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Resource of energy efficiency IN RUSSIA: scale, COSTS AND BENEFITS

Developed for the World Bank

Moscow, 2008

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Units and conversion factors

General Conversion Factors for Energy

To:	**TJ**	**Gcal**	**Mtoe**	**Mtce**	**GWh**
From:	**multiply by:**				
TJ (terajoule) =10^{12}J	1	238.8	2.388×10^{-5}		0.2778
Gcal (gigacalories, 10^{9} cal)	4.1868×10^{-3}	1	10^{-7}		1.163×10^{-3}
Mtoe (million tons of oil equivalent)	4.1868×10^{4}	10^{7}	1	1.43	11630
Mtce (million tons of coal equivalent)	2.9278×10^{4}	$7\text{x}10^{6}$	0.7	1	8132
GWh (gigawatt-hours, 10^{6} kWh)	3.6	860	8.6×10^{-5}		1

List of abbreviations

AC	Alternating current
ASE	Annual savings of energy
Cc	Capital cost of technology
CENEf	Center for Energy Efficiency
CFL	Compact fluorescent lamp
CH_4	Methane
CHP	Combined heat and power plant
CO2	Carbon dioxide
Cor	Variation of current costs or (if there are additional effects - other costs savings, increased output, improved quality, etc.)
CRF	Capital recovery factor
CSE	Cost of saved energy
dr	Discount rate
DHW	Domestic hot water
EAF	Electric arc furnace
EBRD	European Bank for Reconstruction and Development
ESCO	Energy Service Company
ETS	Emission Trading System
EU	European Union
Fig.	Figure
Gcal	Gigacalories
Gce	Gram of coal equivalent
GDP	Gross domestic product
GHG	Greenhouse gases
GJ	Gigajoule(s)
goe	Gram of oil equivalent
GRES	Condensing power plant
GW	Gigawatt
IEA	International Energy Agency
IFEB	Integrated Fuel and Energy Balance
IPCC WG III	International Panel on Climate Change, Working Group III
IT	Information technology
kgce	Kilogram of coal equivalent
kgoe	Kilogram of oil equivalent
kW	Kilowatt
kWh	Kilowatt-hour
l	Liter(s)
LBNL	Lawrence Berkeley National Laboratory (USA)
LPG	Liquefied petroleum gas
m2	Square meter
m3	Cubic meter
OAO ”MMK”	Magnitogorsky Steel Works
OAO ”NTMK”	Nizhnetagilsky Steel Works
OAO ”NLMK”	Novolipetsky Steel Works
OECD	Organization for Economic Cooperation and Development
OAO ”RZhD”	Russian Railway System
PCI	Pulverized coal injection
PNNL	Pacific Northwest National Laboratory (USA)
PVC	Polyvinyl chloride
RAO “EES Rossii”	United Energy System of Russia
RF	The Russian Federation

SEC	Specific Energy Consumption
SElC	Specific Electricity Consumption
t	ton
TACIS	Technical Aid to the Commonwealth of Independent States
tce	ton of coal equivalent
TES	Thermal power plant
TFC	Total final consumption
toe	ton of oil equivalent
TPES	Total primary energy supply
UK	United Kingdom (Great Britain)
USA (U.S.)	United States of America
U.S. EPA	U.S. Environmental Protection Agency
USSR	Union of Soviet Socialist Republics
VINITI	All-Russian Institute for Scientific and Technical Information
VNIIZhT	All-Russian Research Institute for Railroad Transport
WTO	World Trade Organization
$US	U.S. dollar(s)

Disclaimer

Any effort to assess energy efficiency potential faces many limitations. Energy consuming facilities vary by scale, climate and load, quality of general energy management and maintenance, as well as quality of processed materials and conditions of processed or mined natural resource deposits, rate of recycling products, climate conditions (which vary significantly throughout the vast territory of the Russian Federation) etc. All these factors impact specific energy consumption and consequent energy savings potential. Based on these conditions, energy efficiency investments may also produce different results under different circumstances.

Energy production at facilities with the marginal energy costs have to be reduced first to maximize effects of energy efficiency improvements. But many local energy markets are poorly connected or completely isolated (there are 50,000 local district heating markets in Russia), thus making evaluation of country wide marginal costs unpractical and impossible. The analysis below uses average prices, but in reality energy and energy efficiency equipment prices considerably differ through the territory of the Russian Federation. It is hardly possible to screen all energy consuming facilities to evaluate the energy efficiency potential. Data on typical sites are extrapolated for all similar facilities (always based on a set of assumptions), allowing it to mitigate the dimension of the analysis problem at the expense of bringing more uncertainty to the final assessment results.

Another challenge is to identify incremental capital costs of implementing the energy efficiency potential. This difficulty roots in the fact that a large part of equipment is to be replaced to let the systems perform their basic functions, and the new equipment is generally more energy efficient. So efficiency often comes at no additional cost.

Therefore, any assessment of the potential is assumptions-related. The assessment results are to be presented in intervals. But for the purpose of aggregation it often is not convenient. Volumes of potentials presented in this paper by single numbers should be taken as the middle of the uncertainty range. The level of confidence grows, as the assessed category of the energy efficiency potential comes from the technical to the economic and then to the market potential. By nature this effort is very close to the identification of energy resources deposits, where the process starts from very uncertain evaluation of the volume of potential resources to the much more reliable amount of proven resources.

1. Introduction

Russia has an enormous, although poorly mined, energy resource, namely its energy efficiency potential. By its ability to ensure Russia's economic growth it 2-4-fold exceeds expected primary energy production increase until 2020. During the initial stage of transition process (1990-1995), poor energy productivity of Russian economy deteriorated even further. Then, driven by the economic revival, energy intensity of Russian GDP declined by 24% in 2000-2006. However, despite this significant energy intensity reduction, Russia still stays among the least energy efficient countries in the world.

Present-day Russia inherited an energy intense and energy inefficient economy from its Soviet past. However, lack of effective national energy efficiency policies, unbalanced energy pricing policies, lack of proper legislation and regulations, institutions and general public awareness of energy saving opportunities resulted in the conservation of high energy intensity in the last 15 years.

The Russian government is implementing power sector gradual liberalization program and announced substantial increase of domestic gas and electricity prices by 2011. If such energy price hike is not mitigated by energy efficiency improvements, affordability of energy services may shrink for many sectors, slowing down the economic growth.

The government is presently working on the modernization of a federal program targeted to promote energy efficiency. The G8 summit chaired by Russia in St. Petersburg in 2006 also raised the profile of the energy efficiency issues in the country. Yet, these new initiatives are facing many barriers, as Russia still tends to give a low priority to energy efficiency. Many believe, that being so rich in energy resources, Russia can address energy shortages by mere escalating energy supply. Others argue, that Russia is inherently more energy intensive due to its climatic conditions, and attempts to change the situation will negatively affect the economy and well-being of the people.

The objective of this study is to identify areas with high energy efficiency potential and gauge the costs and benefits to help Russia and the World Bank identify priority areas and prioritize energy policy initiatives. At a later stage, this information will be used to recommend specific policy actions to maximize the net benefits, taking account of possible impacts these policies may have on various groups of the Russian population.

Energy efficiency potential was last evaluated in detail for the USSR back in 1988 and 1990 using two approaches: screening detailed opportunities and costs to improve energy efficiency in every energy use sector[1] and cross-country comparisons of energy use efficiency[2]. Ever since that time, the figures have only endured arithmetic manipulations, and from 1992 they have been showing up unchanged in various government documents. Obviously, at this point these figures have very little to do with current Russian realities.

Development and implementation of energy efficiency policies require a more adequate mapping of the scale and structure of the energy efficiency potential. This report presents assessments of the technical, economic, and market energy efficiency potentials as of 2005. Energy efficiency potential is structured by economic activities and energy carriers in compliance with the matrix of Russia's integrated energy and fuel balance, which was also estimated in the framework of this effort.

Where it was possible (the electricity sector, a number of industrial plants), the energy efficiency potential was estimated based on the analysis of all facilities. In other instances (boiler-houses,

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[1] I. Bashmakov and V. Chupyatov. Energy Conservation. The main factor for reducing greenhouse gas emissions in the former Soviet Union. PNNL. December. 1991. USA; Fuel-, heat-, and electricity savings. V. Bykov Editor. VINITI. Moscow, 1989.

[2] I.A. Bashmakov and A.A. Beschinsky Editors. Comparative analysis of the energy sector development and energy efficiency in the USSR, USA, and West Europe in 1970-2000. Energy Research Institute. Moscow. 1990. Vol. 1 and 2.

buildings, etc.) it was estimated for a representative sample of facilities with further extrapolation for all energy consumers of this class in Russia.

Like evaluations of oil and natural gas reserves, estimates of the energy efficiency potential scale and structure are of a probabilistic nature. Therefore, in many cases, the potential ranges are presented for various energy resources and economy sectors. If the potential is presented in one number, this number is assumptions-related and the accuracy of the potential assessment is no better than ±5%. All assumptions for the energy efficiency potential assessments are thoroughly documented in this paper. This study has a number of other limitations, many of which result from unavailability and inaccuracy of data on energy consumption or energy consuming facilities, incomparability of Russian data with the information on energy use and specific energy consumption for other countries used for benchmarking. Among other factors, energy use and specific energy consumption depend on climate; scale and loads of energy using facilities; their time in operation; quality of maintenance and quality of processed materials; etc.

Data on energy efficiency implementation costs, taken from Russian and foreign publications, as well as from feasibility studies developed by CENEf and other companies in 2000-2007, were used to evaluate economic and market energy efficiency potentials. For example, heat supply systems assessments were based on the results of municipal utilities and heat supply systems renovation programs implemented in Khanty-Mansiysky Autonomous Okrug, Orlovskaya, Sakhalinskaya, Magadanskaya, Tomskaya Oblasts, Khabarovsky Krai, and more than 60 cities, for which thorough data collection had been accomplished for several hundreds heat supply systems. CENEf used the results of programs developed for the residential and public sector in dozens of Russian municipalities, including under the World Bank project in Rostov Oblast and Norilsk city, and under the EBRD project for health care institutions in Moscow. CENEf also used its own data obtained while developing more than 40 Regional Building Energy Efficiency Codes.

This paper was written for the World Bank by: I. Bashmakov (sections 1-7, 8.1-8.5; 8.7; 9); and CENEf experts K. Borisov (section 8.3), M. Dzedzichek (section 8.7), I. Gritsevitch (section 8.6), and A. Lunin (sections 8.1-8.2).

Authors are very grateful to the experts from Moscow World Bank and IFC offices G. Sargsyan, I. Gorbatenko, B. Nekrasov, K. Mokrushina, and S. Solodovnikov for detailed comments and suggestions allowed to improve the quality of this paper.

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2. “Russia – go energy efficiency!” (Summary of findings)

In 2000-2006, energy intensity of Russia’s GDP declined by 24%, and electricity intensity by 21%

⇒ These outstanding rates mainly result from structural changes and economy of scale effects, while loading up old, built back in the Soviet era, production facilities;

⇒ After full load is approached in a country lacking any federal energy efficiency policy, these energy efficiency improvement rates are no longer sustainable;

⇒ Since 2005, Russia started another economic transition: a switch from “recovering” to “investment” growth, which slowed down energy intensity improvements;

⇒ For electricity, the decoupling effect was quite visible until 2005, and nearly expired in 2006-2007.

But even after fantastic progress in recent years Russia is still ranking among the least energy efficient economies

⇒ In 2006, energy productivity of Russia’s economy was only 20% better, than in 1990;

⇒ In 2004, energy intensity of Russia’s GDP was twice over the global average and that of the U.S., and three times over the EU-15 and Japanese levels.

Since 2005, Russian economic growth has been clearly lacking energy. Russia is facing high economic risks of poor energy efficiency:

⇒ Poor energy efficiency in Russia may hamper further economic growth. In 2005-2006, only 16-21% of consumers’ applications for power grid connection were met;

⇒ Reducing energy exports and inability to play the geopolitical role of a reliable energy supplier;

⇒ Contribution to inflation provoked by expected dynamic gas, electricity, and heat price growth, not compensated by efficiency gains;

⇒ Declining energy affordability for many energy users;

⇒ Reduced competitiveness of Russian industries;

⇒ Growing frequency of accidents determined by additional load on worn energy generation, transmission, and distribution equipment;

⇒ Escalating capital costs of new energy supply facilities construction totaling to $US 1 trillion in 2006-2020.

Achieved rates of energy intensity decline are not sustainable, if not supported by specific policies

⇒ Unlike oil and gas resources, energy efficiency potential is distributed relatively evenly across regions and sectors of economy;

⇒ To maintain high progress in energy efficiency improvements Russia should “go energy efficiency” – use aggressive policies to realize the energy efficiency potential Russian economy is “pregnant” with.

The assessment has shown, that the Russian energy efficiency potential amounts to 45% of primary energy consumption in 2005, or 282 mtoe (294 mtoe with the elimination of gas flaring), or 57% of 2005 oil production, or 54% of 2005 natural gas production

⇒ This is about annual primary energy consumption in France, in the U.K., or in Ukraine, half of energy consumption in Japan, and over 2% of global primary energy consumption;

⇒ The potential is presented in Figure 2.1 and in a two-dimensional table (see Table 2.1): each cell shows potential for given energy-use activity or sector and for each of the seven energy carriers considered;

⇒ Corresponding energy-related CO_2 emission reduction is 793 million tons of CO_2 (about 50% of 2005 emissions), which exceeds the U.K. and the Netherlands joint annual emissions and is equal to 2.9% of global energy-related CO_2 emission.

The potential to improve final energy consumption (FEC) totals 154 mtoe

⇒ Technical energy efficiency improvement potential of buildings (68 mtoe, with 53 mtoe in residential and 15 mtoe in public and commercial buildings) scales up that high mostly because of space heating and hot water inefficiencies;

⇒ There is a substantial technical potential in the manufacturing (41 mtoe, which is above annual primary energy consumption in countries like Poland, the Netherlands, or Turkey). Russia is much behind many countries in the application of most energy efficient technologies in manufacturing. For example, only 15% of clinker was produced using the efficient dry method in 2005 compared to 100% in Japan, 93% in India, and 65% in the U.S. Specific energy consumption in pig iron production in Russia in 2005 was as high as back in 1991;

⇒ The technical potential in the transportation sector is 38 mtoe.

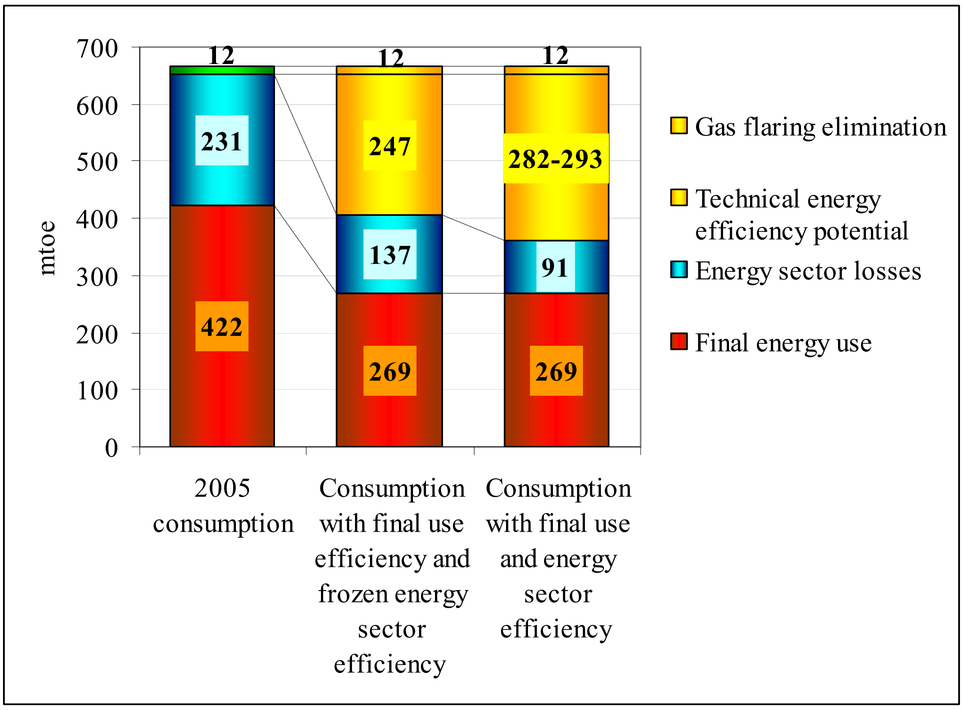


Figure 2.1. The energy efficiency resource (golden zone). The scale of Russian primary energy consumption reduction induced by the complete implementation of the technical energy efficiency potential

Table 2.1. Aggregated map of Russia’s technical energy efficiency potential (mtoe, $US billion and million t CO_2)*

Energy supply and consumption sectors	**Coal**	**Crude oil**	**Petroleum products**	**Gas**	**Other solid fuels**	**Electricity**	**Heat**	**Total**	**2005 energy consumption**	**Incremental investments to implement the potential*** **	**Potential CO2 emission reduction ******
Total, including the elimination of natural gas flaring	**58.34**	**2.50**	**34.65**	**192.09**	**6.92**			**294.49**		**324-357**	**793.3**
Elimination of natural gas flaring				**12.09**				**12.09**		**3-5**	**28.2**
Total primary energy supply	**58.34**	**2.50**	**34.65**	**180.00**	**6.92**			**282.40**	**653.02**	**321-352**	**765.1**
Electricity generation	23.87	0.00	2.53	64.88	1.73			*93.01*	*186.75*	106	254.3
Heat generation	23.31	0.46	7.38	71.02	3.47	1.82		*107.45*	*194.00*	8	282.5
Fuel production, transformation, transmission, and distribution.	2.15	2.04	0.17	5.92	0.07	10.08	20.86	41.29	85.21	19	29.1
Total final energy consumption	**9.01**	**0.00**	**24.57**	**38.18**	**1.65**	**19.52**	**60.72**	**153.64**	**422,38**	**188-219**	**199.2**
Agriculture and forestry	0.02		1.53	0.08	0.04	0.73	0.50	2.90	6,21	2	4.9
Fishery									0,04		0.0
Mining		0.00	0.14			0.37	0.60	1.12	7,19	2	0.4
Manufacturing	8.41		1.19	9.86	1.40	7.72	12.90	41.49	109,54	35	60.2
Construction	0.00		0.20	0.01	0.01	0.25	0.04	0.50	1,70		0.6
Transport	0.00	0.00	21.29	14.95	0.00	1.67	0.39	38.30	94,40	124-130**	99.1
Municipal utilities	0.00		0.01	0.00	0.00	0.36	0.34	0.72	3,61	25-50	0.1
Services sector	0.01		0.02	3.12	0.01	4.60	7.44	15.20	36,31		7.4
Residential	0.57		0.18	10.16	0.19	3.82	38.50	53.42	108,24		26.5
Non-energy use									45,73		

Numbers in italic are for total energy inputs to power and heat generation. Final energy consumption and those numbers are not additive due to the fact that both sectors have positive energy outputs - correspondingly power and heat, which are used by final consumers (see Table 7.1 below).

*Potential in energy transformation sectors includes both the reduction of energy carriers in final use activities and technological advancing of transformation technologies.

**Incremental investment costs for automobile transport are about $US 100 billion.

*** Incremental investments in energy efficiency of power and heat generation were assessed for 2005 production levels. They should be downsized by about $US 40 billion to reflect reduced heat and power demand due to energy efficiency improvements by final users and fuel production and transformation sector.

Source: Estimated by CENEf.

**** Emission reductions originated in different end-use sectors due to electricity and heat demand, as well as transmission and distribution losses reductions, are accounted for in power and heat generation sectors.

The potential doubles, when associated energy use reduction in the energy production and transformation sector, as well as advancing of this sector technologies, are accounted for

⇒ The effect of end-use energy consumption reduction is multiplied due to the reduced demand for final energy to be produced and delivered by the energy sector. This indirect effect equals 94 mtoe. Improved efficiency in the energy sector itself allows to reduce primary energy consumption by additional 46 mtoe. The distribution of integrated technical energy efficiency potential (adjusted for both indirect effects and technical improvements) by sectors is presented in Figure 2.2;

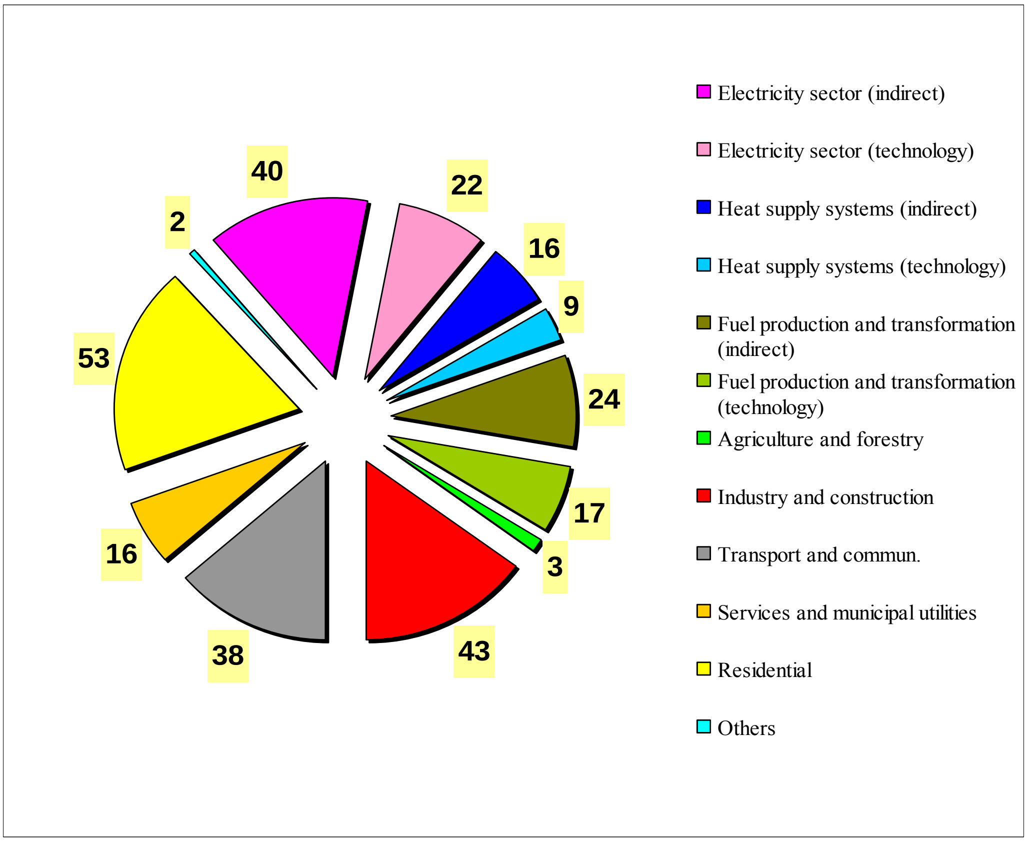
⇒ The efficiency of Russian condensing power stations is 36% versus average OECD 38% efficiency for coal-fired and 41% efficiency for gas-fired plants, with the best practices of nearly 57%;

⇒ Average efficiency of Russian industrial boilers is 67% versus 95% best world practices;

⇒ Reduction of final electricity use by 1 toe leads to the total reduction of primary energy use by 4.7 toe; reduction of final district heat use by 1 toe results in the reduction of primary energy use by 2.8 toe; reduction of final fuel use by 1 toe brings along reduction of primary energy use by 1.1 toe;

⇒ The potential in both heat and electricity generation is the sum of efficiency improvements at the generation facilities and the result of power- and heat end-use reduction. In electricity generation, the potential is 93 mtoe, and in the heat supply sector 107 mtoe;

⇒ The potential of fuel production and transformation efficiency improvement equals 41 mtoe.



Energy savings in the energy sector reflect not only technical improvements in power and heat generation, energy transformation, transmission and distribution (technology), but also reductions induced by savings in end-use consumption (indirect).

Figure 2.2. Distribution of integrated energy efficiency potential by sectors (mtoe)

Improving the efficiency of electricity use allows it to reduce power consumption by 340 billion kWh, or 36%

⇒ The major potential is in buildings (97 billion kWh) followed by manufacturing (90 billion kWh);
⇒ Reduction of electricity use through modern power generation technologies to the best world levels will bring down fuel consumption in electricity generation by 93 mtoe.

Improving the efficiency of final district heat use and reduction of distribution losses results in potential reduction of heat consumption by 844 million Gcal, or 53%

⇒ The major potential is in residential buildings (385 million Gcal) followed by heat transmission and distribution losses, as well as heat use in the energy sector (237 million Gcal) and by manufacturing (129 million Gcal);
⇒ Reduction of electricity use through modern power generation technologies to the best world levels will bring down fuel consumption in electricity generation is down by 106 mtoe.

Natural gas consumption reduction potential equals 240 billion m3, which is around 55% of domestic consumption in 2005 and substantially exceeds Russian 2005 natural gas export

⇒ 47 billion m3 of that potential originates from improved gas end-use efficiency, 15 billion m3 from the use of flared associated gas; 89 billion m3 from reduced district heating demand and technical progress in heat generation, 81 billion m3 from reduced electricity demand; and the rest 8 billion m3 come from the progress in fuel production and transformation technologies and improved transmission and distribution efficiencies;
⇒ If the equivalent of natural gas consumption reduction is exported at the 200-250 $US/1,000 m3 price, it may bring about $US 48-60 billion in additional export revenues;
⇒ If accompanied by export of saved crude oil (2.5 mtoe) at 100 $US/barrel and of saved petroleum products (35 mtoe), additional $US 28 billion of export revenues may be expected.

Screening major technical options to implement the energy efficiency potential allowed it to identify top 15 technologies capable of bringing large energy savings at reasonable costs:

⇒ Combined cycle natural gas turbines;
⇒ Efficient gas boilers and clean coal-fired boilers;
⇒ Renovation of heat supply networks with partial decentralization of district heating systems in areas with low heat load densities;
⇒ Renovation of electric grids;
⇒ Improving oil refining technologies;
⇒ Improving gas transportation efficiency and utilization of associate gas;
⇒ Dry and semi-dry clinker production technologies;
⇒ Pulverized coal injection technologies in blast furnaces and coke dry quenching technology;
⇒ Efficient electric motor systems;
⇒ Efficient steam transportation and steam consuming systems;
⇒ Heat recovery, including heat pumps;
⇒ Hybrid automobiles;
⇒ Efficient windows and housing weatherization;
⇒ Efficient lighting;
⇒ Energy metering.

