capacity),
- Elektrotjazhmash, Kharkov, Ukraine

Transformers, Autotransformers, Reactors

In Russia transformers are produced by the following companies:

- Uralelektrotiazhmash, Ekaterinburg
- Transformator, Toliatti
- Elektrozavod, Moscow.

There is also a large number of transformator repair works in different regions of Russia that produce small capacity transformers (up to 2,5 MVA).

In the former Soviet Union, the leader of transformer production was Zaporozhtransformator, located in Zaporozhye, Ukraine. The leading research and design institute, specialising in transformers, is the Transformer Building Institute in Zaporozhye, Ukraine. The largest transformers have voltages of 330, 500, 750 and 1150 kV, single capacity up to 1200 MVA and group capacity of single-phase transformers of 1600 MVA.

Distribution Transformer Plant in Minsk, Belorussia, used to be the largest distribution transformer producer in the Soviet Union. The plant manufactures transformers of 6, 10 and 35 kV with capacity up to 1600 kVA.

High Voltage Equipment

High voltage air, small-oil volume circuit breakers and sulphur hexafluoride switches with voltages up to 750 kV (1150 for the transmission line Itat-Chelyabinsk) are produced by Uralelektrotjazhmash and Elektroapparat, St. Petersburg. These companies produce also vacuum, small-oil volume circuit breakers and sulphur hexafluoride switches for 6-10 kV distribution facilities and instrument voltage and current transformers.

Insulators for all voltages are produced by the ELVO Company (the former Velikiye Luki High Voltage Equipment Factory), located in Velikiye Luki. Pedestal insulators for all voltages are produced by the Insulator Company, situated in the same town.

Lightning arresters and pedestal insulators are produced by the Kornilov Porcelain Factory (the former Proletary), St. Petersburg. Bushing insulators are manufactured by the Insulator Company in Moscow and suspension insulators - by the Insulator Attachments Plant in Sredneuralsk.

Many insulator manufacturers in Russia produce polymer pedestal and suspension insulators as well. High quality sulphur hexafluoride 6-10 kV switches are produced by the Joint Venture ABB-Moselektroschit Company, Moscow. High quality 110 and 220 kV insulators are manufactured by the Joint Venture ABB-Uralelektrotjazhmash.

The largest power panel producers in Russia are Elektroschit (6-10 kV), Moscow and Elektroschit (6, 10 and 35 kV), Samara. Power panels for control consoles, automatics and relay protection are manufactured by Elektropult, St. Petersburg, and by the Joint Venture ABB Relay-Cheboksary, which producers micro-processor based power panels for electricity transmission lines. Two St.Petersburg companies, the Scientific and Research Centre Mechanotronika (based in the Electromechanics Plant) and Elektronmash, produce microprocessor relay protection and automatic systems.

5. CONCLUSIONS

The period of economic transformation in Russia has proved to be a very difficult time for the Russian energy equipment manufacturing and technology development sectors. The companies have to change all their structures, procedures and approaches. New technologies and innovations, providing the required level of efficiency, must be introduced as quickly as possible. This is the only way to compete with the multinational companies that have entered the Russian market.

The mixture of free market elements with central planning thinking and approaches is exactly what we see in the Russian economy today. The country and its economy is undergoing huge changes. It is already accepted in Russia, that the return to central planning is not possible but the fact, that long lasting reforms have not yet yielded positive results makes the whole market situation very tense. The reforms have faced considerable difficulties in altering the mind sets and everyday practices, deeply rooted in people's mentality. It is evident, that the country is only in the middle of the transformation process. Russia is currently in a stage, when the process of creative destruction has already destroyed the old structures, and the new ones have not been created yet. The scale of changes is so profound, that it will take several generations. To achieve sustainable results, are-thinking of strategies and wide scale education of the whole nation will be needed. To make functioning of the market systems efficient, the changes have to take place at all the levels of decision making throughout the society.

Development of the structure of power generation and fuel mix in Russia will be a reflection of the new demands, which are difficult to forecast right now. Some of the factors, that will effect this development, have been discussed in the present paper. They include the deterioration of the installed power generation equipment, changes in the market structures and fuel mix that slowly gain momentum in Russia, low investment in the fundamental research and technology development, chaotic public policy and lack of political consensus concerning the key issues of the energy sector, costly restructuring of manufacturing from the grandeur approach to a user oriented thinking, etc.