The economic potential amounts to 215-230 mtoe, while the market potential totals 188-200 mtoe with expected 2010 energy prices and 130-143 mtoe with the 2007 energy prices

⇒ Economic energy efficiency potential was assessed using 6% discount rate and the opportunity cost of 200 $US/1000 m^3 export natural gas price. In addition, 10 euro/t CO2 carbon emission reduction price was accounted for;

⇒ Market energy efficiency potential was assessed using a 12% discount rate (50% for some measures in the residential sector) and mid-2007, as well as expected 2010, domestic energy prices;

⇒ Both potentials were assessed against the 2005 baseline in corresponding sectors. They will scale up by 10-17%, if the reduction of energy use in the energy transformation sectors determined by a lower final energy demand is accounted for.

In many instances, additional energy efficiency comes at no cost, or at a very low incremental capital cost

⇒ Analysis of new buildings under construction in Moscow has shown, that erection of more efficient buildings does not imply any additional costs; so higher costs are determined by other factors, such as the number of floors, building geometry and orientation, the costs of materials, labor costs, etc.;

⇒ For new refrigerators and many other appliances available in the Russian retail market, there are no additional costs for higher energy efficiency. So additional energy efficiency is a “free lunch” for motivated customers;

⇒ Installation of automatic process control systems allows for electric arc steel production increase by 15-20% with simultaneous 7-14% reduction of specific energy consumption;

⇒ Investment in efficient lighting costs 0.07-0.14 ruble/kWh of saved electricity versus 2 rubles/kWh residential electricity price;

⇒ Procurement of inefficient power capacity through efficient lighting or weatherization programs requires 20-60 $US/kW versus 700-2,000 $US/kW of additional capacity cost.

Primary energy production increase in Russia in 2006-2020 will hardly exceed 60-140 mtoe. In other words, the economically viable energy efficiency resource exceeds (at least two-fold) the expected increase in primary energy production

⇒ Comprehensive implementation of the energy efficiency potential may allow for 8-10 years of Russian economic development without additional primary energy consumption;

⇒ On the contrary, attempts to keep high economic growth rates with conserved double over global average energy intensity are bound to activate the hampering role of the energy sector;

⇒ There are historical precedents in regions with very strong energy efficiency policies: in California, per capita GDP went up by 80% in the last 30 years, while per capita electricity consumption kept stable at about 7,000 kWh per annum, or close to the present Russian value, while GDP per capita in Russia is only 20% of that in California;

⇒ 1 toe of primary energy delivered to support economic growth generated by energy efficiency measures requires on average 2-3 times less capital, than the same amount of energy delivered through additional supply options;

⇒ If only cost-effective measures are implemented, this ratio scales up 4-6-fold.

The federal government should take the lead in exploiting resources from Russian “energy inefficiency hills”

⇒ Savings potential through energy- and water efficiency improvements in public buildings accounts to $US 3.5-5.0 billion, including at least $US 1.2 billion per annum in 2006 prices in federal buildings alone;

⇒ The effectiveness of energy efficiency measures will additionally increase in the years to come due to the electricity and escalating natural gas tariffs.

3. Energy efficiency of Russia's economy: evolution of main indicators

Energy intensity of Russian GDP in 2000-2006 declined by 24%, and electricity intensity by 21%. These outstanding rates mainly result from structural changes and economy of scale effects, while loading up old, built back in the Soviet era, production facilities. After full load is approached in a country lacking any federal energy efficiency policy, these energy efficiency improvement rates are no longer sustainable.

After Russia launched transition to a market economy, energy intensity of Russian GDP grew up by 20% (in 1990-1995), determined by a deep economic crisis, and then stabilized at this level[3] during a recession phase, which lasted through 1998 (see Fig. 3.1). Energy intensity growth effect was mainly determined by declining load of production facilities (reverse effect to the economy of scale, when reducing load was not accompanied by a decline in non-production related energy use) and relatively stable energy consumption in buildings against the background of declining GDP.

Revival of Russian economy since 1999 was accompanied by dynamic reduction of GDP energy intensity and provided reverse impacts of the above factors. The economy of scale factor was the major driving force of specific energy intensities reduction. Structural changes, introduction of new technologies both in newly created and renovated facilities also contributed to the GDP intensity reduction. As a result, GDP energy intensity was showing 4.6% annual decline in 2000-2006, thus largely decoupling energy demand and economic growth.

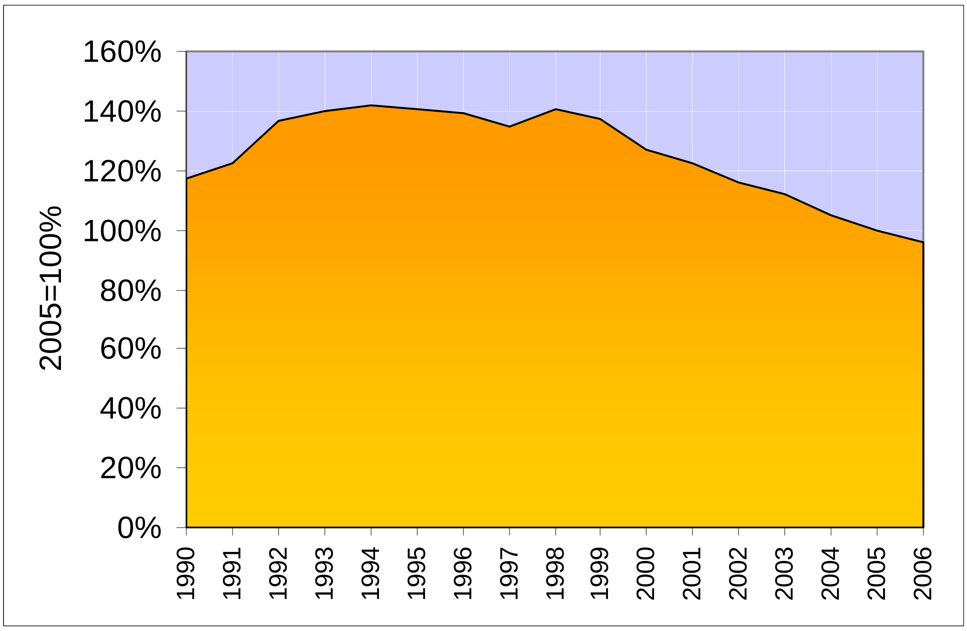


Figure 3.1. Energy intensity evolution of the Russian GDP: 1990-2006

In 2006, energy productivity of Russian economy was 20% better, than in 1990, but even after a fantastic progress in several recent years Russia is still ranking among the least energy efficient economies: in 2004, its GDP energy intensity was twice over the global average and that of the U.S., and three times over the EU-15 and Japan levels (see Fig. 3.2).

After 2005, Russia launched another economic transition: from the "recovering" to the "investment" growth, which slowed down energy intensity improvements. The possibility to continue economic growth by loading production facilities built back in the Soviet era is exhausted: in 2006-2007, in the most energy intensive industries they run at 90-100% load. This

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[3] Russian Energy Picture. January-March 1997. CENEf.

diminishes decoupling effects and accelerates domestic energy and electricity demand growth against the background of limited no-load supply capacities. Substantial investments were allocated "to buy time" by adding large power and natural gas supply capacities. But no one can "buy time", and the overloaded investment complex of the Russian economy is unable, in a given limited time frame, to productively absorb significant additional investments in energy supply without escalating price growth for investment goods and services, and so it is unable to build enough additional capacities to supply energy to meet the growing energy demand. At the same time, investment activities growth speeded up the development of energy intensive industries and thus accelerated even further energy demand growth.

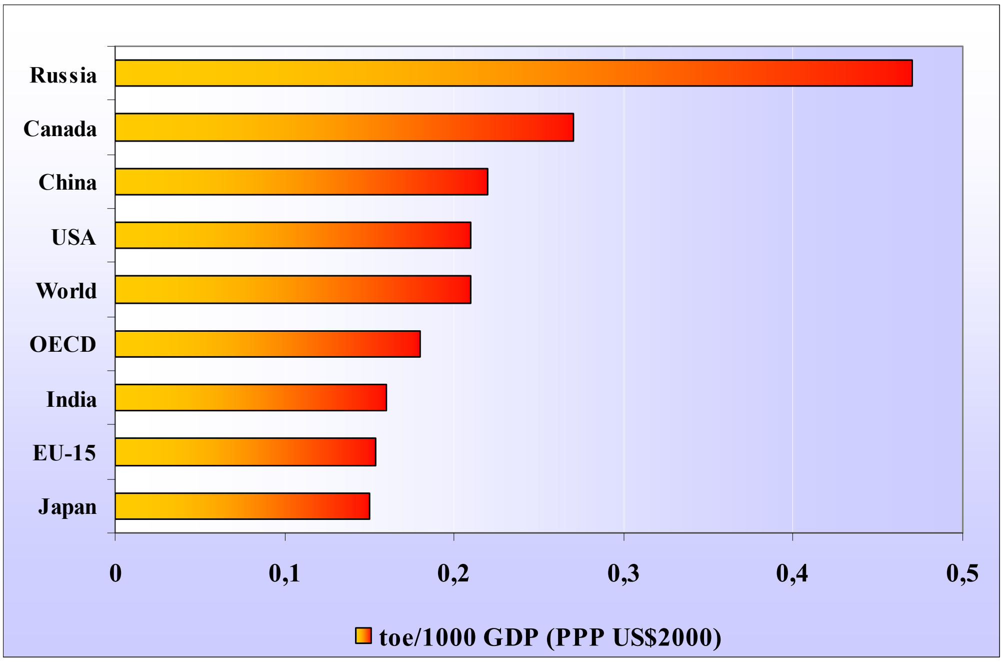

Figure 3.2. "Russia, go efficiency" finger point: cross-country GDP energy intensity comparisons. 2005 Energy intensity of GDP

For electricity, the decoupling effect was quite visible before 2006, and nearly expired in 2006-2007. But in 2006, overall electricity consumption in Russia went up by record 4.2% and end-use consumption by 5.3%, accompanied by a change in the composition of demand drivers. In the first quarter of 2007, the climate factor contributed to the reduction of electricity consumption by 20 billion kWh compared to the first quarter of 2006. Accounting for this effect, the conclusions that the contribution of technological factors to slowing down electricity demand is diminishing, and that the contribution of accelerated energy intense industries development to fostering electricity demand is growing, stay valid for 2007.

4. High economic risks of poor energy efficiency

Since 2005, Russian economic growth has been clearly lacking energy. In some regions, applications for new connections to the power grid are only met by 10-20%, and with natural gas grid connection applications the situation is much worse, even for such large energy consumers as power plants.

Poor energy efficiency in Russia may hamper further economic growth. In 1998-2005, even 4.6% average annual reduction of GDP energy intensity failed to stop dynamic energy demand escalation. Shortage of natural gas and electric capacity is, like an epidemic, advancing to more and more regions, and has become a factor determining “the limits of growth”. Energy shortages are not only the result of fast economic growth, but also of natural gas, electricity, and heat use inefficiencies. Presently, business is moving to locations with some energy capacity reserves.

Russia will face high economic risks, if it keeps poor energy efficiency any further:

⇒ Slowing down economic growth or (and) reduced energy exports;

⇒ Inability to play the geopolitical role of a reliable energy supplier or/and reduced national energy security resulting from inability to meet growing energy and capacity demand;

⇒ Reduced technical accessibility to gas and electricity supply systems determined by capacity and resource shortage and growing connection charges;

⇒ Contribution to inflation resulting from gas, electricity and heat price growth, not compensated by efficiency gains;

⇒ Declining energy affordability with the pressure to exceed utilities’ affordability thresholds for households against the background of low comfort in old buildings with obsolete engineering infrastructures;

⇒ Growing burdens on municipal, regional, and federal budgets to pay the energy bills of public facilities and to support low-income households in paying their energy bills;

⇒ Reduced competitiveness of Russian industries and Russian regions, lacking spare energy capacities;

⇒ Inability of power and heat utilities to “press time” and rapidly mobilize enormous investments to meet growing gas and electric capacity demand, while facing growing operational costs determined by natural gas prices growth;

⇒ Additional load on worn-out equipment increases the risk of growing frequency of accidents;

⇒ Growing capital costs of energy supply facilities construction, lack of natural gas for newly commissioned facilities and a switch to coal with consequent enormous environmental pollution and GHG emission growth risks.

The risks of low economic affordability are enforced by already announced escalation of regulated energy prices (natural gas price for final users in 2011 is expected to 2.7-fold exceed the 2006 level).

To sustain economic growth momentum, energy efficiency improvements should be able to additionally reduce energy demand by 200-600 mtce. With the expected range of GDP annual growth rates 5-7% and annual reduction of GDP energy intensity, say, by 2,5%, in 2020 additional 300-560 mtoe will be needed to meet energy demand against the background of expected additional primary energy supply not exceeding 150-200 mtoe until 2020.

The question is: does Russia have such potential, and is it able to use it, or will energy export be sacrificed to support domestic energy consumption growth?

5. Previous experience in assessing Russia's energy efficiency gap and potential

Three comprehensive assessments of energy efficiency improvement potential were made in late 80'es – early 90'es for the Former USSR and then Russia. The first study, led by V. Chupyatov, was based on the data collected from all ministries and their subordinate scientific institutions and evaluated both potentials and costs to improve energy efficiency in all sectors of the Soviet economy. This study estimated total technological potential at 22 PJ, or 525 mtoe (expanded to 29 PJ, or 690 mtoe, if measures where the energy efficiency effect was not a primary goal of investments are included), while economic potential was evaluated at 84-96 mtoe in the electricity generation sector; 27-64 mtoe in the energy sector (fuel production and transformation); 123-143 mtoe in the industrial sector, and 46-88 mtoe in the building sector, so totaling to 300-400 mtoe, or 57-76% of the technological potential[4]. Later on, part of this assessed potential was allocated to Russia based on its share in corresponding economic activities of the USSR. It totaled 245-320 mtoe[5].

In the government documents, this estimate has never changed since 1993. In the "Energy Strategy of Russia", approved by the federal government in 2003, the potential was still cited equal to 250-300 mtoe[6]. In this document, the potential was split out by three cost categories: 20% with the costs below 29$/toe; 65% with the costs between 29 and 72$/toe, and the rest 15% with the costs over 72$/toe.

The second study, led by I. Bashmakov and A. Beschinsky, was mainly targeted to evaluate the energy efficiency gap with developed countries and to identify explanatory factors based on comprehensive and detailed cross-country comparisons of energy efficiency indicators. It concluded, that[7]:

- ⇒ In the energy sector, even accounting for a larger share of energy export in the energy production of the FUSSR, energy intensity (energy production and transformation) per unit of GDP was 70% above that of the USA and 2,4 time over the Western Europe level;
- ⇒ In industry, for 27 compared products, the potential to improve energy efficiency was estimated at least at 125-155 mtoe, i.e. half of energy consumption for the manufacturing of these products in 1985 (265 million tce);
- ⇒ Contribution to this gap of higher material intensity of the Soviet industry was 45%, of less progressive technological structure 35%, and of higher specific energy consumption of similar technologies due to poor energy management was another 20%;
- ⇒ Transport in the USSR was about as energy efficient as in Western Europe and Japan (higher freight intensity in the USSR was compensated by a more efficient transportation mode structure), but more efficient, than in the USA;
- ⇒ In the residential sector, after housing structure is made comparable, specific energy consumption for space heating of 1 m^2 of living space was found twice less efficient in the USSR compared to the USA.

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[4] I. Bashmakov and V. Chupyatov. Energy Conservation. The main factor for reducing greenhouse gas emissions in the former Soviet Union. PNNL. December 1991. USA; Fuel-, heat- and electricity savings. V. Bykov Editor. VINITI. Moscow, 1989.

[5] Federal target program "Energy conservation in Russia". RF Ministry of fuel and energy. Russian energy efficiency agency. Moscow, 1998.

[6] Russia's Energy Strategy until 2020. Government Executive Order No. 1234-r of 28.08.03.

[7] I.A. Bashmakov and A.A. Beschinsky Editors. Comparative analysis of the energy sector development and energy efficiency in the USSR, USA, and West Europe in 1970-2000. Energy Research Institute. Moscow, 1990. Vol. 1 and 2.

This study provided no cost data on the implementation of the energy efficiency potential. It should be noted that both studies identified similar potential in the industrial sector, which accounted for about half of overall energy use in this sector in late 80-es.

The third study estimated direct and indirect energy efficiency potential for the FUSSR and Russia, as well as implementation costs[8]. It concluded that direct and indirect potential to save energy prior 2005 was 472 mtoe plus additional potential from structural changes (234 mtoe). So the total potential was estimated at 706 mtoe, or 51% of 1990 USSR's primary energy consumption. The Russian share of this potential for 1992 was estimated at 497 mtoe. Total capital costs of the implementation of this potential in 1992 prices were estimated at $US 4 billion. It was also concluded, that implementation of this potential would release 200 billion m3 of natural gas for export and produce 37% of CO2 emission reduction.

The latest effort to estimate national energy efficiency potential was made by CENEf in 2006 for the RF Ministry of Economic Development and Trade[9]. Only one week was given to CENEf for this express-study, so obviously, no detailed evaluation was possible for the industrial sector. This express-assessment showed, that the technological energy efficiency potential amounts to 38-40% of primary energy consumption, or to 260-275 mtoe.

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[8] I. Bashmakov. Costs and benefits of CO2 emission reduction in Russia. In "Costs, Impacts, and Benefits of CO2 Mitigation. Y. Kaya, N. Nakichenovich, W. Nordhouse, F. Toth Editors. IIASA. June 1993.

[9] I. Bashmakov. Gas: exporting the energy efficiency resource. Gazovy biznes. November-December 2006.

6. Methodological issues framing this study

New energy consuming technologies can be defined in the following way[10]:

⇒ **Breakthrough** – not yet proven, in the stage of pilot implementation, with a further need for RD&D support for practical testing and advancing;

⇒ **Proven, yet not cost-effective,** needing support to overcome cost barriers (learning-by-doing through larger-scale application);

⇒ **Proven and cost-effective,** taking the market niche without specific governmental support.

This study considers proven technologies and includes a brief discussion of breakthrough technologies.

Another principle of technologies categorization is by specific energy use to produce a unit of product or service:

⇒ **"Theoretical minimum"** - specific energy consumption required by thermodynamic laws to perform necessary work or material transformation;

⇒ **"Practical minimum"** – the best practically achieved specific energy consumption worldwide with application of proven technologies[11];

⇒ **"Actual use abroad"** – average or the most wide spread specific energy consumption in other countries;

⇒ **"Russian best"** - the best practically achieved specific energy consumption in Russia;

⇒ **"Russian average"** - average specific energy consumption statistically observed and reported for Russia. It was used to assess the energy efficiency potential;

⇒ **"Russian worst"** - the least energy efficient unit statistically observed and reported for Russia.

There are quite a few concepts and definitions of the energy efficiency potential. Three definitions of energy efficiency potential were used in this study:

Technical (technological) potential is estimated with an assumption that the whole existing equipment stock is immediately replaced with the best available practically applied models. In other words, specific energy consumption will overnight go down from "Russian average" to "practical minimum". Technological potential only provides hypothetical energy efficiency opportunities, with no account of implementation costs and limitations.

Economic potential is a part of technical potential, which can be cost-effectively implemented, using public cost-effectiveness criteria: discount rates, opportunity costs (export price of natural gas), environmental and other indirect effects and externalities, etc. In this study a 6% discount rate is used for assessing the economic potential. Of all ancillary benefits, for assessing the economic potentials at least two were used in this study: indirect energy savings in energy supply and transformation sector determined by reduced final energy consumption and the costs of GHG emission reduction determined by measures implemented. It takes time to realize the economic potential. In this study, economic potential was estimated with an assumption that the whole existing equipment stock is immediately replaced with the best available economically sound models with no consideration of how this replacement can be distributed in time accounting for capital stock turnover limitations or time needed to scale up production of new technologies.

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[10] Energy Technologies status and Outlook.

[11] Major most recent sources are: E. Worrell, M. Neelis, L. Price, et al. World best practice energy intensity values for selected industrial sectors. LBNL-62808. June 2007. and Energy Technology Perspectives 2006, Scenarios and Strategies to 2050. OECD/IEA. 2006.

Market potential is a part of economic potential, which can be cost-effectively implemented using private cost-effectiveness investment decision-making criteria and under existing market conditions, prices and limitations. Real market situation determines availability of technical opportunities, investment and other resource allocation, decision-making rules, practices and criteria. There are three major lines of division with economic potential: decision-making practices (centrally planned economies always use energy twice or thrice less efficiently compared to market economies, other things equal); discount rates, and energy prices (no opportunity costs or externalities are accounted for in private decision-making, if they are not incorporated in market prices). In this study two sets of discount rates were used to assess the costs of saved energy: 12% of all energy consumers excluding households, and 50% for households. No indirect energy savings are taken into account while evaluating the market potential. Depending on the decision of the Russian government to apply flexible Kyoto instruments, economy in general, as well as private companies, may additionally benefit from implementing energy efficiency projects by selling GHG emission quotas or JI project-generated emission reductions. In this study, the average price of 10 euros per 1 t CO2 (13.675 $US/1 ton CO_2) was used to account for the effects of flexible Kyoto instruments on the increase of both economic and market energy efficiency potentials.

Only part of the market potential is information-supported. **Information-secured potential** is a part of the market potential existing in the form of feasibility studies or individual decisions based on estimates. Finally, there is a financial-supported part of the energy efficiency potential. **Financial-secured potential** is a part of the information-supported potential (i.e. accepted for financing feasibility studies), for which funding is secured. Finally, exactly this limitation determines, which projects will be implemented.

As a rule, data from industrial companies' investment plans, from special energy efficiency studies, as well as from audited Russian facilities were used to determine the technical energy efficiency potential and related costs and benefits. Based on these projects, a list of energy efficiency technologies and measures was developed, and then, with an account of applicability for other similar facilities, the result was extrapolated for the whole stock of such facilities. Much information on "practical minimum" and "actual use abroad" was borrowed from the most recent literature on energy efficiency potential assessments and on specific technologies.

While identifying the economic and market potentials, only cost-effective part of the technical potential was taken into account based on the analysis of energy conservation costs curves (see below) built under different assumptions with applied social and private discount rates, given existing and expected by 2010 fuel prices and heat and electricity tariffs.

In this paper, where it was possible and practical, an estimate of Russia's energy efficiency potential was based on the actual energy efficiencies of energy consuming facilities distribution curves from the "Russian best" to the "Russian worst". All units/facilities were split into three groups:

- ⇒ Green – most efficient currently operating units/facilities with or close to "**practical minimum"** of specific energy consumption;
- ⇒ Yellow – units/facilities with specific energy consumption above the green zone, but below "**actual use abroad" (**in some instances, below the "Russian best"), which was considered as acceptable for the first two coming decades of the XXI century;
- ⇒ Red – all facilities with specific energy consumption above **"actual use abroad",** which urgently need replacement or upgrade to release the energy efficiency improvement potential.

The efficiency potential was estimated as the result of "shaving off" the red zone (low range) and both red and yellow zones (high range) of "Russian inefficiency hills". The potential is also equal to the gap between "practical minimum" minus "Russian average" multiplied by the scale of given product or service output in 2005. In many instances, it was not possible (for statistical and commercial classified information reasons) to show distribution of facilities by specific energy consumption. In such instances distribution along specific average energy consumption observed for separate Russian regions was used as a proxy.

While estimating the costs of saved energy it should be recognized, that energy consuming facilities vary by scale, climate and load, quality of general energy management and quality of maintenance. In industry, some more items may be added to this list, such as quality of processed materials or conditions of processed or mined natural resources deposits, rate of recycling products, etc. All those factors influence specific energy consumption and consequent energy savings. Therefore, such exercise is to be done with some precaution. Smaller units may have higher specific energy consumptions, but they may have other economic benefits (lower product transportation distances, etc.). This issue was checked using data on inventory of electric arc furnaces (EAF) for the USA for 1997[12]. EAFs with nameplate capacity above 200 t/year can be as efficient, as those with the capacity over 1,000 t/year. For low capacity units, the range of specific energy consumption varies widely (see Fig. 6.1). Many smaller units clearly have specific energy consumption below the national average. So assessment based on the gap between "practical minimum" and "national average" works even for smaller facilities. The age of facility and the level of advancing the technology modification appeared to be as important, as unit capacity (see Fig. 6.2). So, most modern facilities have specific energy intensity much below that of large ones built 30-40 years ago.

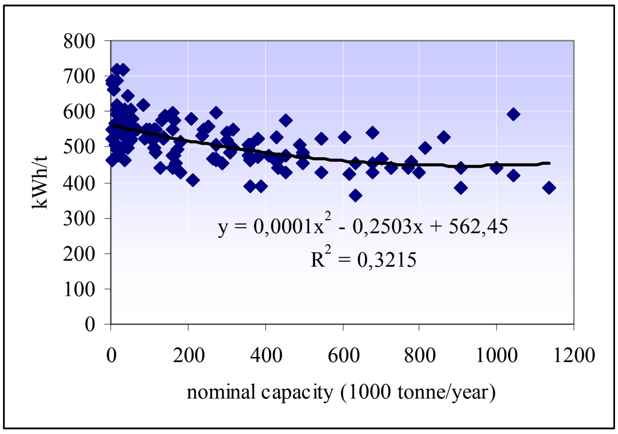

Figure 6.1. Relationship between specific energy consumption and production capacity

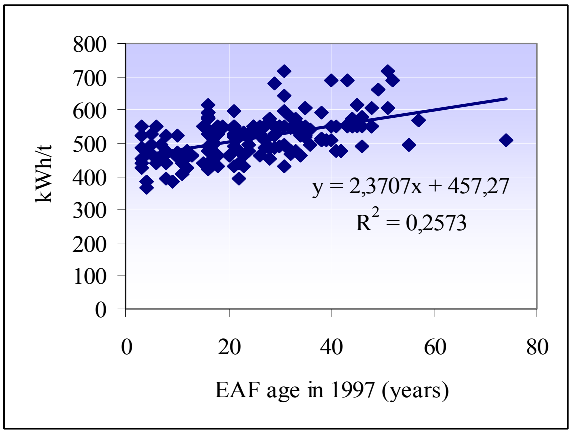

Figure 6.2. Relationship between specific energy facility time in operation

To assess the economic viability of energy efficiency options, the costs of saved energy index, or the cost of energy efficiency supply, was used. It is compared with energy prices and is estimated by the following formula:

Costs of saved energy (CSE): $$CSE = \frac{CRF * Cc + Cop}{ASE} \qquad (6.1);$$

with Cc – capital costs of technology; Cop – variation of current costs or (if there are additional effects - other costs savings, increased output, improved quality, etc. - this component is negative); ASE – annual savings of energy; CRF – capital recovery factor, which is calculated as follows:

$$CRF = \frac{dr}{1-(1+dr)^{-n}} \qquad (6.2);$$

with *dr* - discount rate (0.06; 0.12; and 0.5).