Notwithstanding the difficulties of economic transition, we believe, that the technological potential for different fuel is extensive. The choices ultimately made will be a product of often conflicting and unmonitored forces. The future structures of the Russian energy sector and economy as a whole, will reflect today's policies to achieve the target objectives. Energy will contribute to and be influenced by macro-economic choices in industry and politics. Thus, the current instability in Russia will undoubtedly find its reflection in the overall competitiveness of the country in the next millennium. One can only hope, that this will be sooner or later recognised also by the Russian policy makers.

The prerequisites for the successful development of the energy sector in Russia are the sound nature resources, continuing improvements in productivity and a substantial potential for further technological innovation. Co-operation with the foreign energy companies and/or purchase of the western technologies together with focusing on specific policy issues will certainly facilitate transition to a more effective and competitive power generation.

The size of the new power generation plant is, however, expected to decrease as a result of advances in the production techniques. This will make it possible to construct power plants rapidly and in response to a demand. However, the need to ensure back-up supplies through a strong network will be of major importance. This is likely to become one of the main concerns of the Unified Energy Systems of Russia.
Technological changes, coupled with economic and market structure changes, will lead to major organisational shifts in the energy sector. The possibilities for new and innovative ways of delivering energy services to the end-user will force a culture change. We expect the companies to become much more active in the decentralised production of energy and in the provision of effective services to the end-user. A lean, flexible and innovative engineering approach as well as innovative financial engineering schemes will characterise the future energy provider.

Thus, the movement towards a new technological structure in the energy sector is perceptible. Development of the information and computer technologies will further accelerate the trend. These technologies are capable of indirectly promoting better energy consumption patterns by rationalising the manufacturing process, and matching it ever more closely to consumer demand. The adoption of new energy technologies will be driven by the economics and by the availability of information. A key factor will be the emergence of new market forces to drive change and to facilitate entry of the new, innovate market players.

New energy technologies could also facilitate addressing environmental and energy security concerns without jeopardising economic goals. Indeed, environmental concerns could even be used as drivers for technological innovation and thus enhance the prospects for long-term economic growth, thereby upsetting the "conventional wisdom" that there are necessary trade-offs involved in the simultaneous pursuit of economic and environmental goals.

New technology can decisively influence the future shape of the fuel mix. Conventional energy production will see improved technical solutions, with smaller distribution units leading to a smoother energy supply and demand match in terms of installed capacity and technology fit. Resource depletion can be pushed back. Energy economics can be reworked to reflect the higher efficiencies and lower costs. New technologies will become available, but low prices for conventional fuel will limit their penetration to the Russian market in the medium term.

Innovation is the key to harnessing this technology potential. Innovation is part of the market process, it is a driving force of the economy. As in the past, the energy sector in Russia today is still characterised by large, long term projects which limit the opportunities for innovation. Present trends in power generation are shifting away from the giant power stations towards smaller units. The availability of ever smaller, less expensive power generation and energy conversion units facilitate faster turnover of the capital stock, which, in its turn, facilitates innovations. This process has been reflected by the manufacturers of air plane jets and small capacity turbines for industrial and marine purposes, which have already started to introduce their small power generation design solutions. Unfortunately, a very small domestic market demand and reluctance of the foreign buyers makes long term surviving of many research and development projects questionable.

While some benefits result in the medium term, the major technological changes may occur not earlier than by the end of 2020-ies. The reason for this is the unprecedented scale of changes, envisaged in Russia. These changes will illustrate the potential for radical changes also in the energy system. While the innovations will take long to implement, they will deliver tangible results over time.

Overall, gas will be the fuel to gain the largest market share. Different fuels have, at different times, dominated the fuel mix. Today, it is the turn of gas to dominate in energy investments. Paradoxically, as a result of successive waves of investment in different fuels, the current era provides a wider choice than ever before and possibly than in the future. The challenge for policy makers is to maintain and extend that choice into the new millennium.
Technology developments can have a decisive impact on the future shape of the fuel mix. The future progress of the penetration of new energy technologies is probably one of the greatest uncertainties in any analysis of the energy futures. New technologies will need to ensure development of the renewables, with their promise of clean energy and new ways of using fossil fuels, to maximise utilisation efficiency and minimise environmental impacts. However, the rate of penetration of this kind of technologies will largely depend on the public policy support to research and development in the field.

The impact of a technology is not necessarily specific, but it is more likely to be cumulative as it has occurred in the growing efficiency of combined cycle gas turbines. Similarly, the impact of a technology on the demand side of energy use is a less dramatic but equally important component of improving energy intensity of an economy. There is a need to study the ways, in which regulations, standards, advice, education, subsidies, investment incentives etc. can contribute positively to improving energy intensity on a country-wide basis.

The intensity gains are predicted to result from widespread adoption of the combined cycle technology for power generation, use of clean coal technologies, investments in co-generation plants and improvements in the installed equipment.