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[12] Data borrowed from: Ernst Worrell, Natan Martin, and Lynn Price. Energy Efficiency and Carbon Dioxide Emissions Reductions Opportunities in the U.S. Iron and Steel Sector. Ernest Orlando Lawrence Berkeley National Laboratory, University of California. July, 1999.

Importantly, some studies use private discount rate as high as 30-50% to assess the market potential; such high values reflect the preference for short paybacks when energy efficiency financing is evaluated[13].

In this analysis, *Cop* includes annual change in operational and maintenance costs, discounted avoided capital costs, and annual production benefits (additional production or reduction of products losses due to frequent failure of obsolete equipment). Comparing the costs of saved energy with current or expected energy prices and tariffs allows identifying the economic viability of energy efficiency measures. Since the formula uses discount parameters, which may differ for various market agents, the market energy efficiency potential may considerably differ from the economic energy efficiency potential.

There are several methodological problems related to the evaluation of cost-effectiveness of energy efficiency investments:

⇒ Availability of additional effects or costs (ancillary costs or benefits). Capital investments may be made not only (if at all) in energy efficiency improvements, but in addressing other problems, for example, to improve energy supply reliability through the replacement of worn-out energy equipment, and energy efficiency improvement may just be a side-effect. If this is the case, capital investments in energy efficiency are to be regarded as incremental costs, if more efficient equipment is more expensive[14];

⇒ Additional effects should be evaluated in monetary terms whenever possible and presented with a negative sign while assessing variation of current costs in (6.1);

⇒ Reduction of distribution losses and of production costs in the fuel&energy sector (for example, reduced fuel consumption by electricity plants, or diesel fuel and electricity consumption by coal mines, etc.) are one of additional side-effects of end-use energy efficiency improvements. These parameters can be assessed quantitatively by applying a method described below;

⇒ In the market there may be no samples of old models to replace similar worn equipment, against which incremental costs should be estimated;

⇒ Many energy efficiency projects generate savings of several energy resources and water. Therefore, it seems correct to take capital investments to overall energy efficiency effect, and to account water savings in current cost savings;

⇒ Potentially, energy efficiency improvement projects can generate significant positive environmental effects, which, if monetized, can be accounted for with negative sign in Cop parameter. For example, the measure related to GHG emission reductions can be evaluated using average GHG emission reduction price in EU ETS.

Most estimates in equipment renovation projects are made without assessing incremental costs, because the project must provide financing for equipment purchase without breaking down equipment costs by elements used to address investor's specific economic needs. As a result, the costs of the project component specifically aimed at energy efficiency improvement are often considerably overestimated. As CENEf's experience shows, project evaluations 2-4 times overestimate the real incremental costs of saved energy.

A special study on energy efficiency project ancillary benefits for 81 projects in the USA concluded: ancillary benefits escalated overall project effects by 44%, and reduced the projects

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[13] Energy Efficiency and Carbon Dioxide Emissions Reductions Opportunities in the U.S. Iron and Steel Sector. Ernest Orlando Lawrence Berkeley National Laboratory, University of California. July, 1999; K. Train. Discount rates in comsumers' energy related decisions: a review of the literatiure. *Energy*. Vol. 10, No. 12, pp. 1243-1253, 1985.

[14] This difference may be negative, too.

simple paybacks to less than 1 year. It is exactly the inclusion of ancillary benefits that makes the net negative CSE possible[15].

A simple example illustrates the proposed approach: purchasing a compact fluorescent lamp (CFL) to replace an incandescent lamp. We assume that a 11W CFL costs 67 rubles, while a 60W incandescent lamp costs 20 rubles. If residential consumers' discount rate is 50%, lighting is used 2,000 hours/year, and the lifetime of an incandescent lamp is 1,000 hours (one more incandescent lamp will be needed before the end of the year) versus 10,000 hours for the CFL:

$$CSE = \frac{0.58*(67-20)-20}{0.049*2000} = 0.07 rubles;$$

in other words, the costs of 1 kWh saved is only 7 kopeks (given over 2 rubles/kWh tariff in Moscow). If the estimates were based on full, rather than incremental, capital intensity, the costs of saved energy would be 19 kopeks, i.e. almost 3 times higher. With social discount rate (6%) the corresponding CSE becomes negative -9 kopeks, because annualized incremental capital costs (0,24*47) are below incandescent lamp replacement costs.

Each measure corresponds to its cost of energy saved, and for each sector an energy cost savings curve should be built. The cross-point of this curve and average energy price for this sector will help assess the cost-effective part of the energy efficiency potential.

The costs of saved energy were compared with the 2007 and expected 2010 energy prices. In mid-2007, average domestic natural gas acquisition price was 1,801 rubles/1000 m^3, or 70.35 $US/1000 m^3, or 87 $US/toe. The decision is made that in 2008-2010 it would double or reach 141 $US/1000 m^3. The RF Ministry of economic development and trade expects 2010 export natural gas prices 170-236 $US/1000 m^3. Offering large natural gas saving potential (exceeding present Russian natural gas export) for sale would reduce natural gas prices at international markets. So to reflect opportunity costs the middle range of expected natural gas export price for 2010 was used, which corresponds to 200 $US/1000 m^3 or 248 $US/toe. The 2010 domestic price for coal was accepted equal to 72 $US/toe; for petroleum products – 240 $US/toe, for heat – 390 $US/toe, and for electricity – 1095 $US/toe. When 10 euro/CO$_2$ price was used for associated emission reduction, price for natural gas as adjusted upwards by 18.3 $US/toe, for petroleum products – 25.2 $US/toe; for coal – 30.9 $US/toe; for heat – 25.8 $US/toe and for electricity – 59.6 $US/toe.

Energy efficiency improvement activities and investments can be also categorized as low cost **housekeeping/energy management measures** (metering, energy consumption data collection and processing, etc., contributing to 15-20% of overall energy savings); **replacement investments** (made for the extension or maintenance of the production capacity, providing 25-35% energy savings); **dedicated energy saving investments** (retrofits mainly to reduce energy costs, 45-60% of savings)[16]. For the replacement investments *Cop* in formula 6.1 above may include additional output after production processes replacement, or reduction of capital repair costs needed to keep equipment in operation escalated with equipment in operation time. In the example above, the cost of expired incandescent lamp may be considered as avoided capital repair cost.

Approaches to aggregate sectoral energy efficiency potentials through the whole energy production chain down to final consumer deserve a special attention. There is no abundant literature on techniques to integrate sectoral energy efficiency potentials or on approaches to translate reductions of end-use energy consumption into reduction of primary energy consumption. Such transformation is regularly performed only for electricity. It also should be done for district heating, and it can be done for all activities in the energy production and transformation sector and even for

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[15] R. Lung, A. McKane, R. Leach, D. Marsh. Ancillary Savings and Production Benefits in the Evaluation of Industrial Energy Efficiency Measures, 2005. ACEEE 2005.

[16] M. Rietbergen, J. Farla, K. Blok. Quantitative evaluation of voluntary agreements on energy efficiency. In Proceedings of workshop "Industrial energy efficiency policies: understanding success and failure. Utrecht. The Netherlands. LNBL. June 11-12, 1998.

energy transportation. Following this sequence, the role of indirect energy efficiency improvement effects scales up.

Another aspect is the end-use energy to primary energy transformation technique: whether it is done with the assumptions of frozen energy sector technologies and fuel mix, or account for technological evolution and fuel substitution. Often only power generation efficiency factors are considered, while other energy sector activities and technologies are ignored.

In 1993, Bashmakov proposed presentation of energy efficiency potential in the format of energy balance and developed a technique to account for indirect effects[17]. It is based on the following presentation of the relationship between primary and final energy consumption by sectors: PE= AE*PE+FE, or PE=$(E\text{-}AE)^{-1}$*FE, with PE – a vector of primary energy consumption by energy carriers[18], AE – a square matrix of coefficients of primary energy carrier *i* to produce and deliver to end-user one unit of energy carrier *j*, FE – a vector of final energy consumption by energy carriers. Each a_{ij} coefficient shows, how much coal, petroleum products, gas, electricity and heat are needed to deliver to all end-users one unit of, say, coal. While this approach requires additional data collection, it provides more correct and more significant indirect effects. Any change in FE has not only direct, but also significant and measurable indirect effects on energy demand. And any change in energy sector technologies leads to the evolution of AE matrix to AE^1, and also produces both direct and indirect effects (see section 7.4 for more explanations and quantitative illustrations).

Below both approaches accounting for indirect effects – related to generation and transmission of electricity and district heat only, as well as more comprehensive evaluation of indirect effects – were used to aggregate sectoral energy efficiency potentials.

Application of the above method requires energy savings in each process (FE*i*) split by energy source – FE*ij*. Then vector FE*ij* is multiplied by matrix $(E\text{-}AE)^{-1}$ to estimate PE*ij* – integral (direct plus indirect) energy savings. When the market potential is assessed, the indirect potential is not accounted for, and the value of the potential is estimated by comparing CSE with weighted energy price in this sector (including electricity and heat). Economic potential is assessed by comparing CSE for integral potential, using export gas price as an opportunity costs.

Evaluation of the energy balance matrix with and without energy efficiency improvements is an alternative to the above approach. Energy efficiency improvement potential for each sector and each energy carrier is then a difference between actually statistically reported consumption for 2005 and estimated consumption with the overall potential implementation. These two methods generate pretty close results. To make each of these options possible, it is important to develop an integrated fuel and energy balance for 2005.

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[17] I. Bashmakov. Costs and benefits of CO2 emission reduction in Russia. In “Costs, Impacts, and Benefits of CO2 Mitigation. Y. Kaya, N. Nakichenovich, W. Nordhouse, F. Toth Editors. IIASA. June 1993.

[18] Corrected for stock changes and for net energy exporters for net energy export.

7. Russian Energy Balance

7.1. IFEB (Integrated Fuel and Energy Balance)

Energy efficiency improvement potential is structured in the form of sector (activity) – energy carrier cells in accordance with the Integrated Fuel and Energy Balance (IFEB) table. Each cell shows, in which activity the use of which energy carrier can be reduced through energy efficiency improvements. The energy conservation cost curves are built, where possible, for each sector (activity).

Such presentation of the potential and costs is necessary to better tailor energy efficiency policies to capture this potential with the least cost. It is equally important to show not only direct, but also indirect effects of energy efficiency improvements at final users' facilities through the whole energy supply chain to show overall reduction of associated primary energy use. The interrelationships between energy supply and end-use systems in their integrity is reflected, accounting for their mutual augmentability and substitutability. Besides, such approach provides an appropriate tool for energy efficiency potential aggregation.

Regular Russian energy and economic statistics does not provide comprehensive IFEB data[19]. Only International Energy Agency (IEA) annually publishes such data for the Russian Federation, but it does not specify, how statistically reported Russian energy data are translated into IEA formats[20]. So the IEA data cannot be replicated, and therefore there is not much trust in the results provided. Moreover, the IEA balance splits industrial energy consumption by industries, while energy efficiency potential evaluation requires data on energy consumption by product manufactured.

The RF Government is beginning to realize the importance of an integrated fuel and energy balance development for the purpose of energy situation analysis, planning and projections. The RF Ministry of Industry and Energy has drafted an Executive Order and "Methodological recommendations on the development of projections of regional integrated fuel and energy balances, monitoring, and cooperation between federal and regional agencies of the Russian Federation under this effort". This draft is yet to be approved. It is assumed, that statistics agencies at the federal and regional levels will be responsible for the development of past energy balances, while analytical groups will undertake energy balances projections. So in the near future integrated fuel and energy balances may become a tool for supporting energy policies in Russia. Unfortunately, draft Executive Order suggests energy statistics reporting formats very similar to the old Soviet standards.

On March 20, 2007, the Federal Assembly of the Russian Federation conducted hearings "On legislative support to fuel and energy balance optimization", during which it recommended that legislation be developed to support the development of an energy planning system relying on integrated energy balances[21].

The Russian IFEB used in this paper is based on the integrated fuel and energy balance (IFEB) model, similar to the one used by the IEA (with some modifications), but accounting for the Russian energy statistics formats and specifics. This approach allows it to get a comprehensive

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[19] Russian Statistical Annual 2006 (p. 389) does provide a half-page table titled "Energy balance", which contains no information on energy transformation or end-use energy consumption. This table is too aggregated to be useful for analysis.

[20] Energy Balances of Non-OECD Countries 2003-2004. 2006 Edition. OECD/IEA. 2006.

[21] A special issue (Issue 2, 2007) of the Russian magazine "Energeticheskaya Politica" (Energy policy) was devoted to the publication of the hearings proceedings. The list of attendees included: V. Yazev, A. Makarov, A. Yanovsky, I. Bashmakov, B. Kozhoukhovsky, etc.

picture of the energy situation. It was already effectively used by CENEf to develop IFEB for Kaliningradskaya, Arkhangelskaya, and Astrahanskaya oblasts under the TACIS project[22].

IFEB provides a possibility to see on one page the whole national energy sector picture or "map". It is important to highlight, that information sources for IFEB development by the scheme proposed below and by the scheme suggested by the RF Ministry of Industry and Energy, are the same. Implementation of the Ministerial Executive Order will take at least three to five years. In the future, if this Executive Order is enforced, it will be easy to transfer data from the Ministerial format to the formats suggested below, or vice versa.

The IFEB consists of three blocks: energy resources, resources transformation in the energy sector, and energy end-use. The first block – "resources" – includes primary energy production, export and import, as well as stock changes. The second block describes transformation of energy resources. It includes fuel balances of the power and heat sectors, energy resources mining and extraction, oil refineries, coal enrichment, own energy use by energy sector and transmission and distribution losses. In the format proposed below the second block is split into several sectors: electricity generation, heat generation, fuel production and transformation, own use, production and transmission losses. Altogether, 17 energy sector activities are presented in the balance below. To completely reflect energy sector activities, one may also consider in this part of the balance the energy required for energy transportation, including that used in oil and gas pipelines, railroad to deliver coal and petroleum.

The third block describes energy consumption by 35 end-use sectors and activities (products). Such presentation of end-use sectors allows for better energy efficiency potential identification, which is structured below along products and technologies to produce them rather than along previously used (both by Russian energy statistics and IEA balances) industries, each of which included different activities (production of power, heat, and products alien to the industry profile, etc.), thus confusing the information user. The major difference of the IFEB with IEA balances is presentation of data in manufacturing sector not by branches of industrial sector, but by separate products irrespective of in which branch is was produced.

7.2. Major sources of information

There are several standard forms in the Russian statistical reporting system available for the compilation of a database to" puzzle" the energy balance:

- ⇒ "11 TER" (fuel, heat, and power use);
- ⇒ "6-TP" (heat and power plant operation);
- ⇒ "1-TEP" (information on heat supply);
- ⇒ "6-TP (hydro)" (data on hydropower plant operation);
- ⇒ "6-TP (KES)" (data on electricity network operation);
- ⇒ Electricity balance forms - "E-1", "E-2", and "E-3";
- ⇒ "PE" (data on the operation of thermal power plants owned by non-industrial organizations);
- ⇒ "4-fuel" (data on the fuel stock changes, fuel supply and consumption, waste petroleum products collection and use);
- ⇒ "22 ZhKH" (data on utilities' performance during the reform period, also containing partial information on heat-, natural gas-, and power consumption);
- ⇒ Forms on heat distribution systems' performance, which provide data on heat consumption and on fuel consumption by boiler-houses:
- ⇒ Foreign energy trade data.

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[22] See I. Bashmakov. Fuel and Energy Balance as an instrument for analysis, forecasting and indicative energy planning. "Energeticheskaya Politica". Issue 2, 2007.

It should be noted, that data from different statistical forms may be quite contradictory. Therefore, any manipulation with these data requires caution. Discrepancy mainly originates from different coverage and relative low accuracy of data, especially on district heat and natural gas consumption. Not all institutions are required to submit the whole set of statistical forms. For example, Form “11 TER” is mandatory only for companies with annual fuel and energy consumption above 2 tce[23]. Therefore, some sources allow only for a basic, rather than a comprehensive, picture of energy use, and additional data and data verification are required. Another example: “11 TER” only reflects transportation heat losses in heat transmission lines, and continuously tends to underestimate losses in distribution systems which are reported in the form “1-TEP”.

In spite of its incompleteness, “11 TER” was used as the basic data source for the IFEB development. It serves as the basis for publicly available fuel consumption statistics and is used in the analysis. This form integrates three data blocks: outputs by major industries and production stages; corresponding power-, heat-, and fuels consumption; specific power-, heat-, and fuel consumption factors to produce various types of goods, works and services. The latter group of indicators allows for the evaluation of energy use efficiency. Comparison of specific indicators dynamics and cross-comparison to other regions and countries allows for the evaluation of energy efficiency potential by products.

“11 TER” provides data for 23 energy carriers. It is a somewhat excessive degree of detalization to generally describe the energy picture. Analysis below considers only seven major energy carriers and resources: electricity, heat, coal, crude oil and petroleum products, natural gas, and other solid fuels. Such aggregation is the routine practice for the IEA and many countries, although more details could be provided when necessary for some energy carriers (as for example in Eurostat energy balances[24].

All statistical forms do not allow for automatic data allocation to the above-mentioned three blocks of the IFEB. A special set of labor intensive and fully documented efforts was conducted to follow the logics, rather than the letter, of the IEA energy balance development methods, as determined by the specific nature of available information sources.

7.3. Russian integrated fuel and energy balance for 2005

Assessed by CENEf Russian IFEB is presented in Table 7.1 below. Several important aspects are to be highlighted. Industrial energy consumption presented in this table does not include electricity and heat generated by industrial CHPs, diesel power stations or industrial boilers.

Data on heat end-use are not very reliable. To improve their accuracy, statistically reported negligible heat losses were corrected. The average 15% ratio of heat losses was used in the energy balance table. These losses are lower (5-10%) for industrial consumers, but are much higher for the building sector (over 20%). Including small boiler-houses heat generation as a separate line in energy transformation sector, instead of including fuel used for this purpose into end-use sectors, is another difference from the IEA balances. The principle to build on was as follows: the customer consumes the resource he pays for supplier (either district heat, or fuel), irrespective of the size of the district heating systems.

Total primary energy consumption for 2005 was estimated at 654 mtoe. Much of that (35%) was used in the energy production and transformation sector. If energy transportation (37.8 mtoe) were included in the energy sector activities, the share of the energy sector would come to 41%, a large share of which is used to produce energy for export (about 45% of primary energy produced in Russia is exported).

With about 55% contribution natural gas dominates TPES, followed by petroleum (19%) and coal (16%). Composition of final energy consumption is different: natural gas still dominates (29.3%), very closely followed by district heat (29.2%); petroleum products (21.7%); electricity (12.9%);

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[23] 1 toe = 1,43 tce

[24] The Energy Statistics Guidelines. OECD/IEA. 2007.

coal (6%), and other solid fuels (1%). So natural gas and district heat are two dominant energy carriers to save for end-users.

In final energy consumption split down by sectors or activities manufacturing has the leading role (28.6%), followed by the residential sector (27.3%); transport and communication (23.4%); non-energy use (mainly feedstock, 10.8%), services sector (5.9%) and then by several other activities. District heating, often ignored in the analysis of Russian energy picture, contributes 58% of energy consumption in the residential sector and 33% in manufacturing.

Table 7.1. Russian IFEB for 2005 (mtoe)

	Coal	**Crude oil**	**Petroleum products**	**Gas**	**Other solid fuels**	**Nuclear**	**Renewables**	**Electricity**	**Heat**	**Total**
Production	**134,97**	**470,14**		**517,13**	**14,36**	**39,72**	**15,05**			**1191,37**
Import	11,05	2,38	0,28	6,22				0,87		20,80
Export	-39,23	-252,59	-97,10	-167,27				-1,94		-558,13
Stock changes	-1,26	0,07	0,77							-0,42
TPES	**105,52**	**220,00**	**-96,05**	**356,08**	**14,36**	**39,72**	**15,05**	**-1,06**		**653,62**
Statistical diff.		-7,10	-0,11	-2,00				-0,09	1,00	-8,30
Electricity generation	**-34,19**		**-3,73**	**-91,60**	**-3,35**	**-38,82**	**-15,05**	**81,98**		**-104,77**
Fossil fuels electricity plants	-21,28		-0,91	-45,61	-0,27			25,78		-42,29
CHP	-12,91		-2,46	-44,70	-3,07			27,36		-35,79
Diesel power			-0,36	-1,29	-0,01			0,43		-1,23
Other						-38,8	-15,1	28,4		-25,47
Heat generation	**-41,25**	**-0,79**	**-12,48**	**-129,40**	**-6,26**	**-0,90**		**-3,52**	**161,63**	**-32,97**
Fossil fuels electricity plants	-1,69		-0,07	-3,63	-0,02			-0,15	5,11	-0,46
CHP	-12,58		-2,39	-43,55	-2,99			-1,68	58,65	-4,55
Diesel power				-0,01	0,00	-0,90			0,30	-0,60
Industrial boilers	-13,99	-0,76	-6,95	-58,11	-2,04			-0,82	56,18	-26,48
District heating boilers	-3,12	-0,03	-1,22	-10,15	-0,11			-0,15	11,76	-3,03
Small boilers	-9,87		-1,85	-13,95	-1,10			-0,72	21,84	-5,64
Secondary heat utilization units									7,80	7,80
Fuel production and transform.	**-3,37**	**-211,80**	**200,49**	**-17,80**	**-0,42**	**0,00**	**0,00**	**-19,79**	**-32,53**	**-85,21**
Coal and peat production and transformation	-0,26	0,00	-0,17					-0,67	-0,73	-1,83
Oil production		-0,07	-0,37	-2,73				-4,09	-1,44	-8,69
Oil refinery	-0,10	-208,01	201,03	-7,61	-0,42			-0,89	-4,58	-20,60
Gas production and processing		-0,02		-4,56				-0,68	-1,54	-6,79
Own use								-3,76		-3,76
Distribution losses	-3,00	-3,71		-2,90				-9,69	-24,25	-43,54
TFC	**26,71**	**0,31**	**88,12**	**115,28**	**4,33**	**0,00**	**0,00**	**57,52**	**130,11**	**422,38**
Agriculture and forestry	**0,09**	**0,01**	**3,06**	**0,38**	**0,21**			**1,45**	**1,01**	**6,21**
Fishing	**0,00**		**0,00**	**0,01**	**0,00**			**0,0**		**0,04**
Mining	**0,00**	**0,02**	**0,92**	**0,00**	**0,00**			**2,40**	**3,85**	**7,19**
Manufacturing	**22,74**	**0,02**	**3,04**	**24,52**	**2,72**	**0,00**	**0,00**	**17,05**	**39,45**	**109,54**
Coke	2,53		0,00	0,04				0,13	0,92	3,62
Oxygen								0,57	0,56	1,12
Compressed air	0,05		0,00	0,12				0,53	0,06	0,75
Water pumping and treatment for industrial use	0,00		0,01	0,02	0,00			1,68	0,11	1,82

	Coal	**Crude oil**	**Petroleum products**	**Gas**	**Other solid fuels**	**Nuclear**	**Renewables**	**Electricity**	**Heat**	**Total**
Pig iron	15,40			3,87				0,06	0,22	19,55
Open hearth furnace steel			0,38	1,07	0,04			0,03	0,07	1,58
Basic oxygen furnace steel	0,01			0,19				0,12	0,03	0,35
EAF steel	0,00		0,00	0,23				0,72	0,06	1,01
Rolled steel	1,31		0,05	2,80				0,65	0,40	5,20
Steel pipes			0,00	0,49				0,13	0,10	0,72
Electroferroalloys	0,41			0,01	0,07			0,56	0,01	1,05
Synthetic ammonia				0,30				0,18	0,25	0,73
Furtilizers and carbamide			0,03	0,32				0,38	1,42	2,15
Synthetic caoutchouc			0,19	0,33				0,27	2,09	2,88
Casting and metal works	0,07	0,00	0,03	0,69	0,00			0,18	0,11	1,08
Pulp			0,07		2,41			0,31	2,16	4,96
Paper				0,00				0,38	0,80	1,18
Cardboard	0,00			0,00				0,17	0,59	0,76
Cement and clinker	0,47		0,06	4,62	0,00			0,55	0,02	5,72
Meat	0,00	0,00	0,01	0,03	0,00			0,11	0,33	0,48
Bread	0,04	0,00	0,03	0,39	0,04			0,10	0,23	0,84
Other manufactur.	2,46	0,01	2,19	8,99	0,17			9,22	28,93	51,97
Construction	**0,02**	**0,03**	**0,67**	**0,02**	**0,02**			**0,82**	**0,13**	**1,70**
Transport and communication	**0,21**	**0,00**	**52,75**	**33,16**	**0,01**	**0,00**	**0,00**	**6,82**	**1,44**	**94,40**
Rail	0,20		2,85	0,03	0,01			3,88		6,97
Other	0,01	0,00	0,07	0,05	0,00			0,70	1,10	1,94
Oil pipelines		0,00	0,04	0,32				1,17	0,00	1,54
Gas pipelines				32,65				1,06	0,34	34,06
Water	0,00		0,87							0,87
Road			44,83	0,11						44,94
Aviation	0,00		4,09							4,09
Municipal utilities	**0,01**		**0,06**	**0,02**	**0,00**			**1,80**	**1,72**	**3,61**
Services sector	**0,06**	**0,00**	**0,08**	**11,43**	**0,04**			**9,20**	**15,50**	**36,31**
Residential	**2,83**		**0,91**	**27,18**	**0,94**			**9,37**	**67,02**	**108,24**
Non-specified	**0,13**	**0,00**	**0,40**	**0,15**	**0,06**					**0,75**
Non-energy use	**0,65**	**0,20**	**26,15**	**18,41**	**0,32**					**45,73**

Source: Estimated by CENEf based on statistical sources listed in Section 7.2.1.

It should be noted that data on specific energy consumption for industrial production is available mainly for mass production of homogenous products, like basic materials. More detailed information on energy and materials flows and on processes and activities is not readily available, often regarded confidential and requiring intensive data collection. So in many countries only about 50% of industrial energy use can be allocated to production for which specific energy intensities can be estimated or are statistically reported[25]. For the Russian manufacturing sector it was also possible to disaggregate only about 50% of energy consumption. About 70% of electricity consumption for "other manufacturing" line comes for electric motors and about 30-50% of heat comes for steam consuming processes. So about 20% more energy consumption in the "other manufacturing" sector can be addressed through electric motors and steam systems efficiency improvement technologies.