Our analysis shows, that in no scenario, will these advances happen on their own. Commercial development of the new technologies will take place, but market solutions will not suffice on their own - as demonstrated in the national strategy, which is heavily reliant on hydrocarbons. So some degree of public policy impulsion will be required in order to achieve these advances. How could that impulsion come about?

For example, will the environmental concerns provide the principal motivation for radical technological innovation over the period to 2020? If this were so, it would require a new framework for energy technology policy with substantial changes in the level and direction of technology funding, and creation of new institutional structures. Appropriate roles would also need to be redefined for government and companies. The growing demand for energy in the industry can become another factor, that will drive innovation in Russia.

Many energy-efficient technologies have been developed but their widespread application has been retarded by the investment requirements. Thus, various components of technology policy need more effective integration with the other policy instruments (such as regulations, mandatory standards, voluntary codes, taxes and subsidies). To be effective, policy instruments should also be targeted, fine-tuned and mutually reinforcing. All this present major challenges for policy makers and requires the appropriate level of understanding of the sector. Unfortunately, this is not the case in Russia. We hope, that generation change will bring more competence into policy making and, thus, make those political and regulatory instruments effective.

Structural changes in energy markets can also provide new constraints and opportunities. For example, liberalisation and privatisation policies in the gas and electricity sectors will lead to dramatic changes in the roles and incentives of the major players - government, utilities, equipment suppliers. Both organisationally and technologically innovative companies will have considerable advantages in the more competitive global market. Developments in the "generic" technologies (such as information technology and metering) could also have major impacts on energy production, conversion and use.

At the moment it is difficult to reliably estimate the way, in which reduced expenditure on energy technology can practically affect the energy sector, on one hand, and another priorities such as the environment, industrial and export competitiveness, employment etc., on the other hand. However, it is clear, that low financing will complicate the development of competitive and innovative technologies. A Japanese model of long-term planning to capture market share many decades ahead, backed with substantial government support for advanced technologies such as photovoltaics, could serve as a good example of long term public policy approach for Russia as well. The major problem of Russia in this respect is that the country can not afford to follow this example, until the economy has really gained its momentum. At the same time, it is likely, that the successful start-up of the economy will hugely rely on the improvement of the electricity supplies. There are no easy ways to solve this two-fold dilemma.

Perhaps the market, with sufficient incentives, can be relied upon to deliver a wide range of cleaner, more efficient technologies, despite the envisaged large declines in energy technology expenditure by the companies in the energy sector. Continued erosion of energy technology capacity can severely weaken the country's ability to compete in world market and will influence the long term sustainability of the Russian economy.

The possibility of a pleasant technological surprise should not be discounted completely either. Development of a new low cost and clean energy technology over the next quarter of a century is feasible. History offers many examples of unexpected advances in technology, occurring when all the conventional options have been exhausted. In any circumstances, such fortuitous development cannot be taken for granted.

LIST OF LITERATURE

Energetik (10/ October, 1998): "Energy consumption in the Russian economy and forecasts of change". Analytical report, 3-6.

ETLA. (January 1999). Discussion Paper No.664. Grigori Dudarev - Michael Zverev, Energy Sector in Russia. Economic and Business Outlook.

Fuel and Energy Complex (1-2/1998). Analytical Report by the Ministry for Fuel and Energy of the Russian Federation.

Itogi magazine(August 11, 1998): “Nuclear GOELRO means clean and bright”, 12-16.

Ministry for Fuel and Energy of the Russian Federation (MinTopEnergo). Statistical Reports (1993-1997).

Ministry of Economics of the Russian Federation. Statistical Report (1998).

RAO Unified Energy Systems of Russia, Statistical Reports (1993-1997): “Annual Results of the Unified Energy Systems of Russia”.

RAO Unified Energy Systems (1997):“Annual Corporate Report”.

RAO Unified Energy Systems, Statistical Reports (15.12.98). Internet site www.eesnet.ru.

Shafrannik, Y. (1995): New Energy Policy in Russia. Atomenergoizdat.

State Statistics Committee (GosKomStat) (1997): "Annual Report. Russia", GosKomStat.