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[25] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006.

7.4. Evaluation of direct and indirect effects generated by improving end-use energy efficiency

As discussed in Section 6 above, translation of final energy savings into saved primary energy requires that indirect effects of end-use energy efficiency improvements be evaluated through the whole energy supply chain. Data in Table 7.1 allow for intermediate energy consumption matrix evaluation (see Table 7.2), followed by the calculation of AE matrix (a square matrix of coefficients of primary energy carrier *i* to produce and deliver to end-user one unit of energy carrier *j,* see Table 7.3), as well as a reverse $(E\text{-}AE)^{-1}$ matrix (see Table 7.4).

The table 7.2 should be read: to produce and deliver to final users 160.74 mtoe of district heat, 41.25 mtoe of coal, 129.4 of natural gas, are needed throughout the whole energy sector and 24.25 mtoe are heat losses. In the last case the for every 1 mtoe of district heat produced, 0.151 mtoe is lost as presented by coefficients in Table 7.3.

Table 7.2. Intermediate energy consumption by Russian energy complex. 2005 (mtoe)

	Coal	Crude oil	Petroleum products	Gas	Other solid fuels	Electricity	Heat
Coal	-3,26		-0,10	0,00		-34,19	-41,25
Crude oil		-3,78	-0,07	-0,02		0,00	-0,79
Petroleum products	-0,17	-0,37	-2,81	0,00		-3,73	-12,48
Gas		-2,73	-7,61	-7,46		-91,60	-129,40
Other solid fuels			-0,42	0,00	0,00	-3,35	-6,26
Electricity	-0,67	-4,09	-0,89	-0,68		-13,45	-3,52
Heat	-0,73	-1,44	-4,58	-1,54			-24,25
Total primary or secondary energy production	**134,97**	**470,14**	**200,49**	**517,13**	**14,36**	**54,11***	**160,74***

* Nuclear and hydro electricity and heat are excluded
Source: Estimated by CENEf.

Table 7.3. Direct coefficients of primary energy supply by energy complex per unit of energy production in 2005 (mtoe/mtoe)

	Coal	Crude oil	Petroleum products	Gas	Other solid fuels	Electricity	Heat
Coal	0,024	0,000	0,001	0,000	0,000	0,632	0,257
Crude oil	0,000	0,008	0,000	0,000	0,000	0,000	0,005
Petroleum products	0,001	0,001	0,014	0,000	0,000	0,069	0,078
Gas	0,000	0,006	0,038	0,014	0,000	1,693	0,805
Other solid fuels	0,000	0,000	0,002	0,000	0,000	0,062	0,039
Electricity	0,005	0,009	0,004	0,001	0,000	0,249	0,022
Heat	0,005	0,003	0,023	0,003	0,000	0,000	0,151

Source: Estimated by CENEf.

Table 7.4. Full coefficients of primary energy supply by energy complex per unit of energy production in 2005 (mtoe/mtoe)

	Coal	Crude oil	Petroleum products	Gas	Other solid fuels	Electricity	Heat
Coal	1,03	0,01	0,01	0,00	0,00	0,87	0,34
Crude oil	0,00	1,01	0,00	0,00	0,00	0,00	0,01
Petroleum products	0,00	0,00	1,02	0,00	0,00	0,10	0,10
Gas	0,02	0,03	0,07	1,02	0,00	2,32	1,04
Other solid fuels	0,00	0,00	0,00	0,00	1,00	0,08	0,05
Electricity	0,01	0,01	0,01	0,00	0,00	1,34	0,04
Heat	0,01	0,00	0,03	0,00	0,00	0,02	1,19
Total	**1,07**	**1,07**	**1,14**	**1,03**	**1,00**	**4,73**	**2,75**
Total, including fuel transportation	**1,08**	**1,07**	**1,16**	**1,11**	**1,00**	**4,94**	**2,84**

Source: Estimated by CENEf.

To produce 1 toe of electricity, 1.69 toe of natural gas is needed; but to produce this gas, some additional energy (0.068 toe, including 1.69*0.001 toe of electricity and 1.69*0.003 toe of heat) is required, to produce which again 0.11 toe of gas is needed. Evaluation of full coefficients of primary energy supply by the energy complex per unit of energy production allows it to express this endless chain of calculations through a single multiplier – the so-called full coefficient (see Table 7.4). The last two lines in Table 7.4 show such multipliers and their composition for the assessment of integral effects of end-use efficiency improvements. These coefficients may be interpreted as follows: if end-users save 1 toe of petroleum products, the total energy need in the whole energy sector will decline by additional 0.14 toe (or 0.16 toe, if liquid fuel in transportation is accounted for[26]). The highest multipliers are for electricity and heat generation. They far exceed regular multipliers accounting only for the fuel efficiency of electricity generation (2.5 with 40% efficiency, or 3 with 67% generation transmission and distribution losses[27]) and heat generation (1.25 with 85% efficiency of heat generation and 5% heat losses). If 1 mtoe of electricity is saved in Russia the integrated primary energy savings throughout the whole energy supply chain are not 2.5-3 mtoe as usually calculated accounting only for power generation and electricity transmission and distribution efficiency in Western countries, but 4.7 mtoe (4.9 mtoe if fuel transport by railroads is accounted for).

All estimates for end-use energy efficiency potentials are to be corrected using these multipliers to assess integrated effects expanded throughout the whole energy supply chain. To make the transition from the final to primary energy more simple for some applications Table 7.4 was reduces to 3x3 matrix limited to fuels, electricity and district heat (Table 7.5).

Table 7.5. Reduced form of full coefficients of primary energy supply by energy complex per unit of energy production in 2005 (mtoe/mtoe)

	Fuels	**Electricity**	**Heat**
Fuels	1,06	3,46	1,56
Electricity	0,01	1,36	0,05
Heat	0,01	0,03	1,19
Total	**1,07**	**4,84**	**2,80**
Total, including fuel transportation	**1,10**	**4,92**	**2,83**
Traditionally used coefficients	1.00	2.50-3.03	1-1.25

Source: Estimated by CENEf.

Such coefficients should be used for the technical and economic potentials evaluations. Market agents in their investments projects evaluations never account for potential savings beyond the scope of their business.

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[26] These estimates for multiplies are quite close to the ones assessed in 1992 for the FUSSR. See I. Bashmakov. Costs and benefits of CO2 emission reduction in Russia. In “Costs, Impacts, and Benefits of CO2 Mitigation. Y. Kaya, N. Nakichenovich, W. Nordhouse, F. Toth Editors. IIASA. June 1993.

[27] Worrell, E., Neelis, M., Price, L., Galitsky, C., Zhou, N. World Best Practice Energy Intensity Values for Selected Industrial Sectors, 2007. Berkeley, CA: Lawrence Berkeley National Laboratory. 2007.

8. Evaluation of the Energy Efficiency Potential

8.1. Power Supply Sector

8.1.1. Electricity generation

Energy efficiency potential in electricity generation was evaluated at 43.4 mtoe, or 22% of 2005 consumption (see Table 8.1), with natural gas use reduction potential of 41 billion m^3. The largest potential is evaluated for condensation power stations followed by CHPs (jointly for electricity and heat generation).

Table 8.1. Evaluation of energy efficiency potential in electricity and heat (at CHPs only) generation (mtoe)

Type of power station	2005 consumption level	Technical potential	Economic potential	Economic potential with Kyoto	Market potential with 2010 prices	Market potential with 2007 prices
Total electricity generation	**194.02**	**43.44**	**39.10**	**40.02**	**30.90**	**5.76**
Coal	46.77	4.01	2.82	2.88	1.05	0.04
Petroleum products	6.12	18.35	18.12	18.13	17.93	2.43
Natural gas	135.15	20.09	17.68	18.53	11.85	3.22
Other solid fuels	5.98	0.99	0.48	0.48	0.07	0.07
Condensing power stations	**67.8**	**22.53**	**21.55**	**22.35**	**17.93**	**2.37**
Coal	21.28	0.05	0.05	0.05	0.05	0.04
Petroleum products	0.91	17.90	17.90	17.90	17.80	2.30
Natural gas	45.61	4.58	3.60	4.40	0.08	0.03
CHP - electricity	**63.06**	**17.91**	**17.14**	**17.2**	**12.78**	**3.28**
Coal	12.91	3.43	2.77	2.83	1.00	0.00
Petroleum products	2.46	0.27	0.19	0.19	0.11	0.11
Natural gas	44.7	13.70	13.70	13.70	11.60	3.10
Other solid fuels	2.99	0.51	0.48	0.48	0.07	0.07
CHP - heat	**61.51**	**2.42**				
Coal	12.58	0.53				
Petroleum products	2.39	0.12				
Natural gas	43.55	1.29				
Other solid fuels	2.99	0.48				
Diesel power stations	**1.65**	**0.58**	**0.41**	**0.47**	**0.19**	**0.11**
Petroleum products	0.36	0.06	0.03	0.04	0.02	0.02
Natural gas	1.29	0.52	0.38	0.43	0.17	0.09

Source: Estimated by CENEf

90% of the technical potential is economically viable; 72% is viable with expected 2010 market fuel prices and decision-making conditions, and only 13% with 2007 fuel prices. If potential benefits of CO2 reduction trading are accounted for, then both potentials grow up to 40 mtoe. Thus the share of economically viable potential comes to 85%.

Both economic (assessed with expected 2010 fuel prices) and market (assessed with 2007 and expected 2010 fuel prices) potentials are very sensitive to the assumptions made regarding the change of renovation capital costs and operation costs[28]. For gas-fired power plants, specific capital cost of renovation was taken at 700 $US/1kW; for petroleum products at 800 $US/1 kW,

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[28] Statistically reported Russian average 2007 energy purchasing prices (Social and economic status of Russia. January-June 2007. p. 154) were corrected by expected price growth in 2008-2010 (see “Social and economic development scenario conditions and the basic parameters of the integrated financial balance of the Russian Federation for 2008 and until 2010”. The RF Ministry of Economic Development and Trade. March 2007.

and for coal-fired plants at 1,400 $US/1 kW[29]. It was assumed, that only loaded-up in 2005 equipment would be replaced, while idle machinery is not[30]. Reduction of scheduled and emergency repairs of worn equipment was accounted for as a change in operation costs.

Based on the above assumptions, capital investment demand to improve the efficiency of condensation power plants is assessed at $US 49.8 billion, of CHPs at $US 55.4 billion, and of diesel power plants at $US 1.3 billion, thus totaling to about $US 106 billion[31]. Apart from energy efficiency improvements, this investment would generate other important benefits, including better reliability of electricity supply, lower capital repair costs, and lower pollution.

8.1.2. GRESs

In Russia, 104 thermal power plants using condensing equipment produce around 300 billion kWh with 345 gce/kWh average specific fuel consumption, which corresponds to 36% efficiency. It is below the average OECD value for coal- and residual oil-fired (38%) and gas-fired (41%) plants[32]. In Russia, only two power stations (Sochinskaya TES and Severozapadnaya GRES-2) are reported to have the efficiency above 40%. Five other GRES (Permskaya, Sredneuralskaya, Nizhnevartovskaya, Kostromskaya, and Surgutskaya) run at above 38% efficiency. The worst GRES specific fuel consumption for electricity generation is as high as 1.615 gce/kWh (see Fig. 8.1).

Major problems related to the operation of Russian GRES include:

1. Practical implementation of the “Inertia Strategy”: minimal effort is taken to maintain equipment in the operation condition and extend its lifetime; therefore, the frequency of accidents is growing and the fuel efficiency is low;
2. Practically zero commissioning of new, efficient large capacities in the recent years, and corresponding high wear of equipment. After 1990, only Pskovskaya GRES and a new block at Nizhnevartovskaya GRES were commissioned. Other commissioning primarily includes low-capacity distributed energy sources, which in Russia are called “small” energy sector. Depreciation of equipment at many plants exceeds 75%;
3. Reduction of electricity generation determined by growing frequency of equipment failures;
4. Reduction of the plants’ load determined by reduced consumption and increased equipment outage for scheduled and emergency repairs;
5. Increased share of own use electricity consumption;
6. Lack of motivation for costs reduction and of qualified personnel.

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[29] These values include only equipment replacement capital costs, and do not include financing costs; and compared with the new construction, they exclude all licensing, land acquisition costs, etc. See Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006. p. 205; F. Nguyen. Power Generation Diversification for electricity, reliability and sustainability. Energy Prices and Taxes. Second quarter. 2007. p. xvii.

[30] At some power plants in 2005 a large part of generating equipment was not loaded. This unloaded equipment was not considered as requiring replacement in the calculations below.

[31] For each power plant with the efficiency below the benchmark specific capital costs were multiplied by loaded in 2005 capacity.

[32] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006.

Figure 8.1. Distribution of 104 Russian GRES by specific fuel consumption to generate 1 kWh of electricity

If Russian GRES exceed 52% efficiency (in other countries, there are combined-cycle plants which run at more than 57% efficiency[33]), they will generate 43.4 mtoe fuel savings (including 42 billion m3 of natural gas). With the minimal efficiency level of 38%, fuel use reduction potential is 10 mtoe.

In 2005, natural gas-fired GRES generated 216 billion kWh (72% of overall electricity generation by GRES) with average specific fuel consumption of 334 gce/kWh, which corresponds to 37% efficiency, reaching 517 gce/kWh for the least efficient units (see Fig. 8.2).

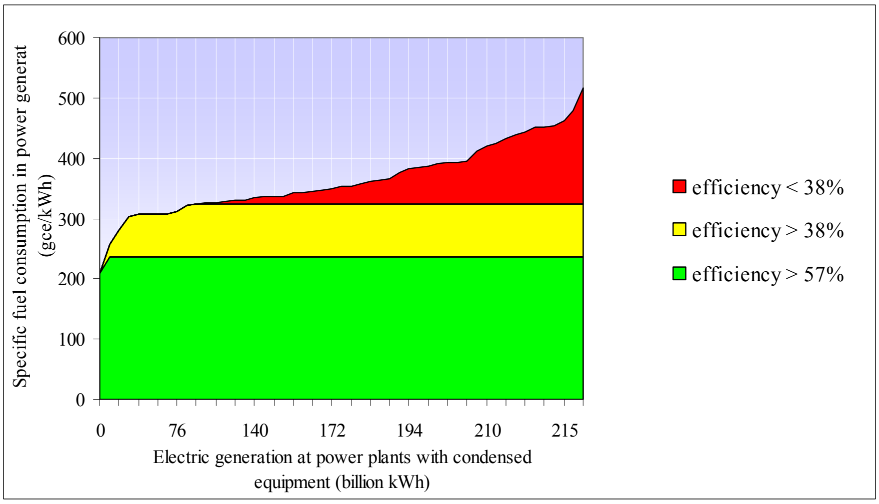

Figure 8.2. Distribution of natural gas-fired Russian GRES by specific fuel consumption to generate 1 kWh of electricity

The following approach was used to evaluate the technical potential at power plants: equipment in operation in 2005 with the efficiency below the benchmark is replaced with the most advanced units of appropriate capacity. Due to the difference in the present efficiency level such replacement yields different efficiency gains at each power plant used in formula 6.1 to account for CSE (see Fig. 8.3). Only costs of power generation equipment replacement were accounted for in CSE calculations, while all the other power plant infrastructure is fixed. So specific capital costs are some below those for erecting new power plants on completely new cite. Specific capital costs of

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[33] G.G. Olkhovsky, A.G. Tumanovsky. Perspective technologies for thermal power plants. Teploenergoeffektivnye technologii. 2003. No. 1.

building 1 kW cited above were taken from respected sources[34]. Reduction of capital repair costs at Russian power plants was accounted for while assessing CSE based on the approach discussed in section 6.

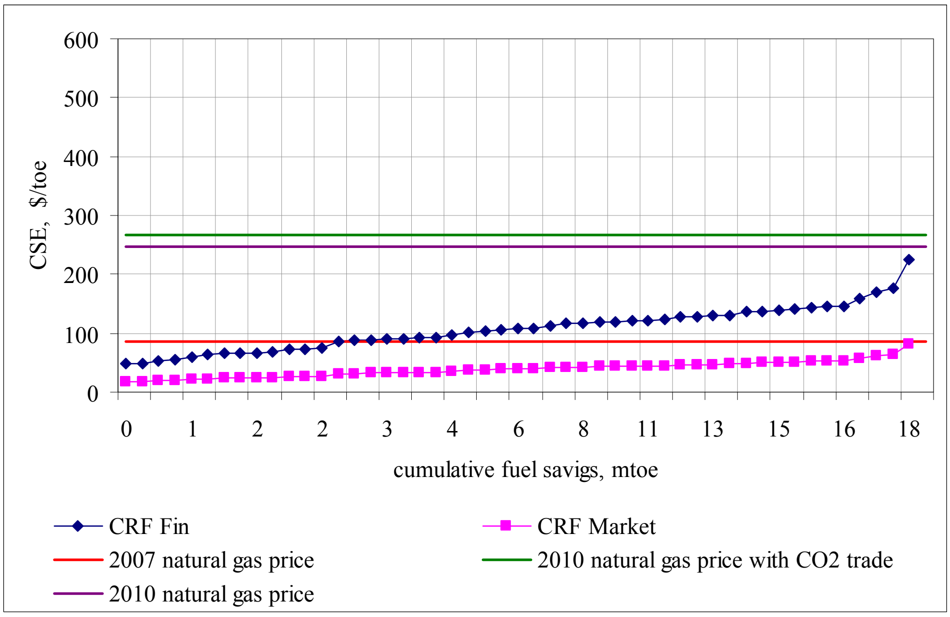

Figure 8.3. CSE for natural gas-fired Russian GRES

The whole technical potential at natural gas-fired condensing power plants (17.9 mtoe) is economically viable. The market potential with the 2007 gas prices is 2.4 mtoe, and with expected 2010 gas prices it expands to 17.8 mtoe (see Fig. 8.3).

Liquid fuel-fired GRES only generated 480 million kWh in 2005 (less than 2% of overall GRES electricity generation) with 419 gce/kWh average specific fuel consumption, which corresponds to 29% efficiency, reaching the highest 1,000 gce/kWh for the least efficient units (see. Fig. 8.4). If the efficiency of these power plants improves to 45%, about 0.05 mtoe can be saved. The technical and economic potentials for mazut-fired GRES to reduce fuel consumption were assessed at 0.05 mtoe, and the market potential is just slightly lower.

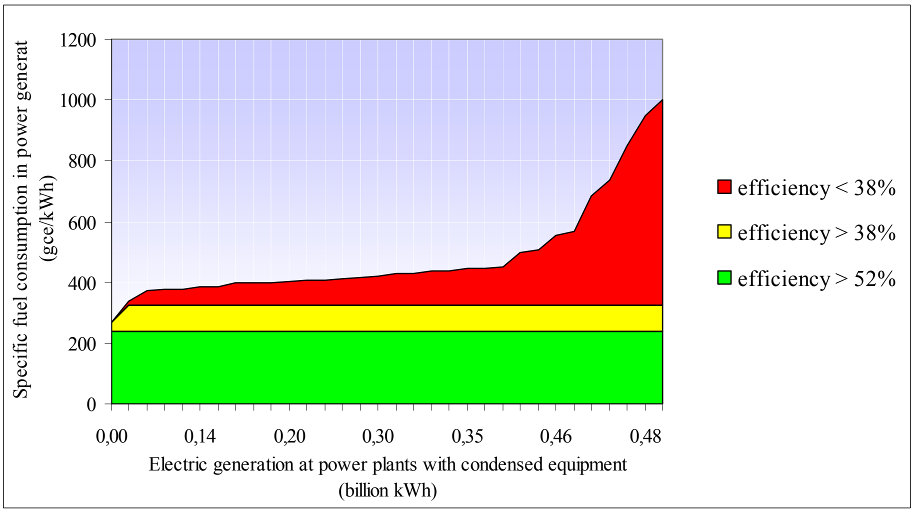

Figure 8.4. Distribution of liquid fuel-fired Russian GRES by specific fuel consumption per 1 kWh electricity generation

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[34] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006; F. Nguyen. Power generation diversification for electricity, reliability and sustainability. Energy Prices and Taxes. Second quarter. 2007. p. xvii.

Coal-fired GRES generated 84 billion kWh in 2005 (28% of overall GRES electricity generation) with 371 gce/kWh average specific fuel consumption, which corresponds to 33% efficiency, reaching unbelievable 1,615 gce/kWh for the least efficient units (see. Fig. 8.5). If coal-fired GRES are upgraded to reach current 45% efficiency level in developed countries, about 5 mtoe of coal may be saved.

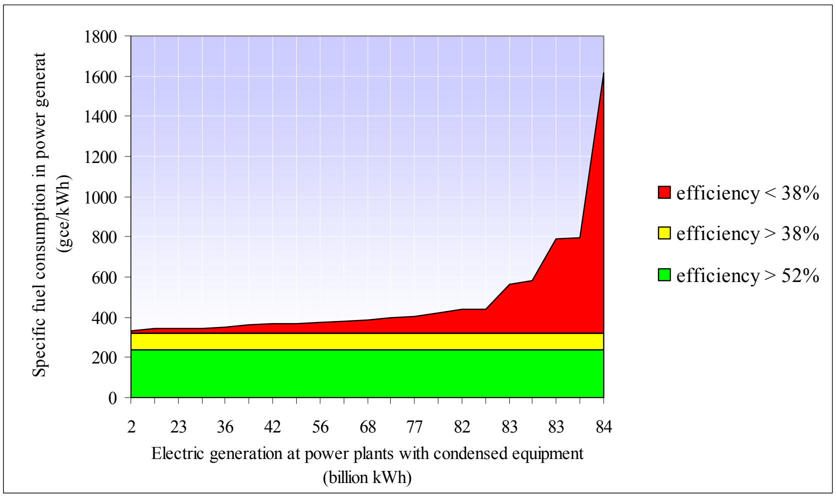

Figure 8.5. Distribution of coal-fired Russian GRES by specific fuel consumption to generate 1 kWh of electricity

The technical potential for coal-fired GRES to reduce fuel consumption was assessed at 4.58 mtoe, while the economic potential at gas price is 3.6 mtoe and 4.4 mtoe with CO_2 emission trading. The market potential is 0.03 mtoe with the 2007 coal prices and 0.08 with expected 2010 coal prices (see Fig. 8.6).

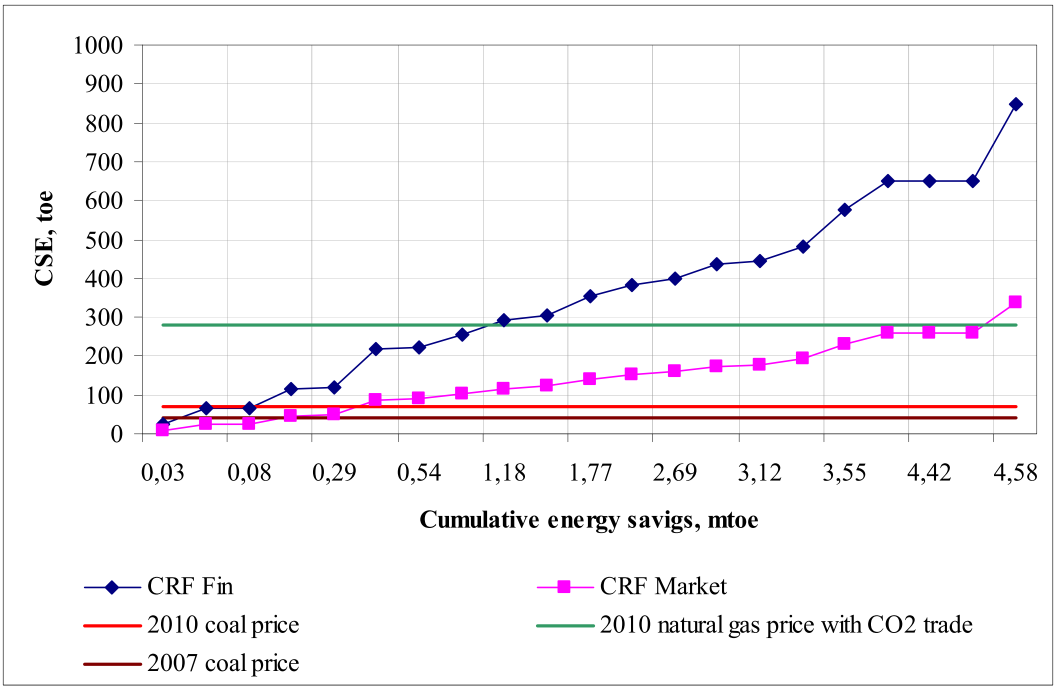

Figure 8.6. CSE for coal-fired Russian GRES

8.1.3. Co-generation plants

Russian co-generation plants produce around 318 billion kWh with 325 gce/kWh average specific fuel consumption, which is below the average efficiency of OECD condensing plants and only 4% below average specific fuel consumption of Russian GRES; in other words, co-generation advantages at large CHPs are minimal.

If electricity were produced by condensing plants with 40% efficiency, and heat were produced by boilers with 90% efficiency, overall fuel consumption would be even somewhat lower, than that of co-generation plants. Average calorific value use factor at Russian co-generation plants is 63%. With an account of heat distribution losses, current co-generation practically has no benefits. At 60 co-generation plants, specific fuel consumption for electricity generation exceeds 500 gce/kWh, which corresponds to only 25% efficiency (see Fig. 8.7), with least efficient units reaching as high as 2,963 gce/kWh.

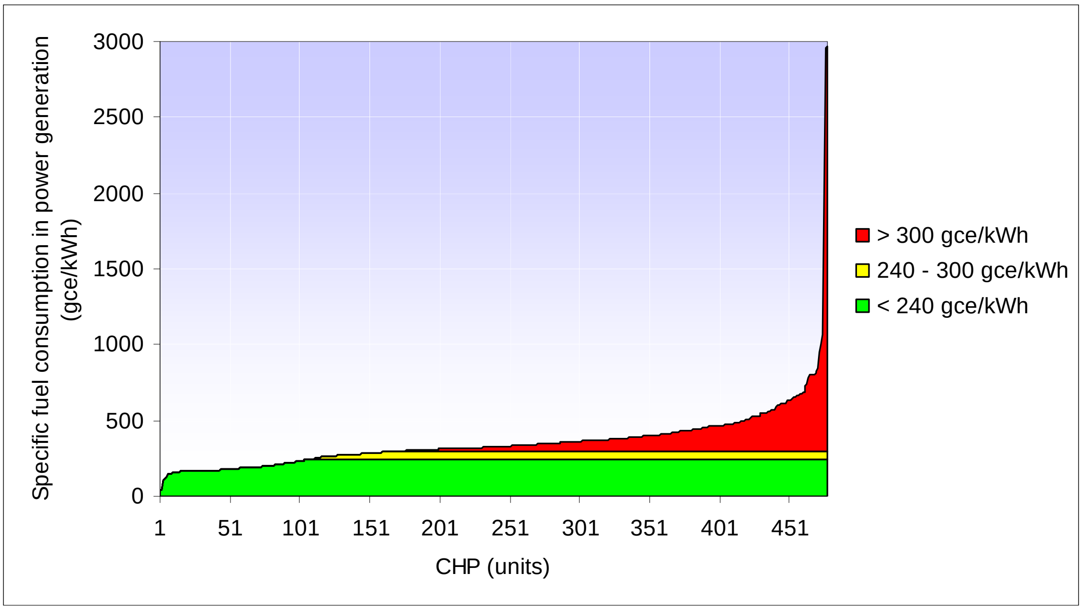

Figure 8.7. Distribution of Russian CHPs by specific fuel consumption per 1 kWh electricity generation

If specific fuel consumption for electricity generation by a co-generation plant goes down to 240 gce/kWh, fuel savings may reach 18 mtoe, including 17 billion m3 of natural gas.

Major problems related to the operation of Russian co-generation plants include: practical implementation of the “Inertia Strategy” at co-generation plants (minimal effort is made to maintain equipment in operation); considerable depreciation of the basic equipment stock combined with the lack of current and capital repairs; longer repair time and growing frequency of failures; reduced electricity generation at cogeneration cycle and reduced equipment load determined by the reduction of industrial output and solvent consumers’ refusal to buy heat from co-generation plants for the high price, unreliable supply and unsatisfactory quality; worsening fuel quality parameters; reduced manageability, and consequently a large number of energy intense machinery work cycles in the electricity generation cycle; growing own needs electricity consumption for heat and electricity generation; lower qualification of personnel.

Equipment replacement and load factor are of more consequence, determining fuel efficiency. Obviously, Russia has missed almost 20 years of the technical progress in co-generation plants renovation and construction. Dependence of specific fuel consumption on the commissioning date does exist (see Fig. 8.8). This figure is very consistent with Fig. 6.2 for the US EAFs.

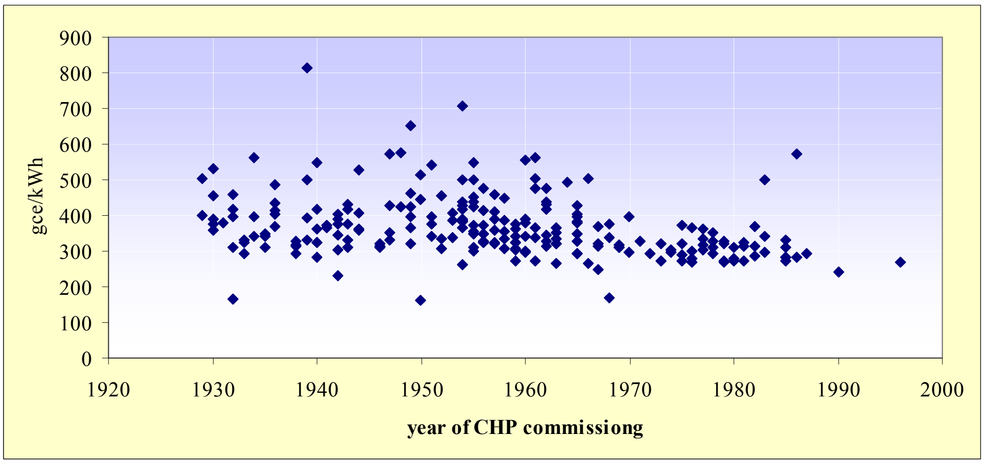

Figure 8.8. Dependence of specific fuel consumption of Russian co-generation plants for electricity generation on the year of commissioning

Measures to improve the efficiency of the equipment installed at Russian cogeneration plants include[35]: plants upgrade to implement the efficiency and capacity potentials to the largest possible degree; technical renovation of the generation capacities, including installation of new equipment and introduction of modern technologies. After renovation, upgrade, and technical refurbishment of cogeneration plants, their fuel efficiency, reliability, and environmental parameters should be equal to, or higher, than those of modern foreign plants.

Natural gas-fired CHPs generated 243 billion kWh in 2005 (77% of overall CHP electricity generation) with 319 gce/kWh average specific fuel consumption, which corresponds to 39% efficiency, reaching 2,963 gce/kWh for the least efficient units (see. Fig. 8.9). Upgrading them to presently reachable 51% efficiency could bring about 14 mtoe (17 billion m3) natural gas savings.

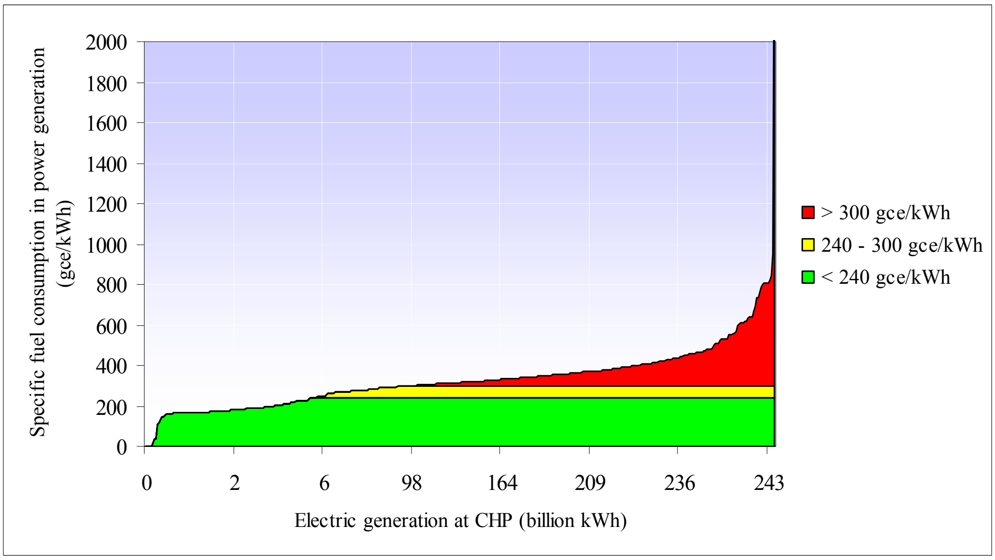

Figure 8.9. Distribution of natural gas-fired Russian CHPs by specific fuel consumption to generate 1 kWh of electricity

The technical potential at gas-fired CHPs is 13,7 mtoe, with a large part of it (13.7 mtoe) constituting the economic potential and only 3.1 mtoe the market potential with the 2007 gas prices scaling up to 11.6 mtoe with expected 2010 gas prices (see Fig. 8.10).

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[35] The concept of RAO EES Rossii technical policy

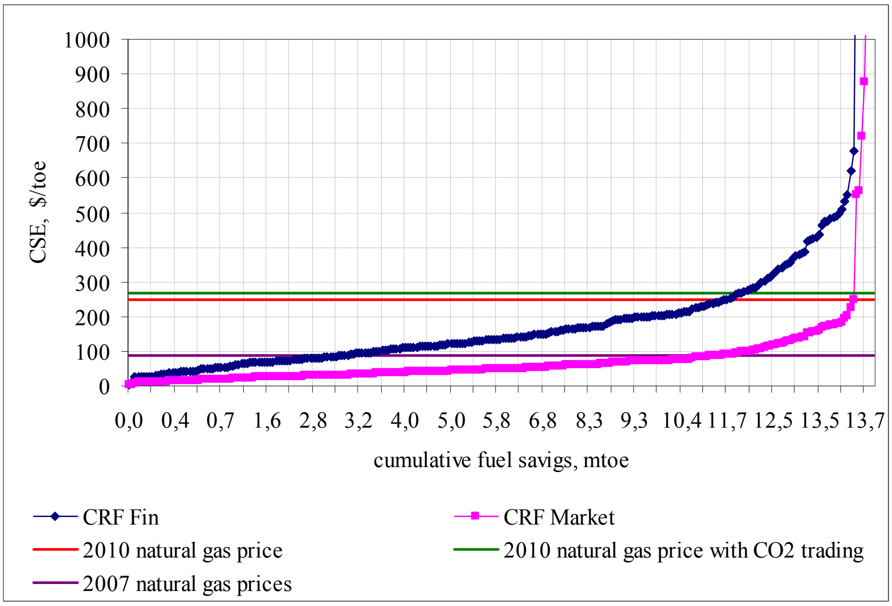

Figure 8.10. Energy efficiency potential implementation costs at natural gas-fired plants

Liquid fuel-fired CHPs generated 4.5 billion kWh in 2005 with 337 gce/kWh average specific fuel consumption, which corresponds to 36% efficiency, reaching 668 gce/kWh for the least efficient units (see. Fig. 8.11). The technical potential for liquid fuel-fired CHP is 0.27 mtoe, the economic potential 0.19 mtoe, and the market potential 0.11 mtoe.

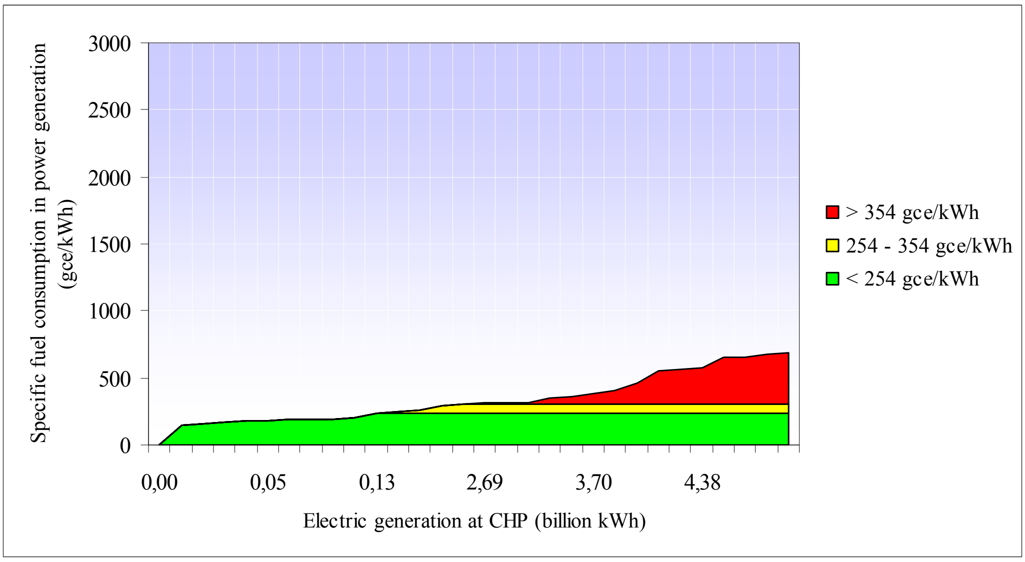

Figure 8.11. Distribution of liquid fuel-fired Russian CHPs by specific fuel consumption to generate 1 kWh of electricity

Solid (mostly coal) fuel-fired CHPs generated 65 billion kWh in 2005 with 342 gce/kWh average specific fuel consumption, which corresponds to 36% efficiency, reaching 2,962 gce/kWh for the least efficient units (see. Fig. 8.12).

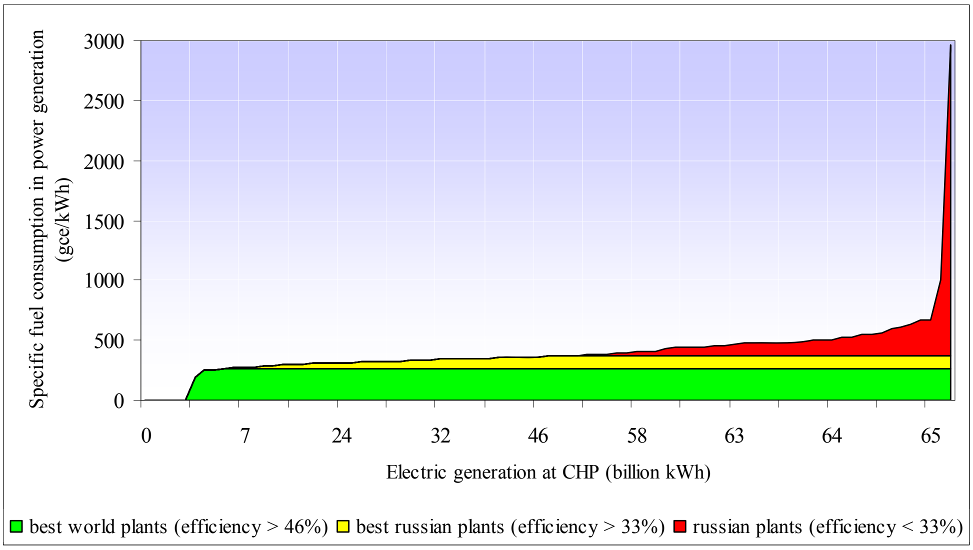

Figure 8.12. Distribution of coal-fired Russian CHPs by specific fuel consumption to generate 1 kWh of electricity

If they are upgraded to 48% efficiency, about 3.4 mtoe may be saved. While the economic potential was assessed at 2.83 mtoe (with CO_2 trading), no market potential was identified with the 2007 gas prices used as an opportunity cost and only 1 mtoe with the 2010 gas prices.

Other solid fuel-fired CHPs (mostly biomass at pulp and paper CHPs) generated 5.6 billion kWh in 2005 with 395 gce/kWh average specific fuel consumption, which corresponds to 31% efficiency, reaching 2,020 gce/kWh for the least efficient units (see. Fig. 8.13). If they are upgraded to 46% efficiency, about 0.5 mtoe may be saved, of which 0.48 is the economic, and 0.07 mtoe the market potential.

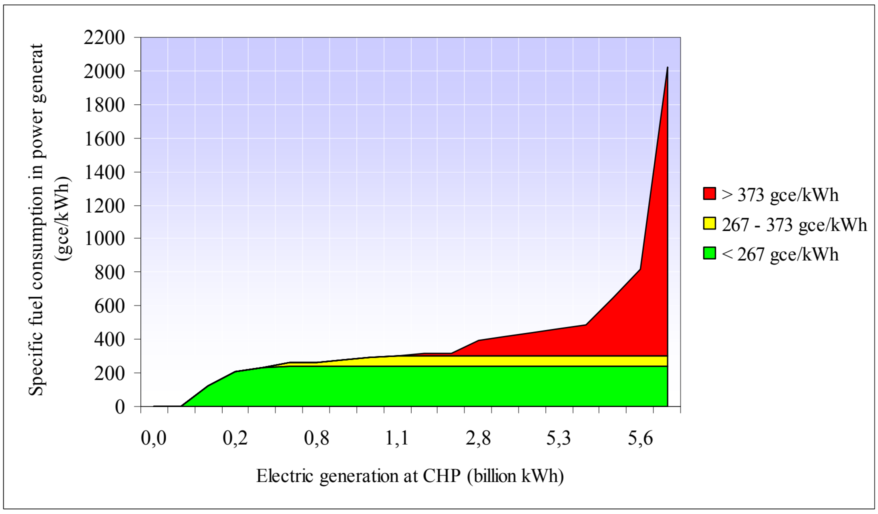

Figure 8.13. Distribution of other solid fuel-fired Russian CHPs by specific fuel consumption to generate 1 kWh of electricity

490 Russian CHPs produced about 584 million Gcal of district heat in 2005 with 150 kgce/Gcal average specific fuel consumption. Specific fuel consumption by co-generation plants for heat production is allocated accounting for competitive heat tariffs of other heat producers. The red zone includes 211 CHPs with specific fuel consumption higher, than that of a boiler running at 90% efficiency (see Fig. 8.14). “Shaving off” the red zone from Fig. 8.14 brings 2,4 mtoe in fuel savings, including 1.6 billion m3 of natural gas. This potential was split among fuels based on the analysis for each group of CHPs with dominant fuel use (see Table 8.1).

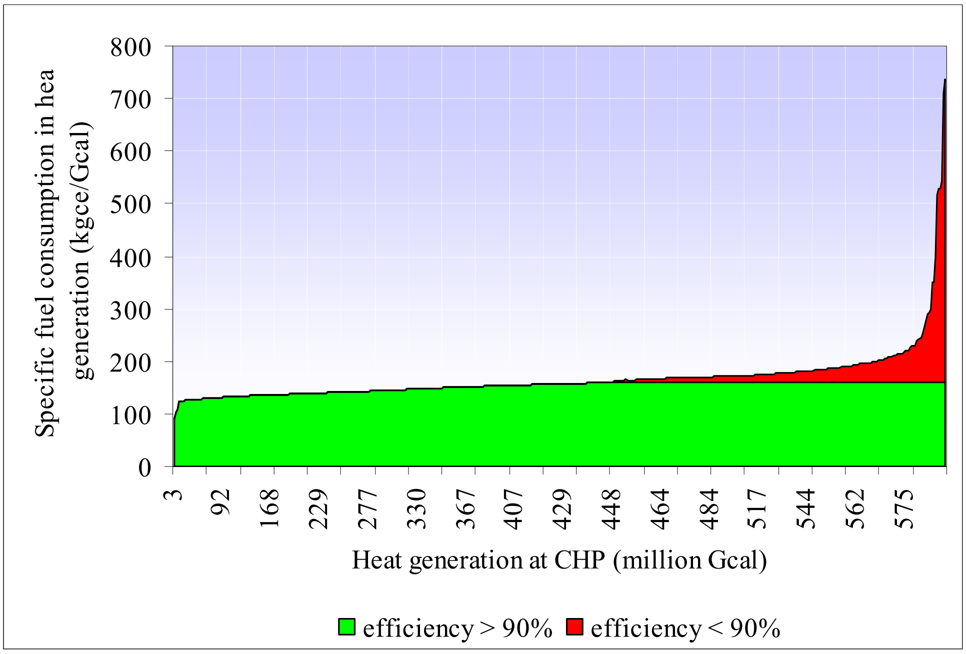

Figure 8.14. Distribution of Russian CHPs by specific fuel consumption to generate 1 Gcal of heat (including industrial CHPs)

8.1.4. Diesel power plants

More than 390 large (over 500 kW capacity) diesel power plants annually produce around 5 billion kWh and use 1.7 mtoe. Natural gas-fired diesels, mainly used in gas provinces, generate 3.8 billion kWh. Average fuel consumption for the generation of 1 kWh is 495 gce, so average efficiency of diesel plants is 25%, which is much below the maximum possible level (see Fig. 8.15).

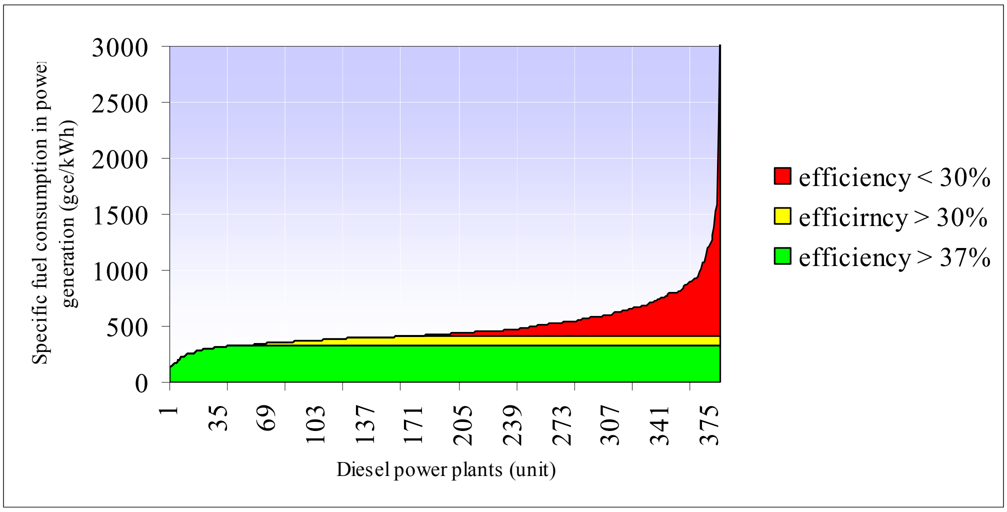

Figure 8.15. Distribution of 382 Russian diesel power stations by specific fuel consumption to generate 1 kWh of electricity

Most diesel power plants have been in operation for 20-30 years. When their time in operation expands from 5 to 20 years, specific fuel consumption grows from 300 to 420 gce/kWh. Average equipment depreciation ratio equals 78%. Such high value determines frequent failures and long outages. High specific fuel consumption is also determined by the fact that diesel fuel is used in remote settlements for purposes other than electricity production (driving vehicles and motor boats). That may explain why at some diesel power stations specific fuel consumption reaches 3,250 gce/kWh, or why fuel is used at 4% efficiency.

Electric efficiency of modern diesel power plants is above 37%[36], of average power plants around 30%, so plants with lower efficiency may be regarded as inefficient. Upgrading Russian diesel power stations to 37% average efficiency would bring 0.59 mtoe in savings of both diesel fuel and natural gas. Only 0.41 mtoe of it is economically attractive (0.47 mtoe with CO2 trading) and 0.11 is market attractive.

8.1.5. Electricity transmission, distribution and own use

Length of Russian power grids with 0.4-750 voltage is over 3 million km. Average electricity distribution losses in Russia grew up from 8% in 1990 to 12.2% in 2005. In Moscow, they equaled 8.4% in 2004, in Sakhalinskaya Oblast 14%, in Moscow Oblast 18%, in Astrakhanskaya Oblast they exceeded 20%. In regions with large industrial consumers, the share of losses is lower. If overall electricity distribution losses are to be identified, it is necessary to sum up data from the plants of RAO "EES Rossii" and other large electricity producers and data from municipal energy utilities. In the OECD countries, average distribution losses equal 6-7%.

Standard electricity distribution losses must not exceed 8.5%. So electricity distribution losses reduction potential in Russia is 40-55 billion kWh, which practically equals overall electricity consumption in Moscow. With average specific fuel consumption by co-generation plants for electricity generation, this value is equivalent to 9-12.6 mtoe reduction of fuel demand. 20-30% reduction is possible, if the cost of saved electricity is below current tariff.

8.2. Heat supply systems

In Russia, the so called "large energy sector" (large GRESs, CHPs and large boilers) produces 1,431 million Gcal, and 185 million Gcal are produced by municipal and private small boiler-houses. Major problems related to the operation of Russian heat supply systems include: lack of municipal energy plans; excessive heat source capacity versus connected loads; excessive centralization of many heat supply systems; high heat distribution losses; poor regulation of heat supply systems to meet variations in heat demand; lack of costs reduction motivation; shortage of qualified personnel.

Most important directions of heat supply systems renovation and development include: renovation of district heating systems with high heat load densities; partial de-centralization of many local heat supply systems with extremely low heat load densities.

8.2.1. Heat generation

District heat generation is often ignored in the energy analysis; in 2005, all heat producers consumed more primary energy (191 mtoe of primary energy and 3.5 mtoe of electricity), than electricity producers. CHPs are responsible for 36% of heat generation, 3.3% of heat is produced by condensing power plants, 0.6% by nuclear heat producing units; 4.8% by heat recovery units; and the rest by boiler-houses. Energy efficiency potential in boilers heat generation was estimated at 10.4 mtoe, or 8.4% of 2005 consumption (see Table 8.2). The largest potential is identified for industrial boilers. Depending on the application of Kyoto flexible mechanisms, about 90% of the technical potential is economically viable, and 30-87% is attractive for market agents.

Statistically reported average efficiency of heat generation is as follows: CHP – 95.3%; industrial boilers – 68.6%; district heating boilers – 80.3%; small boilers – 81.6%[37], while in the West Europe it is as high as 92-95%. 95% was used in energy efficiency potential assessments for reference efficiency for gas- and liquid fuel-fired boilers, and 85% for coal-fired boilers.

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[36] Data are borrowed from major equipment manufactures' websites.

[37] Statistics report specific energy consumption to generate a unit of heat. As CENEf's experience in many energy audits shows, in practice small boilers are the least energy efficient. So statistical data do not mirror the real situation.

Table 8.2. Evaluation of energy efficiency potential in boilers heat generation, mtoe

Type of power plant	2005 consumption level	Technical potential	Economic potential	Economic potential with Kyoto	Market potential with 2010 prices	Market potential with 2007 prices
Total boiler-houses	**123.24**	**10.39**	**9.40**	**9.41**	**7.91**	**2.56**
Coal	26.98	2.23	2.23	2.23	1.13	0.74
Petroleum products	10.81	0.57	0.57	0.57	0.57	0.57
Natural gas	82.21	6.63	6.61	6.62	6.21	1.25
Other solid fuels*	3.25	0.97				
Industrial boiler-houses	**81.85**	**7.70**	**7.08**	**7.08**	**5.63**	**1.09**
Coal	13.99	1.54	1.54	1.54	0.44	0.08
Petroleum products	7.71	0.46	0.46	0.46	0.46	0.46
Natural gas	58.11	5.09	5.08	5.08	4.73	0.55
Other solid fuels*	2.04	0.61				
District boiler-houses	**14.64**	**2.01**	**1.97**	**1.98**	**1.93**	**1.20**
Coal	3.12	0.52	0.52	0.52	0.52	0.50
Petroleum products	1.25	0.06	0.06	0.06	0.06	0.06
Natural gas	10.15	1.40	1.39	1.40	1.35	0.64
Other solid fuels*	0.11	0.03				
Small boiler houses**	**26.76**	**0.68**	**0.35**	**0.35**	**0.35**	**0.27**
Coal	9.87	0.17	0.17	0.17	0.17	0.16
Petroleum products	1.85	0.05	0.05	0.05	0.05	0.05
Natural gas	13.95	0.14	0.14	0.14	0.13	0.06
Other solid fuels*	1.10	0.33				

*Due to the diversity of other solid fuels used, it is not possible to break down the potential by the cost categories in the framework of this study.

**There are not enough data to evaluate the potential of small boilers by cost categories. An assumption was made that its structure is similar to that for district heating boilers.

Source: Estimated by CENEf

In 2000-2006, average specific fuel consumption to generate 1 Gcal of heat showed a 3.5% decline at all Russian large boilers, mainly due to a better load, renovation and new construction of industrial boilers equipment in recent years. However, during the same period there has been practically no progress in the energy efficiency improvement of municipal district heating boilers.