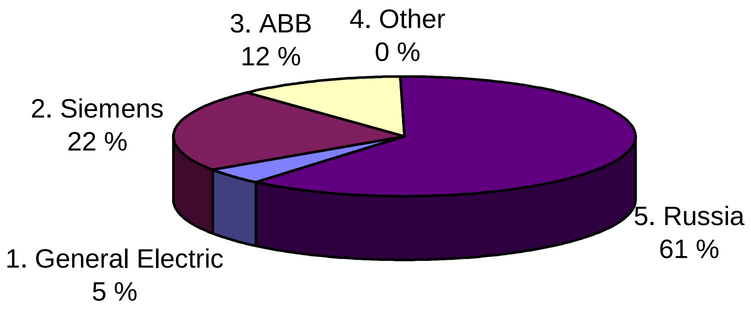
State Statistics Committee (GosKomStat) (1997) Annual report "Industry in Russia", GosKomStat.

State Statistics Committee (GosKomStat) (1998) Annual report "St.Petersburg Industry", GosKomStat.

St. Petersburg Economic Forum 98, Working Papers (1998): "Problems of the energy industry".

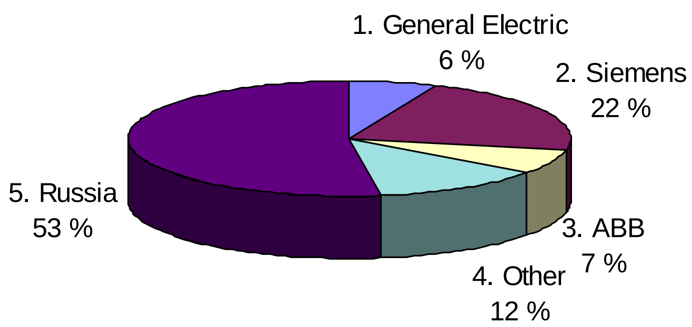
APPENDIX. RUSSIAN DOMESTIC MARKET SHARES BY PRODUCTS.

Graph 1. Russian Domestic Market Shares. Turbines.



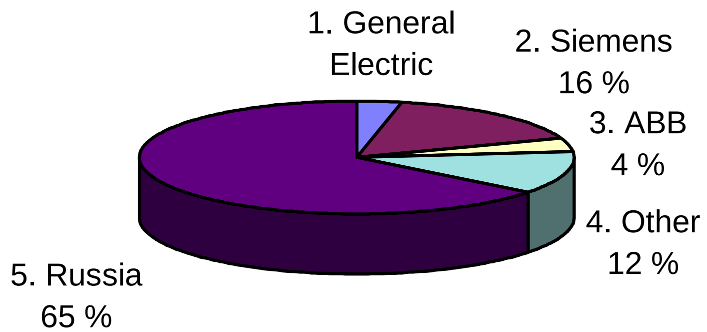
Source: Author's Own Compilation.

Graph 2. Russian Domestic Market Shares. Generators.



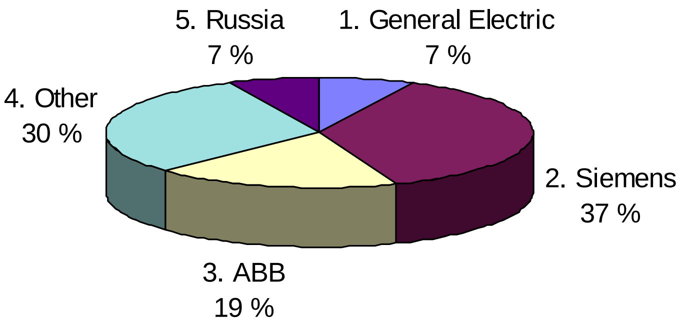
Source: Author's Own Compilation.

Chart 3. Russian Domestic Market Shares. Boilers.



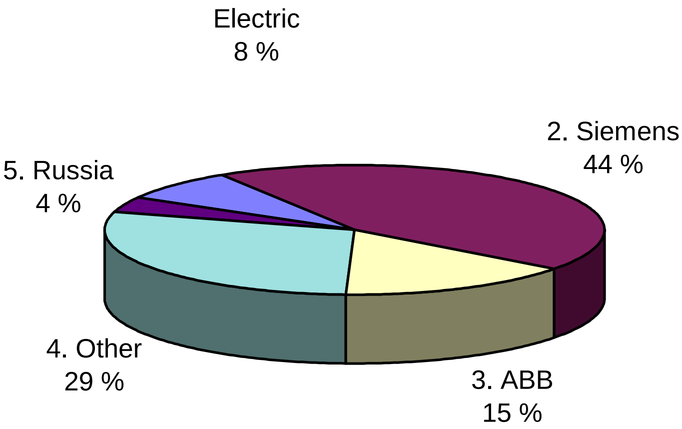
Source: Author's Own Compilation.

Chart 4. Russian Domestic Market Shares. Automatic Controls.



Source: Author's Own Compilation.

Chart 5. Russian Domestic Market Shares. Service and Training.



Source: Author's Own Compilation.