The analysis of more than 230 district heating systems in Khanty-Mansiysky autonomous okrug made by CENEf showed, that only 8% of all boiler-houses run at more than 85% efficiency; 64% at more than 80%, while 28% at less than 60%, including 13% at less than 40% efficiency (see Fig. 8.16). Natural gas-fired boilers have the least specific energy consumption (SEC), followed by petroleum-, coal- and wood-fired boilers. Distribution of SECs along heat generation looks better due to the fact that large heat supply systems are more energy efficient compared to the small ones.

Basic problems to be addressed in the renovation and development program include: high specific fuel consumption of heat generators; lack of fuel consumption and heat supply metering; physical wear of the equipment; use of inadequate quality fuel resulting in burners failures; lack of automation; poor quality of water treatment; violation of the temperature schedule; shortage and low qualification of boiler-house personnel.

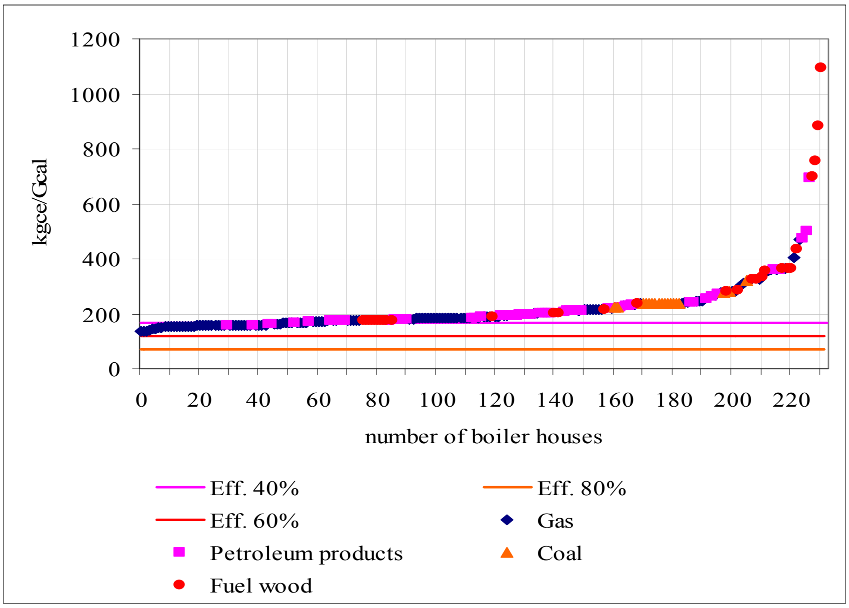

Figure 8.16. Distribution of boiler-houses by specific fuel consumption for heat generation (based on a representative sampling of 235 boiler-houses located in Khanty-Mansiysky autonomous okrug, data on SECs are shown for different fuels against lines displaying three heat generation efficiency levels)

Gas-fired industrial boiler-houses produce approximately 457 million Gcal (35% of total heat generation). Advancing them to the modern technology level can bring 5.09 mtoe in gas savings, much of which (5.08 mtoe) is economically efficient and market attractive. Only 0.55 mtoe is market attractive with the 2007 gas prices, scaling up to 4.73 mtoe with expected 2010 gas prices (see Fig. 8.17). For each Russian region, average efficiency of boilers was used as a reference to identify possible efficiency gains. Special incremental investment costs, as well as change in operational costs, were taken from district heat rehabilitation feasibility studies conducted by CENEf in recent years. The technical potentials for liquid fuel-fired and coal-fired industrial boilers are 0.46 mtoe and 1.54 mtoe (see Fig. 8.18). Investment demand for this potential implementation is about $US 7 billion.

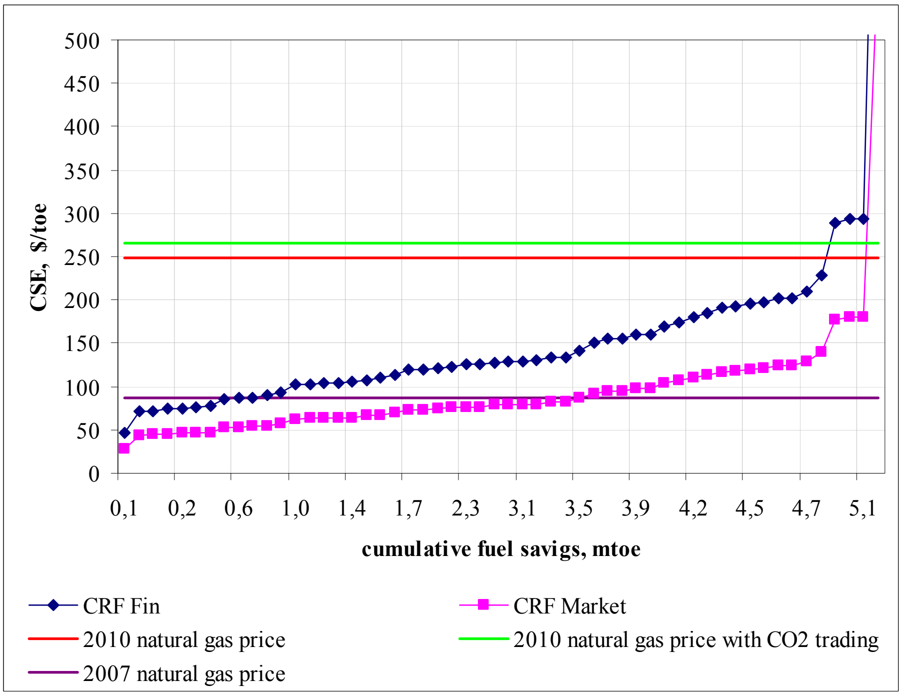

Figure 8.17. The cost of saved energy (CSE) after the implementation of energy efficiency measures at industrial gas-fired boiler-houses

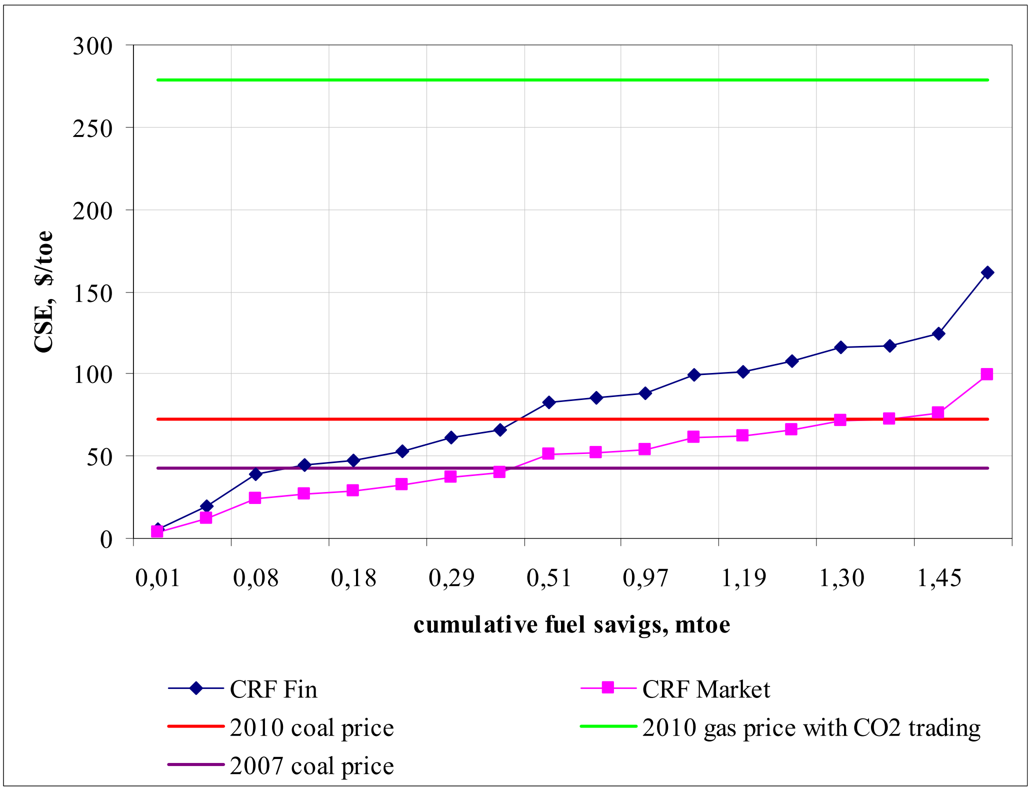

Figure 8.18. The cost of saved energy (CSE) after the implementation of energy efficiency measures at solid fuel-fired industrial boilers

District heating boilers produce 117 million Gcal of heat with 178 kgce/Gcal average specific fuel consumption, which corresponds to 80% boilers efficiency. Advancing gas-fired district boilers to the modern technology level can bring 1.4 mtoe in fuel savings. For liquid fuel-fired district heating boilers the technical potential is 0.06 mtoe, and for solid fuel-fired district boilers 0.52 mtoe. District heat boilers renovation program costs are approximately $US 1.5 billion.

The highly worn-out equipment and poor quality of operation also result in excessive electricity consumption by heat supply systems. Renovation of pumps at boiler-houses will bring 13 million kWh, or 1.12 mtoe, savings.

8.2.2. Heat transmission and distribution

Russian municipal heat networks are 184 thousand km long, of which 34 thousand km need urgent replacement. No data is available on the length of the industrial networks. Average time in operation of heat networks exceeds 13 years, and depreciation is 65%. In many West European countries with well developed heat supply systems distribution losses are 2-10%. In Russia, maximum heat distribution losses should not exceed 10%. This is the maximum level of losses at which district heating systems are physically more energy efficient, than distributed generation. A large part of losses beyond the 10% limit root in improper district heating design (excessive centralization of many district heating systems (see the yellow zone in Fig. 8.19)). In addition, worn and poorly maintained heat supply systems generate substantial additional losses (see the red zone in Fig.8.19). In Russian municipal heating systems heat distribution losses are estimated at 20-25%. In industrial heating systems they are smaller. So average heat losses were assessed in this study at 15% of overall heat generation, or at 24.5 mtoe.

Major problems related to Russian heat networks operation include: high operation costs (50% of overall costs in heat supply systems); excessive centralization in three quarters of heat supply systems, especially in small settlements; lack of investment in the renovation, and so considerable wear of heat networks; exceeding in many municipalities the critical level of network failures; poor insulation and high heat distribution losses; violation of hydraulic modes of heat networks and corresponding under- and over-heating of many buildings; lack of metering and automation in heat supply systems.

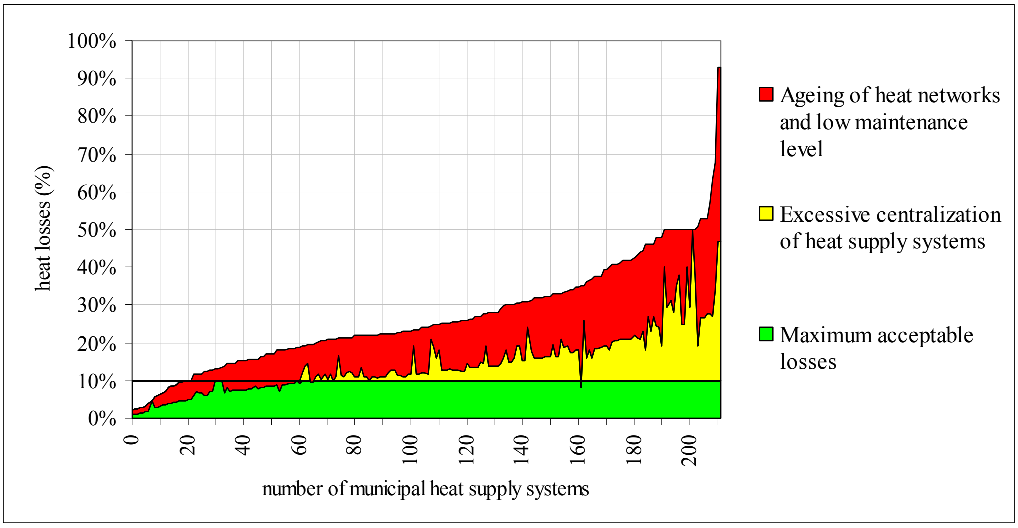

Figure 8.19. Distribution of heat networks by heat distribution losses, based on a representative sampling of 220 heat supply systems

Heat losses reduction potential was assessed at 4.3%, or at 17.3 mtoe, accounting for various pipe diameters and service life. Three pipe diameter ranges were used for each Russian region to assess the investment demand in heat transmission and distribution systems: below 200 mm; 200-400 mm; and over 400 mm. Corresponding specific investments per 1 m of pipeline ($US 154; $US 270; and $ US 450) were used in the CSE assessments. Statistically underreported heat losses were corrected using CENEf's model based on the typical status of pipelines (distribution by diameters, time in operation, mode of construction). No maintenance cost reduction effect resulting from lower accidents repair were accounted for. Much of this potential (17.11 mtoe) appeared to be cost-effective by the economic investment criteria, and 15.9 mtoe by the market investment criteria with the 2007 heat prices, and 17.0 mtoe with expected 2010 heat prices.

Capital cost to implement this potential is estimated at $US 18.6 billion. Not all these costs can be attributed to heat losses reduction. The main goal of replacing heat pipes is to keep supply heat to the consumers, reduce supply interruptions and repair costs, extend heat pipes service life. So only part, say, 50%, of heat networks renovation investments can be attributed to heat losses reduction, thus bringing incremental investment down to $US 9.8 billion.

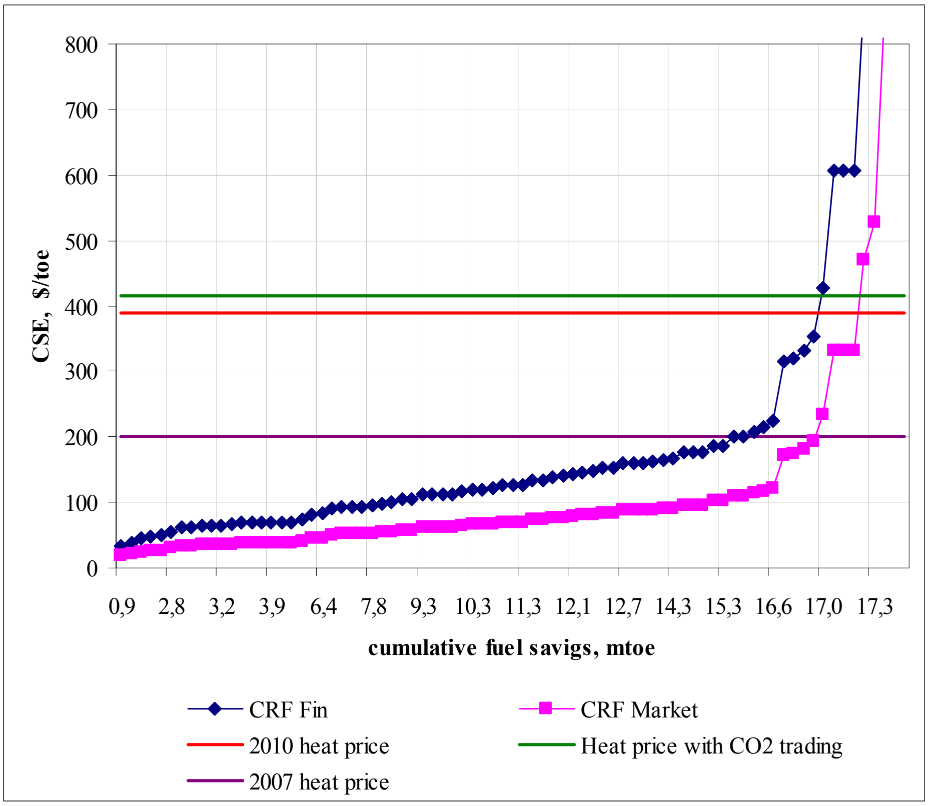

Figure 8.20. The cost of saved energy (CSE) after the implementation of energy efficiency measures at heat transmission and distribution networks

8.2.3. Fuel production and transformation sector

8.2.3.1. Oil extraction and petroleum refineries

Oil extraction and oil preparation at oil fields is responsible for 8.7 mtoe consumption (with electricity contribution of 4.1 mtoe), and petroleum refining for additional 15.1 mtoe. So total consumption by these two activities amounts to 23.8 mtoe, or 3.6% of 2005 TPES with one third of that electricity use.

The decline trend of specific energy consumption (SEC) in the oil extraction sector observed since 2000 was reversed after 2004 for both average SEC and primary extraction method (see Fig. 8.21). The lowest reported SEC in Russia was in Astrakhanskaya Oblast (gas condensate production with SEC=1.44 kgoe/t), while the highest in Sakhalin with developing offshore production (SEC=79 kgoe/t); Tumenskaya Oblast had SEC close to the Russian average. Specific electricity consumption (SElC) in 2005 was 14% above the 1991 level, so no progress in the last 15 years is reported.

Clearly, the efficiency indicators to a large degree depend on the oil deposits specifics and on the oil extraction methods. The secondary or tertiary extraction methods are more energy intense, using more heat and fuel. In 2001-2005, the share of these methods in oil production kept stable, so the reason for SEC growth was different. One of the reasons may be declining attention to cost reduction projects in the oil sector enjoying very high prices since 2000.

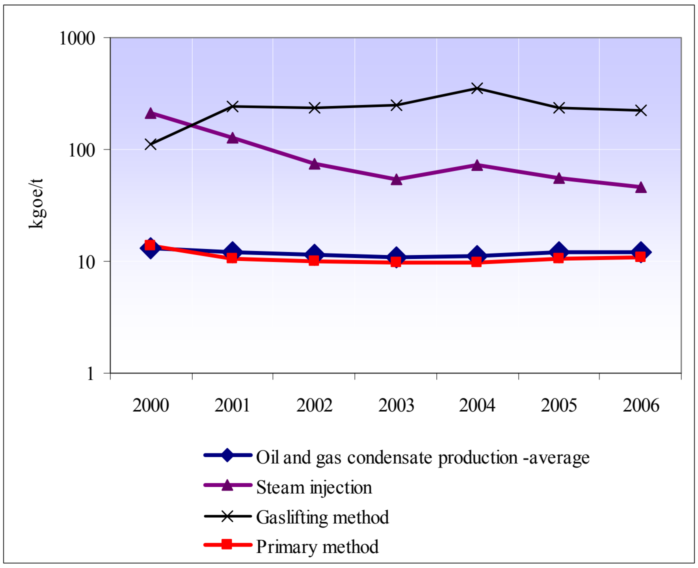

Figure 8.21. Specific energy consumption in Russian oil extraction sector

No data is available on specific energy consumption in oil extraction for other countries to compare with. This makes evaluation of energy efficiency potential for oil extraction and of relevant costs difficult. In 2005, SEC for oil extraction was 9% above the 2003 level, and SElC was 14% above the 1991 level. Much of 46 billion kWh used in oil extraction are related to the operation of electric motor systems driving pumps, with at least 20% efficiency potential[38]. Keeping in mind that oil extraction technologies in Russia are far from the best available, it is reasonable to assume that SEC may be reduced by 20% from the 2005 level. That provides 1.75 mtoe energy efficiency potential.

Utilization of associated natural gas presently flaring in process of oil production provides large potential for improving energy use. By Russian estimates, associated gas flaring is 14-20 billion m3 per year, with the largest estimates reaching 25 billion m3[39]. There are several options to utilize presently flared associated gas: gas collection, drying and providing to gas transportation systems to deliver to gas users; pumping gas back to the well to increase pressure, using liquid fractions as motor fuel and petrochemical feedstock; use it for onsite electricity and heat generation. The cost of associated gas utilization is in the range of 220-350 $US/1000 m3, so with 6% and 12% discount rate natural gas on sale should exceed 35-52 $US/1000 m3. Domestic Russian prices are approaching this level and before 2010 will be far above, thus providing better economics for associated gas utilization. This potential may be realized in full only after some barriers are removed, and the following is established: free access to gas transmission networks for associated natural gas producers, effective associated natural gas pricing policy, and free access to power grids for electricity generated using associated gas; scaling up penalties for associated gas flaring and others. This program may cost $US 3.5-5.5 billion.

A modern refinery is a complex integrated system producing a variety of oil fractions and products depending both on the quality of crude oil and production processes used. Form “11-TER” reports SECs for several refinery processes (see Table 8.2). Average SEC in Russian petroleum refining went down in 2000-2005 by 9% to 2.8 GJ/t. SECs much depend on the process used to produce refinery outputs. Major trend in advanced technologies is driven by increasing share of lighter products in the output mix, but these cracking and reforming technologies are more energy intense, than atmospheric or vacuum distillation (see Table 8.2).

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[38] P. Scheihing, M. Rosenberg, M. Olszewski, C. Cockrill. U.S. Industrial Motor Driven Systems Market Assessment. In Proceedings of workshop “Industrial energy efficiency policies: understanding success and failure. Utrecht. The Netherlands. LNBL. June 11-12, 1998.

[39] Presidential gas. Oil and gas. Kommersant. Business guide. 28.08.2007. Pp. 20-21.

The lack of comparability for SECs in this industry is an important problem (see notes to Table 8.3). A recent study by the IEA “Energy Technology Perspectives 2006”[40] does not provide any assessments of energy efficiency potential in petroleum refining and SECs for the best energy efficient technologies. So the assessment below relies on selected foreign data sources dating back to late 90’es and on more recent data for India and the USA[41].

Table 8.3. Specific energy consumption in petroleum refineries

	Average Russia 2005[1]	The Netherlands and Germany[1]	Japan, South Korea	India	USA[3]
Petroleum refining total	2.83	3.1-3.2	0.77-1.16	2.5-3.95	
Atmospheric distillation	1.37		0.58	0.58-0.61[2]	0.64-1.45
Hydro-cracking	4.36				1.24-2.50
Thermal-cracking	2.07				
Catalytic-cracking	3.04				1,67-2,67
Catalytic-reforming	4.21				1.66-2.67
Hydro-treatment	1.07				0.47-1.28
Delayed coking	2.60				0.89-1.79
Lubricant oil	21.34				11.75

[1] Per 1 t of output

[2] India –government benchmark

[3] Per 1 t of output accounting for generation and transmission losses of electricity, but with no account of hydrogen or oxygen consumption. To make SEC numbers more comparable, the industry has developed so called MBN index, in which the refinery throughput is adjusted using energy factor. For India in 2003.

Complexity of refinery systems makes allocation of energy consumption to specific products difficult. G. Phylipsen et al. assessed the best practice SECs per t of product and came up with the following findings: gasoline – 3.8 GJ/t; kerosene – 1.6 GJ/t; gasoil – 3.2 GJ/t; mazut – 1.8 GJ/t. With present Russian petroleum products output it yields average 2.8 GJ/t, or is equal to the 2005 Russian average. In the literature, both SEC per ton of input or output are often used by industry experts to assess energy use efficiency.

Basic measures to improve energy efficiency and refineries include: improvement of energy management; steam distribution and heat recovery; process heaters; flare gas recovery; distillation; hydrogen management; and efficient motors. To assess the energy efficiency potential, only two most energy consuming processes were used: atmospheric distillation and hydro-treatment. The U.S. best practices and average numbers were used to evaluate the potential. For atmospheric distillation, it was assessed at 2.3-3.2 mtoe (see Fig. 8.22), and for hydro-treatment at 0.23-1.01 mtoe.

Total potential to improve energy efficiency in oil refinery is assessed in the range 2.5-4.2 mtoe, or 31-54% of energy use in these two processes. Assuming the possibility to reduce energy consumption in other petroleum refining processes by 20%[42], the potential totals to 4.0-5.6 mtoe, or 26-37% of overall petroleum refinery energy use. Specific investments are in the range of 200-500 $US/toe. So with 6% and 12% discount rates, the CSE is 16-64 $US/toe, which is cost-effective with present and expected petroleum prices.

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[40] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006.

[41] Energy and environmental profile of the U.S. petroleum refining industry. Office of industrial technologies. Energy Efficiency and Renewable Energy. U.S. Department of Energy. December 1998; G.J.M. Phylipsen, K. Blok and E. Worrell. Handbook on International Comparisons of Energy Efficiency in the Manufacturing Industry. Dept. of Science, Technology and Society, Utrecht University, the Netherlands. April 1998; J. Sathaye, L. Price, S. de la Rue du Can, D. Fridley. Assessment of Energy Use and Energy Savings Potential in Selected Industrial Sectors in India, 2005. Berkeley, CA: LBNL. 2005; E. Worrell, C. Galitsky. Energy Efficiency Improvement in the Petroleum Refining Industry, 2005. Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry.

[42] J. Sathaye, L. Price, S. de la Rue du Can, D. Fridley. Assessment of Energy Use and Energy Savings Potential in Selected Industrial Sectors in India, 2005. Berkeley, CA: LBNL. 2005;

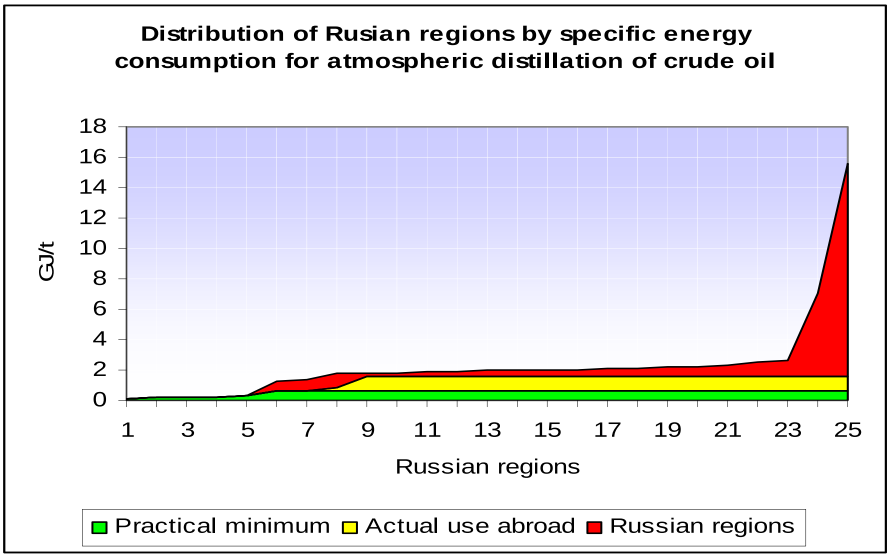

Figure 8.22. Energy efficiency potential in atmospheric distillation of crude oil

8.2.3.2. Coal production and transformation

Coal production consumes 1.1 mtoe, of which 52% is electricity (mainly used by electric motors for pumps, compressed air systems, fans for ventilation and coal transporters). There was substantial progress in SEC per ton of coal mined: in 2000-2005 it shrank by 27%, while the ratio of underground mining was relatively stable (36-37%), and SECs went down for both technologies.

Underground mining in Russia in 2005 was 3.5 times more energy intense, than surface one (0.29 GJ/t versus 0.08 GJ/t). As with oil extraction, the SECs for coal mining are very coal deposit specific, and no data are available to make correct comparisons with other countries. The range of SECs variation for Russian coal mining regions is enormous: from 0.01 to 0.65 GJ/t for surface mining and from 0.20 to 3.76 GJ/t for underground mining. The growth of surface mining by, say, 5% will bring 0.08 mtoe in energy savings, or 4% of the 2005 energy consumption in coal mining. An assumption was made that 15% reduction of energy use is possible in coal mining and processing. So this sector offers 0.26 mtoe potential.

8.2.3.3. Natural gas production and processing

Natural gas production and processing is responsible for 6.8 mtoe energy consumption accompanied by additional 2.9 mtoe transmission and distribution losses, and 32,7 mtoe used by gas pipelines[43], thus totaling to 42.4 mtoe, or 6.5% of Russian TPES. This makes natural gas supply sector not only an energy producer, but also the largest energy consumer in the country.

In this study, potential reduction in gas production and on-field processing is estimated at 20%, with equal distribution of this volume among consumption at gas fields, gas processing facilities, gas losses and gas transportation consumption.

8.3. Manufacturing sector

8.3.1. Energy efficiency potential in manufacturing

Fourth Assessment Report by IPCC estimates industrial energy efficiency potential of West Europe and the U.S. at 20-22%, of China at 15-30%. Large opportunities open in ferrous metallurgy, pulp&paper, and non-energy intense industries. Other recent international assessments of industrial energy efficiency potential concluded, that industry offers a significant savings

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[43] See section 8.6.2 below for more detailes.

potential at low- or even no cost. This potential deserves more attention, than it has received so far[44]. OECD assesses the potential in manufacturing at 18-26%[45].

A large diversity of industrial plants and processes makes it very difficult to evaluate energy efficiency potential in the industrial sector in much detail. Literature on energy efficiency potentials evaluation mainly focuses on several relatively homogenous products: ferrous and non-ferrous metals, pulp and paper, cement, glass, large-scale production of chemical and petrochemical products, with less data available on textile, food processing and machinery. Major energy intense products listed are responsible for only half of the global industrial energy end-use, with the rest consumed by industries with very diverse outputs. Much of the remaining energy is consumed by so-called crosscutting industrial technologies, such as electric motors, steam systems, oxygen and compressed air production, water pumping and treatment facilities, cooling, ventilation and space heating, lighting, which are widely used through the whole industrial sector. This allows for expanding the scope of the analysis for possible energy efficient technologies application beyond the 50% industrial consumption boundaries to address industries with diverse outputs, like machinery or electronics production. The discussion below is structured by the regularly used logic: the potential in most energy intense industries is followed by cross-cutting industrial technologies.

Inconsistency of SECs reported by Russian statistics and those available from the foreign literature are an additional analysis constraint. This prevents from detailed evaluation of energy efficiency potential in chemical and petrochemical production.

Industrial co-generation plants and boiler-houses were included in the energy efficiency potential assessment in the electricity and heat supply sectors above. Therefore, the potential evaluation below does not include industrial electricity and heat generation, CHPs, transmission and distribution, or energy resources extraction, enrichment and refining addressed earlier. The results of the potential evaluation for manufacturing sector are presented in Table 8.4.

The whole final energy efficiency potential in the manufacturing sector was assessed at 41.5 mtoe, and it reaches 96.4 mtoe, when expressed in primary energy with accounting for all indirect energy saving effects in energy production and transformation sectors. This is above overall annual primary energy consumption in countries like Poland, the Netherlands, or Turkey.

Importantly, improving the efficiency of electricity and heat use brings 34.4 mtoe, or about 43 billion m3 in indirect natural gas savings, while direct savings are 9.9 mtoe and 12 billion m3 respectively.

Energy cost savings curves were built for only part of the potential identified in the manufacturing sector (see Fig. 8.23). Incremental investment costs and operational cost change were taken from the sources referenced in corresponding sections below. Direct technical potential was assessed for 50 most important energy efficiency measures and technologies (considered in more detail below) at 30.6 mtoe. Most of it – 30.4 mtoe (99%) – is economically attractive and stays below the expected 2010 average final energy price with 6% discount rate used. The market potential (with 12% discount rate and expected 2010 energy prices) scales down to 26.2 mtoe (85% of the technical potential). With CO2 emission trading it stays at 29.7 mtoe. The market potential with the 2007 prices is 24.8 mtoe (80% of the technical potential).

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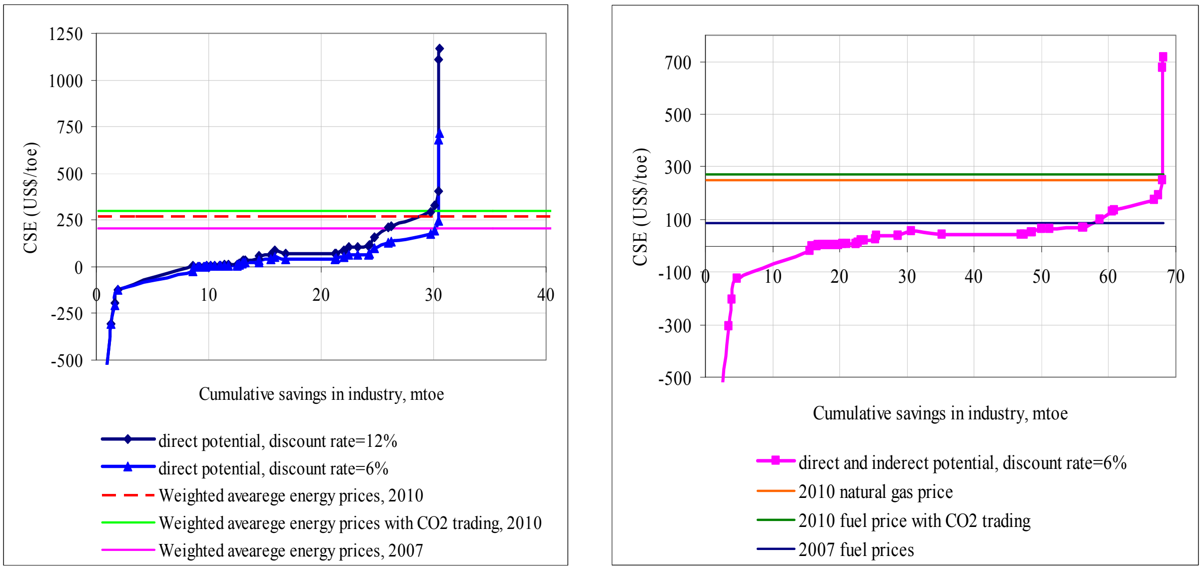
[44] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006.

[45] Tracking industrial energy efficiency and CO2 emissions. OECD/IEA. Paris. 2007.



a b

Figure 8.23. Cost of saved final energy (a) and primary energy (b) curves for energy efficiency improvements in Russian manufacturing industry (each dot plotted reflects a separate technology)

When indirect effects are accounted for and primary energy savings are assessed, the economic potential grows up to 66.8 mtoe (67.46 with CO2 emissions trading), of which 15.6 mtoe carry net negative costs.

Only capital investments in measures with positive CSE but below the expected 2010 average fuel price or average final energy price were accounted for to estimate total investment demand for the implementation of 50 measures in the manufacturing sector. The outcome of this assessment is: $US 2005 **20 billion of incremental investment are needed to achieve annual savings of 30 mtoe of final energy or about 67 mtoe of primary energy. In other words, on average it costs only $US 294 to implement 1 toe of economic energy efficiency potential in manufacturing.**

The estimates for 2010-2020 show, that $US 1990-2740 are required to increase primary energy production by 1 toe[46]. Scaling identified specific incremental investments to the whole potential evaluated for manufacturing (see Tables 8.4 and 8.5 above); it comes to $US 2005 27-30 billion bringing 96 mtoe savings. Part of that comes just to maintain the present level of production. Therefore:

> **1 toe of primary energy delivered to support economic growth generated by energy efficiency measures requires on average 6-9 times less capital investment, than the same energy delivered through additional supply options.**

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[46] Russia's long-term economic development projections for 2007-2030 (scenarios). Russian Academy of Science, Institute for economic projections. Moscow, May 2007.

Table 8.4. Technical energy efficiency potential evaluation for manufacturing (mtoe)

Products and processes	Final energy							Primary energy[1]						
	Coal	**Petroleum products**	**Gas**	**Other solid fuels**	**Electricity**	**Heat**	**Total**	**Coal**	**Petroleum products**	**Gas**	**Other solid fuels**	**Electricity**	**Heat**	**Total**
Coke production	1.68	0.00	0.02	0.00	0.09	0.61	**2.41**	2.01	0.07	0.95	0.04	0.15	0.74	**3.96**
Oxygen production	0.00	0.00	0.00	0.00	0.20	0.19	**0.39**	0.24	0.04	0.71	0.03	0.27	0.23	**1.52**
Compressed air production	0.02	0.00	0.06	0.00	0.27	0.03	**0.38**	0.27	0.03	0.77	0.02	0.36	0.04	**1.50**
Water pumping and treatment for industrial use	0.00	0.00	0.01	0.00	0.50	0.03	**0.55**	0.46	0.06	1.31	0.04	0.68	0.05	**2.59**
Pig iron	4.70	0.00	1.18	0.00	0.02	0.07	**5.97**	4.90	0.03	1.53	0.01	0.08	0.12	**6.66**
Open-hearth furnace	0.00	0.36	1.00	0.04	0.02	0.06	**1.48**	0.05	0.38	1.25	0.04	0.04	0.09	**1.85**
Basic oxygen furnace steel	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
EAF steel	0.00	0.00	0.11	0.00	0.36	0.03	**0.50**	0.33	0.04	1.05	0.03	0.49	0.04	**1.98**
Rolled steel	0.92	0.03	1.96	0.00	0.45	0.28	**3.64**	1.45	0.12	3.61	0.05	0.64	0.36	**6.22**
Steel pipes	0.00	0.00	0.12	0.00	0.03	0.03	**0.18**	0.04	0.01	0.24	0.00	0.04	0.03	**0.37**
Electroferroalloys	0.10	0.00	0.00	0.00	0.14	0.00	**0.25**	0.23	0.02	0.36	0.01	0.19	0.01	**0.81**
Synthetic ammonia	0.00	0.00	0.09	0.00	0.06	0.08	**0.23**	0.07	0.01	0.32	0.01	0.08	0.09	**0.59**
Fertilizers and carbamide	0.00	0.01	0.06	0.00	0.07	0.28	**0.42**	0.16	0.04	0.55	0.02	0.11	0.33	**1.21**
Synthetic caoutchouc	0.00	0.05	0.08	0.00	0.07	0.52	**0.71**	0.23	0.11	0.81	0.03	0.10	0.61	**1.89**
Casting and metal works	0.02	0.01	0.21	0.00	0.05	0.03	**0.32**	0.08	0.02	0.40	0.01	0.07	0.04	**0.62**
Pulp	0.00	0.04	0.00	1.29	0.17	1.16	**2.66**	0.53	0.17	1.67	1.36	0.25	1.38	**5.36**
Paper	0.00	0.00	0.00	0.00	0.17	0.35	**0.52**	0.26	0.05	0.81	0.03	0.24	0.42	**1.81**
Paperboard	0.00	0.00	0.00	0.00	0.05	0.16	**0.21**	0.09	0.02	0.29	0.01	0.06	0.19	**0.68**
Cement and clinker	0.20	0.02	2.00	0.00	0.24	0.01	**2.47**	0.43	0.06	2.80	0.02	0.33	0.03	**3.67**
Meat	0.00	0.00	0.02	0.00	0.06	0.16	**0.24**	0.10	0.03	0.33	0.01	0.08	0.19	**0.75**
Bread	0.02	0.02	0.24	0.02	0.06	0.14	**0.50**	0.13	0.04	0.56	0.03	0.09	0.16	**1.02**
Other	0.74	0.66	2.70	0.05	3.69	8.68	**16.51**	6.84	1.92	21.56	0.78	5.16	10.41	**46.66**
Non-ferrous metallurgy	0.00	0.00	0.00	0.00	0.95	0.00	**0.95**	0.84	0.10	2.38	0.08	1.28	0.02	**4.69**
Manufacturing	**8.41**	**1.19**	**9.86**	**1.40**	**7.72**	**12.90**	**41.49**	**19.72**	**3.35**	**44.26**	**2.69**	**10.80**	**15.60**	**96.42**

[1] Primary energy savings in this table were assessed based on the method described in Section 6.

8.3.2. Ferrous metals

Russian ferrous metallurgy comes second (after gas production and transportation) in Russian energy consumption: in 2005, it consumed 36.1 mtoe (5.5% of TPES), including 35.5 billion kWh of electricity and 21.3 million Gcal of heat. Availability of data for this industry provides the luxury of assessing the energy efficiency potential through two different approaches: (1) comparison with worldwide best practices, and (2) screening Russian metallurgical companies' investment plans.

The first approach reveals the 16 mtoe energy efficiency potential in ferrous metallurgy, or 44% of the 2005 energy use, while the second approach shows 21 mtoe, or 58% of the 2005 consumption.

Iron ore production and enrichment, ore agglomerate and pellets production taken together consume 4.45 mtoe, of which 1.1 mtoe is electricity. Russian statistics reports three SECs: for ore production and enrichment 0.34 GJ/t; for sintering 1.83 GJ/t, and for pellets production 1.28 GJ/t. Corresponding SECs for the U.S. are: 0.58 GJ/t for sintering and 2.42 GJ/t for pellets[47], and corresponding best practice values are: for sintering 1.9 GJ/t steel, for pelletizing 0.6 GJ/t steel [48]. Converting the latter figures from 1 t of steel to 1 t sinter and pellets with the Russian ferrous metallurgy structure one obtains 1.49 GJ/t for sintering, and 0.7 GJ/t for pelletizing.

Major energy efficiency measures include sinter and pelletizing plant heat recovery, reduction of compressed air leaks, improved process control, and the use of waste fuels in sinter plants. Energy efficiency potential for sintering was assessed against the best practices at 0.47 mtoe, and for pelletizing at 0.53 mtoe. For ore production and enrichment, the potential was assumed at 15%, or 0.12 mtoe.

SEC for coke production in Russia is 1.39 GJ/t coke, while the best practices report 0.8 GJ/t steel[49], or 0.92 GJ/t coke, thus leaving 0.36 mtoe for energy efficiency improvements. With both coke production and coke batteries heating Russian SECs is reported equal to 4.1 GJ/t, while the IEA reports an average 8 GJ/t[50], and the US DOE reports 6.2 GJ/t [51]. The comparability problem may hide in the coke production system boundaries.

Utilization of pulverized coal injection technologies in blast furnaces brings substantial reduction in coke consumption. This allows for replacing coke with coal and thus avoiding coke making. Assuming 50% of blast furnaces capacity is switched to pulverized coal injection, the energy efficiency potential totals to 1.55 mtoe. For the rest of coke dry quenching technology, along with coke moisture control systems, programmed heating and variable speed drives in coke oven gas compressors, can save 0.36, 0.03, and 0.11 mtoe respectively, thus bringing potential to 2.41 mtoe, or 67% of energy consumption in coke production.

Pig iron production in Russia in 2005 consumed 19.6 mtoe. SEC to produce 1 t of pig iron in 2005 was 16.9 GJ/t, which is as high as back in 1991 and as bad as in the U.S. in 1994[52]. No progress has been made in Russia in the last 15 years in the improvement of pig iron production efficiency. IEA reports best practice SEC equal to 10.4 GJ/t and average practice for foreign countries in the range of 13-14 GJ/t. LBNL reports the best practice SEC equal to 12.2 GJ/t steel or 11.2 GJ/t of pig iron. SECs of nearly all Russian blast furnaces, except one, are above this range (see Fig. 8.24).

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[47] Energy and environmental profile of the U.S. iron and steel industry. Prepared by: Energetics, Inc. Columbia, Maryland, for U.S. Department of Energy, Office of Industrial Technologies. July 1996.

[48] E. Worrell, M. Neelis, L. Price, et al. World best practice energy intensity values for selected industrial sectors.. LBNL-62808. June 2007.

[49] Ibid.

[50] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006. p. 401.

[51] Energy and environmental profile of the U.S. iron and steel industry. Prepared by: Energetics, Inc. Columbia, Maryland, for the U.S. Department of Energy, Office of Industrial Technologies. July 1996.

[52] Ibid.

Compared to the best technology, the potential to improve energy efficiency comes to 5.97 mtoe, which is 38% of 2005 energy use. Much of this comes from pulverized coal injection. To avoid double counting, the above mentioned potential was not accounted for in pig iron production. Energy efficiency technologies include top pressure recovery turbines, blast furnace gas recovery, hot blast furnace automation, improved blast furnace controls.

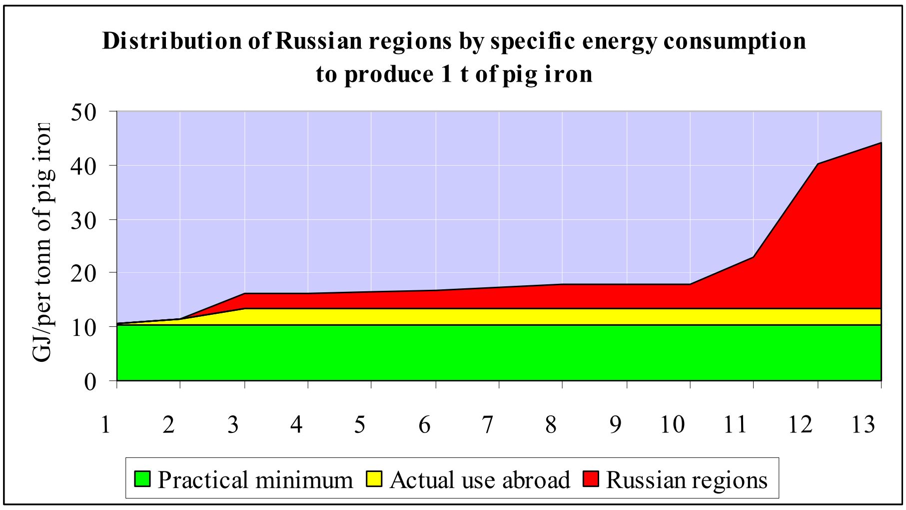

Figure 8.24. SECs in Russian pig iron production

Russian electric arc furnaces (EAF) consume about 1 mtoe of energy, primarily electricity. Unlike in pig iron, the SECs in EAF went down in 1991-2005 by 16%, yet there is much room for further improvement. Average SEC in 2005 was 3.2 GJ/t versus practical minimum 1.6 GJ/t (new EAFs with scrap preheating and increased oxygen use[53]) and actual use abroad 2.1-2.4 GJ/t. In many Russian regions, SECs were far above these indicators (see Fig. 8.25). Energy efficiency potential in reaching the practical minimum or actual use abroad efficiency indicators is 0.34-0.50 mtoe.

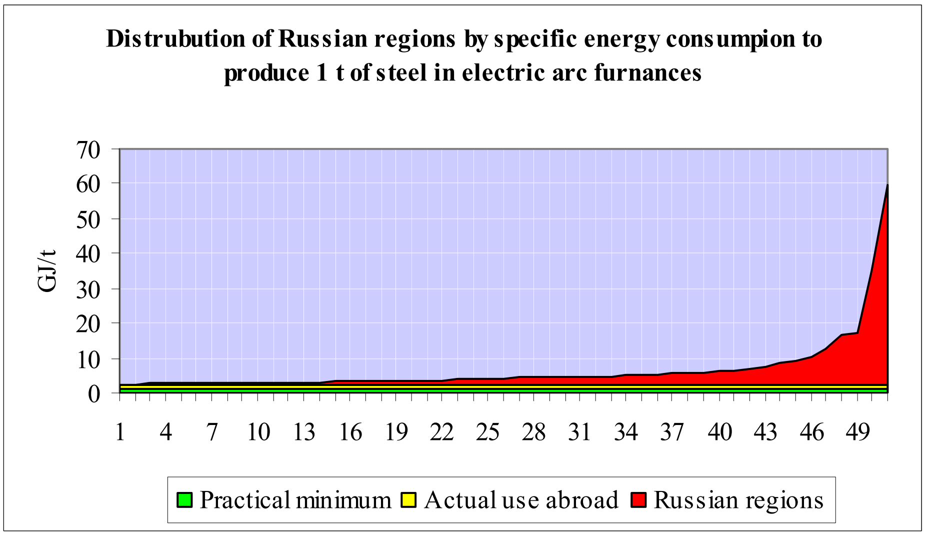

Figure 8.25. SECs in Russian electric arc furnaces

Nearly 1.6 mtoe is used by Russian open-hearth furnace with SEC equal to 5.0 GJ/t in 2005. This technology provides negligible contribution to steel making in OECD countries and is mainly used

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[53] See Using energy and materials more efficiently: a precondition for sustainable development. Conference organized by Korea Resource Economics Association (KREA), Korea Energy Economics Institute (KEEI), Centre for Energy Policy and Economics (CEPE), ETH Zurich, Switzerland and Ecofys, Utrecht, the Netherlands. Seoul, Republic of Korea. September 21-22, 2006, and Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006.

in economies in transition. The gap between the best and the worst SECs in Russian regions is between 2.82 and 10.98 GJ/t. Average energy use in basic oxygen furnace in Russia is only 0.38 GJ/t. So switching the whole steel production from open-hearth to basic oxygen furnace will generate 1.48 mtoe in energy savings.

Slightly over 5.2 mtoe is used for rolled steel production. In 2005, the SEC for rolled steel was 4.01 GJ/t and declined since 1991 by impressive 26%. Nevertheless, the practical minimum for cold rolled steel is 0.4 GJ/t[54] and for hot rolled steel 0.9-1.6 GJ/t, while actual use abroad is correspondingly 1.0-1.4 GJ/t and 2.0-2.4 GJ/t[55]. In Russia, the share of cold rolled steel in 2005 was 33%. For many regions SECs for rolling exceeded the average OECD practices by the order of magnitude (see Fig. 8.26). The energy efficiency potential was assessed using two SEC benchmarks: 1 and 2 GJ/t totaling to 2.6-3.9 mtoe.

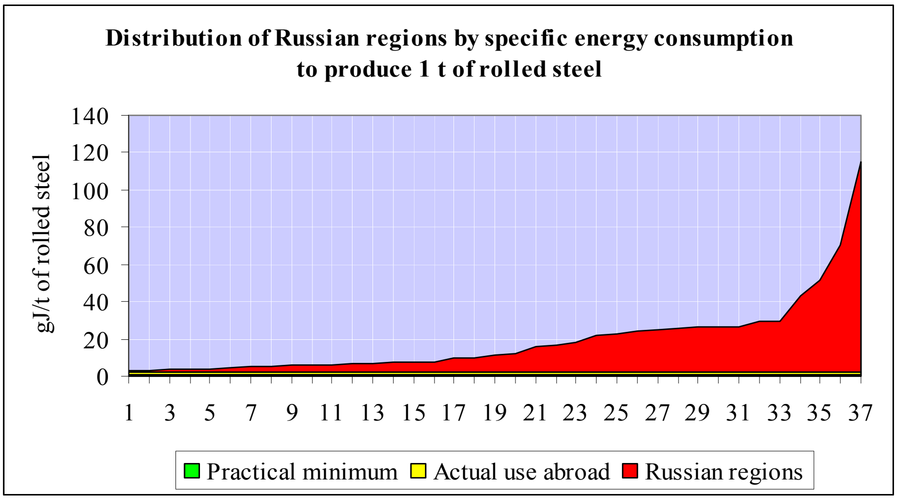

Figure 8.26. SECs in Russian rolled steel production

This potential is provided mainly by transition to continuous, near-net shape and thin strips casting, which eliminates slabs heating and cooling stages and reduces rolling cycles. In 2005, only 66% of steel in Russia was produced by continuous casting machines.

Altogether energy efficiency potential for the introduction or scaling up of 24 technologies was considered. These technologies ranked by relative costs include: electric arc furnace upgrade; improved blast furnace control systems; process control in hot strip mill; recuperative burners; programmed heating; automated monitoring and targeting system; efficient ladle preheating; heat recovery on the annealing line; blast furnace gas recovery; reduced steam use in cold rolling; pulverized coal injection; controlling oxygen levels and variable speed drives; hot blast furnace automation; energy efficient drives for hot rolling; sintering and pellets production improvements; iron ore production and enrichment improvements; waste heat recovery (cooling water); hot charging; insulation of furnaces for hot rolling; thin strip and near-net-shape casting; continuous casting; dry quenching; top pressure recovery systems; and coal moisture control. Cost and savings data for each technology or group of technologies were taken from several sources, and figures for earlier years were adjusted for dollar inflation[56].

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[54] E. Worrell, M. Neelis, L. Price, et al. World best practice energy intensity values for selected industrial sectors. LBNL-62808. June 2007.

[55] Scenarios and Strategies to 2050. OECD/IEA. 2006.

[56] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006; Using energy and materials more efficiently: a precondition for sustainable development. Conference organized by Korea Resource Economics Association (KREA), Korea Energy Economics Institute (KEEI), Centre for Energy Policy and Economics (CEPE), ETH Zurich, Switzerland and Ecofys, Utrecht, the Netherlands. Seoul, Republic of Korea. September 21-22, 2006; Ernst Worrell, Natan Martin, and Lynn Price. Energy Efficiency and Carbon Dioxide Emissions Reductions Opportunities in the U.S. Iron and Steel Sector. Ernest Orlando Lawrence Berkeley

After some technologies are introduced, annual operating costs may change. That means that depending on discount rates used the annualized costs of some technologies may change, as well as their respective cost ranks. The market potential was assessed using weighted average energy price for ferrous metallurgy for 2007 and that expected for 2010. With such assumptions, **the market potential in ferrous metallurgy equals 11,9 mtoe in either case**.

There are two metrics for the economic potential evaluation: (a) accounting for direct effect only with 6% discount rate and using weighted average energy prices, and (b) accounting for both direct and indirect effects (approach discussed in Section 6), but then using only weighted average fuel prices (electricity and district heat excluded).

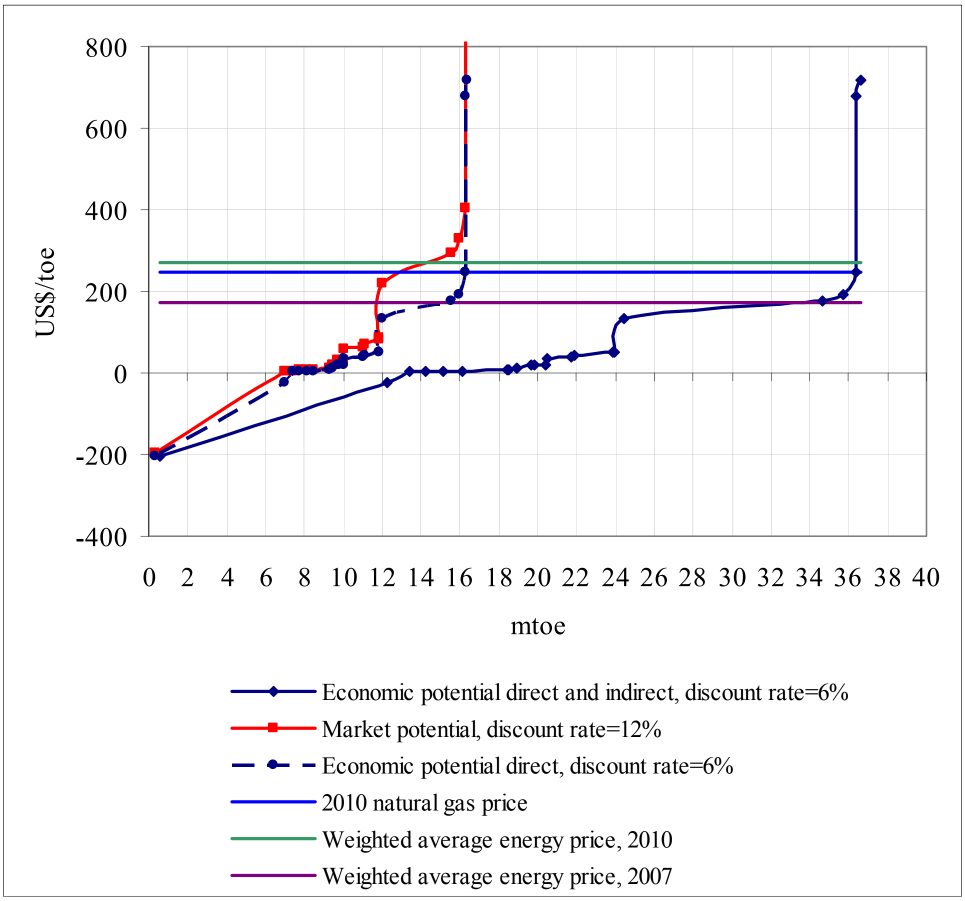

Figure 8.27. Energy cost savings brought by energy efficiency improvements in Russian ferrous metallurgy

With the first approach, the economic potential is evaluated at 16.3 mtoe[57], while the second approach yields the value 34.7 mtoe, after all losses and own needs, as well as energy consumption for the generation and delivery of energy to final consumers in ferrous metallurgy, are accounted for. **So direct technical potential is 16.4 mtoe, direct economic potential 16.3 mtoe, while integrated economic potential accounting for indirect energy use is 36.4 mtoe. The market potential with 2010 energy prices is 12 mtoe. Importantly, a large part of it (7 mtoe) comes with net negative CSE.**

National Laboratory, University of California. July, 1999; Energy and environmental profile of the U.S. iron and steel industry. Prepared by: Energetics, Inc. Columbia, Maryland, for U.S. Department of Energy, Office of Industrial Technologies. July 1996.

[57] This result is very much in line with some special studies which conclude, that optimization of material and energy flows alone at each Russian steel works (without replacing major technologies) allows for 10-25% energy consumption reduction. See Sultanguzin Ildar Aidarovich. Scientific and technical basis for modeling and optimization of the steel works' energy outline. 05.14.04. – Promyshlennaya teploenergetika. Author's summary of a doctoral thesis. Moscow. 2005; and Optimal resource management and strategic planning for a steel works. ZAO NTTs "LAG Engineering". Moscow. 2005.

Alternative approach selected for the evaluation of energy efficiency potential in ferrous metallurgy was based on the analysis of Russian steel works' investment plans to combat considerable wear and obsolescence of basic equipment combined with poor energy consumption management and control.

Evaluation of the energy efficiency potential was based on viewing the technology processes as a comprehensive interrelated system. Basic measures and technologies considered for Russian ferrous metallurgy are structured as follows.

In coke and by-product process:

- ⇒ Renovation and upgrade of coke-oven batteries. This allows for full-load operation bringing 15-20% coke production increase, as well as for 7-9% energy consumption reduction;
- ⇒ Wider application of coke dry quenching technology, which allows it to reduce energy consumption by 35 kgoe/t of coke;
- ⇒ Coke dry quenching heat recovery by recovery boilers with installation of steam turbines for electricity generation, which allows for 10-20% reduction of electricity procurement from external energy sources for coke and by-product industry needs;
- ⇒ In sintering, renovation and upgrade of sintering units to allow for full-load operation and corresponding 5-10% sinter production increase combined with 8-12% energy consumption reduction.

In blast furnace process:

- ⇒ Renovation and upgrade of blast furnaces with 5-15% cast iron production increase and 6-12% energy use reduction;
- ⇒ Blast furnace gas recovery in top pressure recovery turbines allowing for 25-40% reduction of electricity procurement from power grid for blast furnaces processes;
- ⇒ Application of pulverized coal injection (PCI) technology in blast furnaces to help reduce specific natural gas and oxygen use for cast iron production by 80-85%;
- ⇒ Gas injection in blast furnaces and blast-furnace air temperature increase help reduce specific natural gas consumption for cast iron production by 8-12%.

In steelmaking:

- ⇒ Renovation and upgrade of equipment for electric steel industry and installation of automatic process control systems allow for steel production increase at EAFs by 15-20% with simultaneous 7-14% reduction of SEC;
- ⇒ Renovation and upgrade of worn equipment for oxygen converters allows for 10-15% increase of steel production in converters and for 8-15% reduction of SEC for steelmaking in converters;
- ⇒ Replacement of open hearth steel production with EAFs helps reduce energy use by 25-35%. Besides, with increasing share of electric steel production, coke production goes down by 14%, sinter production by 24% and cast iron production by 21%;
- ⇒ Wider application of continuous casting technology at continuous casting machines will help increase steel production by 12-17% and reduce fuel SEC by 28 kgoe/t and electricity SEC by 50 kWh/t;
- ⇒ Using converter waste gas as fuel (converter waste gas recovery) helps reduce specific energy consumption in oxygen-converter steelmaking by 350 kgoe/t.

In ferrous metals rolled products:

⇒ Renovation and upgrade of hot rolling mills and installation of automatic process control systems allows for 17-22% increase of hot rolled products output and 10-15% simultaneous reduction of energy consumption;

⇒ Renovation and upgrade of cold rolling mills and cold-drawn bar mills with installation of automatic process control systems will help increase cold rolled products and cold-drawn bar output by 20-25% and reduce specific energy consumption by 10-15%.

Altogether 15 technologies or groups of technologies were considered. Investment demand for these energy efficiency measures was estimated based on the investment programs of Russian metallurgy plants. This demand (2005, $US million) for coke and by-product process amounts to 2,104; for sinter process to 80; for blast furnace process to 2,504; for steelmaking to 2,811; for hot, cold, and cold-drawn bar rolled products to 140, totaling to $US 7,637 million. Investment distribution by process, measure and technology is shown in Table 8.5.

Table 8.5. The costs of energy efficiency measures and technologies for ferrous metallurgy

Measures	Number of facilities	Facilities' productivity (average)	Specific capital investment	Overall capital investment, $US million
1	2	3	4	5
Coke and by-product process				
Renovation and upgrade of worn and obsolescent equipment of coke-oven batteries	Renovation of 47 coke-oven batteries	500 thou. t of coke	40 $US/battery	**1,880**
Application of coke dry quenching technology in coke dry quenching units	Installation of 7 coke dry quenching units	1,764 thou. t of coke	18 $US/unit	**129**
Coke dry quenching heat recovery in recovery boilers with installation of steam turbines for electricity generation	1,410,000 thou. kWh	157,063 kW (overall capacity of steam turbines)	600 $US/kW	**94**
Sintering plant				
Renovation and upgrade of worn and obsolescent equipment for sintering units	Renovation of 40 sintering units	1,050 thou. t of sinter	2 million $US/sintering unit	**80**
Blast-furnace process				
Renovation and upgrade of worn and obsolescent equipment for blast furnaces	Renovation of 18 blast furnaces	2,000 thou. t of cast iron	60 million $US/furnace	**1,080**
Blast furnace gas recovery in top pressure recovery turbines	528,352 thou. kWh	76,000 kW (overall capacity of top pressure recovery turbines)	1,000 $US/kW	**76**
Application of pulverized coal injection (PCI) technology in blast furnaces	Commissioning of 20 units	1,800 thou. t of cast iron	67 $US/unit	**1,340**
Gas injection in blast furnaces and blast-furnace air temperature increase	18 blast furnaces	2,000 thou. t of cast iron	423 thou. $US/blast furnace	**8**
Steel industry				
Renovation and upgrade of equipment for electric steel industry and installation of automatic process control systems	Renovation of 20 electric furnaces	660 thou. t of steel	30 million $US/furnace	**606**
Renovation and upgrade of worn equipment for oxygen converter steelmaking	Renovation of 13 converters	3,000 thou. t of steel	1.2 million $US/converter	**15**

1	2	3	4	5
Steel industry				
Replacement of open hearth steel making with electric steelmaking technology	Commissioning of 20 electric furnaces	660 thou. t of steel	71 million $US/electric furnace	**1,420**
Application of continuous casting technology at continuous casting machines	Commissioning of 14 continuous casting machines	1,000 thou. t of steel	45 million $US/machine	**630**
Using converter waste gas as fuel (converter waste gas recovery)	Commissioning of 4 units	1 unit is designed for 9,000-10,000 thou. t of steel	36 million $US/unit	**140**
Ferrous metals rolled products				
Renovation and upgrade of hot rolling mills and installation of automatic process control systems	Renovation of 7 rolling mills	5,000 thou. t of rolled products	9.5 million $US/rolling mill	**67**
Renovation and upgrade of cold rolling mills and cold-drawn bar mills with installation of automatic process control systems	Renovation of 7 mills	2,000 thou. t of rolled products	12.2 million $US/rolling mill	**73**

Source: Investment and production programs of Russian steel works (OAO “MMK”, OAO “NTMK”, OAO “NLMK”).

Table 8.6. Rating energy efficiency measures and technologies in ferrous metallurgy (discount factor 0.12)

Measure and/or technology	**Capital investment**	**Additional operational costs (+) or benefits (-)**	**Energy savings**	**The cost of saved energy**
	Million $US	**Million $US**	**Thou. tce**	**$US/tce**
1. Renovation and upgrade of cold rolling mills and cold-drawn bar mills with installation of automatic process control systems	73	-1,104	836.47	**-1,309.3**
2. Renovation and upgrade of hot rolling mills and installation of automatic process control systems	67	-2,784.6	2,439.72	**-1,138.1**
3. Renovation and upgrade of equipment for electric steel industry and installation of automatic process control systems	606	-631.1	646.15	**-864.1**
4. Renovation and upgrade of worn equipment for oxygen converter steelmaking	15	-1,446.9	2,181.82	**-662.3**
5. Application of continuous casting technology at continuous casting machines	630	-646	451.82	**-363.2**
6. Gas injection in blast furnaces	8	-	2,013.99	**0.5**
7. Converter waste gas recovery in oxygen-converter process	140	-	1,363.64	**12.3**
8. Application of coke dry quenching technology in coke dry quenching units	129	-	629.13	**24.7**
9. Replacement of open hearth steel making with electric steelmaking technology	1,420	71.2	7,080.57	**34.1**
10. Application of pulverized coal injection (PCI) technology in blast furnaces	1,340	-	1,968.79	**81.7**
11. Coke dry quenching heat recovery by recovery boilers with installation of steam turbines for electricity generation	94	-	121.28	**93.2**
12. Renovation and upgrade of worn and obsolescent equipment for blast furnaces	1,080	-	859.02	**150.9**
13. Blast furnace gas recovery in top pressure recovery turbines	76	-	45.45	**200.7**
14. Renovation and upgrade of worn and obsolescent equipment for sintering units	80	100.8	147.00	**751.0**
15. Renovation and upgrade of worn and obsolescent equipment of coke-oven batteries	1,880	371	185.79	**3,212.1**

Source: CENEf’s estimates

Implementation of measures related to the renovation and upgrade of sintering and coke and by-products industries and to the replacement of open hearth steelmaking with electric steel technology involve additional costs determined by increased raw materials (coal concentrate, iron ore, metal scrap) demand. Coal concentrate consumption is expected to grow by 4.6 million t, iron ore by 1,680 thou. t, and metal scrap by 1,185 thou. t. Additional costs associated with these measures will amount to $US 543 million.

CSE-based comparison allows for the identification of most viable energy efficiency measures and technologies to be implemented in the first place. CSE-based rating of energy efficiency measures and technologies in ferrous metallurgy is shown in Table 8.7 and Fig. 8.28.

Measures No. 1 through 5 are most cost-effective. They include measures related to the renovation and upgrade of rolling mills; renovation and upgrade of electric steel and oxygen-converter processes; and application of continuous casting technology. For all these measures, the cost of saved energy is below zero, because energy savings are a side-effect. In full compliance with the evaluation based on international comparisons, the part of the potential with negative net CSE is 7 mtoe and with costs below 0.5 $US/toe up to 10 mtoe. This builds trust in the results obtained.

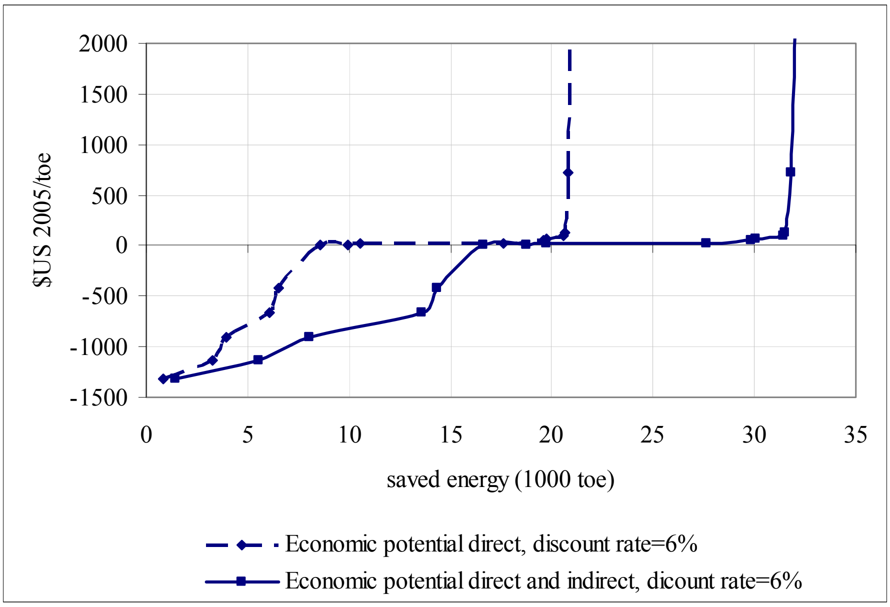

Figure 8.28. Energy conservation curves for Russian ferrous metallurgy estimated for 2005 based on the investment plans of Russian enterprises

With the first approach, direct and indirect technical potential was evaluated at 24 mtoe, while the second approach shows 32 mtoe. The economic potential is correspondingly 21 and 31 mtoe, while the market potential is 12 mtoe and 20.6 mtoe with 12% discount rate. Based on the two above approaches, it is possible to state that:

- ⇒ **direct economic potential in ferrous metallurgy is 16-21 mtoe;**
- ⇒ **integrated economic potential is 24-32 mtoe;**
- ⇒ **direct market potential is 12-20 mtoe.**

8.3.3. Non-ferrous metals

Russian economic and energy statistics does not provide data on non-ferrous metallurgy physical outputs, or on total or specific energy consumption. So only data published by foreign sources is used in this section along with SEC estimates reported in Russian professional literature. According to the IEA energy balances, Russian non-ferrous metallurgy annually consumes about

19 mtoe[58], of which, by CENEf estimate, about 10-11 mtoe can be allocated to aluminum production.

In 2000, production of alumina was assessed at 2.46 million t, production of primary aluminum at 3.25 million t, and overall aluminum production at 3.4 million t[59]. Aluminum production in 2006 is estimated at 3.72 million t[60]. Specific electricity consumption to produce 1 t of primary aluminum in Russia is assessed in the range of 14,500-18,300 kWh/t with 16,000 kWh/t average.[61] This is not too far from the global average (15,268 kWh/t[62]) and 15,180 kWh/t in the U.S.[63], but much above the practical minimum for the best foreign producers (12,000-13,000 kWh/t[64]). **Approaching the practical minimum yields 11 billion kWh, or 0.85 mtoe, of technical energy efficiency potential (electricity savings) to Russian primary aluminum smelting alone.** Energy consumption in aluminum smelting is about two thirds of overall energy consumption in primary aluminum industry. The second most energy intense process is alumina refining from bauxite, followed by the use of carbon anodes and ingot casting. Production of 1 t of secondary aluminum from scrap requires only 5% (1% of electricity and 18% of natural gas[65]) of energy needed for primary aluminum production. In the U.S., secondary production from scrap in 2006 was 30% of overall production and fluctuated in the range of 30 to 37%, while in Japan the corresponding range was 90-97%, and in OECD Europe 30-33%. Direct data are not available for Russia, but some indirect data indicate, that this share does not exceed 5%. Only 20% of domestically produced aluminum is used in Russia. If the U.S. scrap to annual consumption ratio is applied to Russia, there is no, or very little, room to expand secondary aluminum production.

Several technologies allow for energy consumption reduction in the aluminum industry: transition from Soderberg to Hall-Heroult smelting process and gradual improvement of both technologies. Introduction of inert cathodes and anodes (not yet commercially proven) would allow for specific electricity consumption reduction to 11,000 kWh/t accompanied by the reduction of oil and coal consumption by 18 GJ/t, but is applicable only at new facilities, for a significant cell design change is required. Several marginally important technologies exist to improve energy efficiency of continuous casting and rolling, and a certain contribution may be made by detecting and removing aluminum cans from municipal solid waste, by recovering aluminum in wheel production, etc.

Based on estimates of primary and secondary copper production in Russia[66] and on data for SEC in Russia versus practical minimum and actual use abroad[67], the technical potential for the copper industry was assessed at 0.1 mtoe. No cost data are available to assess, which part of the technical potential in ferrous metallurgy is economically viable.

8.3.4. Pulp and paper

In 2005, energy use in pulp and paper production totaled 6.9 mtoe, of which 2.4 mtoe were contributed by so-called “other fuels” (including black liquor). In 2000-2005, SEC for pulp production declined by 13.5%, for paper production by 5.3%, and for paperboard production by

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[58] OECD/IEA. Energy balances of non-OECD countries. 2003-2004.2006 Edition. Paris. 2006, p. II-166.

[59] O. Ustenko. Russia’s Accession into WTO: A Case Study of the Aluminum Industry. Center for Economic and Financial Research.

[60] U.S. Geological Survey, Mineral Commodity Summaries. January 2007.

[61] “Energorynok” <http://www.rosnor.com>.

[62] Energy Technology Perspectives 2006. Scenarios and Strategies to 2050. OECD/IEA. 2006. p. 430.

[63] Energy and environmental profile of the U.S. aluminum industry. Prepared by: Energetics, Inc. Columbia, Maryland, for U.S. Department of Energy, Office of Industrial Technologies. July 1997.

[64] The lowest range (12,000 kWh/t) was sited for Norway using a new concept of heat recovery in Proceedings. 1998 Seoul Conference on Energy Use in Manufacturing: Energy Savings and CO2 Mitigation Policy Analysis. Edited by: Hi-chun Park (Inha University), Jeong-Shik Shin (KEEI). Organized by: Korea Energy Economics Institute, Korea Resource Economics Association. 19-20 May, 1998, POSCO Center, Seoul, Rep. of Korea, p. 119.

[65] Energy and environmental profile of the U.S. aluminum industry.

[66] U.S. Geological Survey, Mineral Commodity Summaries. January 2007.

[67] V.I. Malakhov. The energy efficiency program for Russia’s economy.

18%. This SECs progress was mainly determined by a higher load of paper mills and, to a lesser extent, by advancing the technical basis for pulp production. But even after the reduction they are still much above the both practical minimum and average use abroad.

Russian average pulp SEC (18.1 GJ/t of pulp), as well as those for Russia's regions (although varying substantially) with a few exceptions are much above both the practical minimum (11-12 GJ/t of pulp) and actual energy use abroad (14.3 GJ/t of pulp[68], see Fig. 8.29-8.30). The Chempolis process developed in Finland allows for further reduction of SEC for pulp making to 10.5 GJ/t. Chemical wood pulping dominates over the mechanical one. The former yields black liquor, which can be used for onsite heat and power generation. A large modern chemical pulp mill is self-sufficient in energy terms, using only biomass and delivering surplus electricity and heat to networks.

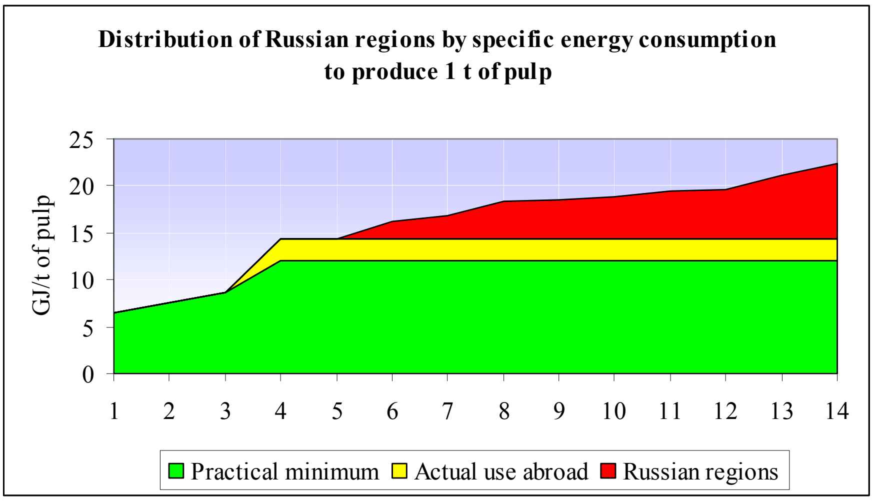

Figure 8.29. SECs in Russian pulp production

There are over 20 potential technologies with possible pulp-making energy efficiency improvements, most of which have relatively small CSEs: continuous digesters (with CSE=80 $US/toe), batch digester modifications (1 $US/toe), heat recovery in thermo-mechanical pulping (4 $US/toe)[69]. Advanced technologies to reduce energy intensity of pulpmaking also include black liquor (and other biomass residuals) gasification, which allows it to address a black liquor high water content problem to improve the efficiency of recovery boilers and electricity generation. It allows for 10-20% energy consumption reduction. Available data show, that this technology investment costs are 830 $US/toe. So with 6% and 12% discount rates it provides energy savings of 65 and 105 $US/toe, making both market and technical potential about equal to the technical one, with only a few exceptions, like thermo-pulping.

Paper making SEC very much depends on paper quality: production of 1 t of writing paper takes as much energy, as 1 t of newsprint paper. Most Russian paper producing plants (except one) have SEC much over the practical best SEC (9 GJ/t, uncoated fine paper was selected for reference), leaving a large potential for improvement.

The most energy intense process in paper making is paper drying, which is responsible for 25-30% of overall energy consumption in pulp and paper making. Technically, energy consumption in paper making can be reduced by 30% through such technologies as impulse drying and condensing

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[68] Energy Technology Perspectives 2006 and Proceedings; E. Worrell, M. Neelis, L. Price, et al. World best practice energy intensity values for selected industrial sectors. LBNL-62808. June 2007; 1998 Seoul Conference on Energy Use in Manufacturing: Energy Savings and CO2 Mitigation Policy Analysis.

[69] N. Martin, N. Angliani, D. Einstein, M. Khrushch, E. Worrell, L. Price. Opportunities To Improve Energy Efficiency in The U.S. Pulp And Paper Industry, 2001. Proceedings Paper Machine Technology, February 7-8, 2001, Lanaken, Belgium. LBNL. 2001.

belt drying. There are over 10 wedges of technologies to improve energy efficiency of paper making, including infrared profiling (CSE=0.2 $US/toe); extent nip press (3 $US/toe); high consistency forming (5 $US/toe); gap forming (36 $US/toe), dry sheet forming (41 $US/toe)[70]. Specific investment demand for impulse drying was estimated at as high as 900 $US/toe and for condensing belt drying at 630$US/toe, or CSE 114 $US/toe and 80 $US/toe. The technical potential to improve energy efficiency in paper making (same as economic and market ones) is 0.33 mtoe.

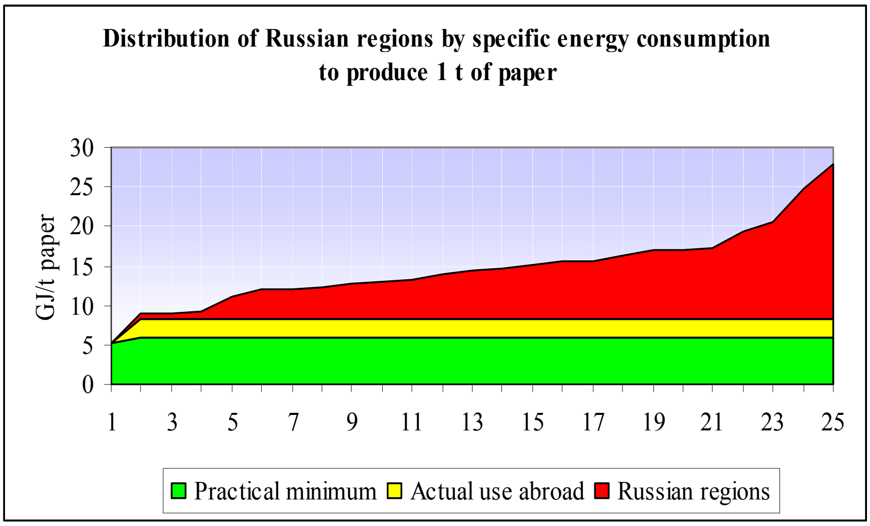

Figure 8.30. SECs in Russian paper production

Russian average SEC in paper board production (11.77 GJ/t) is also much above the practical minimum and actual use abroad (7.8 GJ/t for kraftliner was selected for benchmark[71]). The highest specific energy consumption for Russia is as high as the one for Canada (26 GJ/t)[72]. The “red” zone in Fig. 8.31 illustrates the technical potential of 0.21 mtoe.

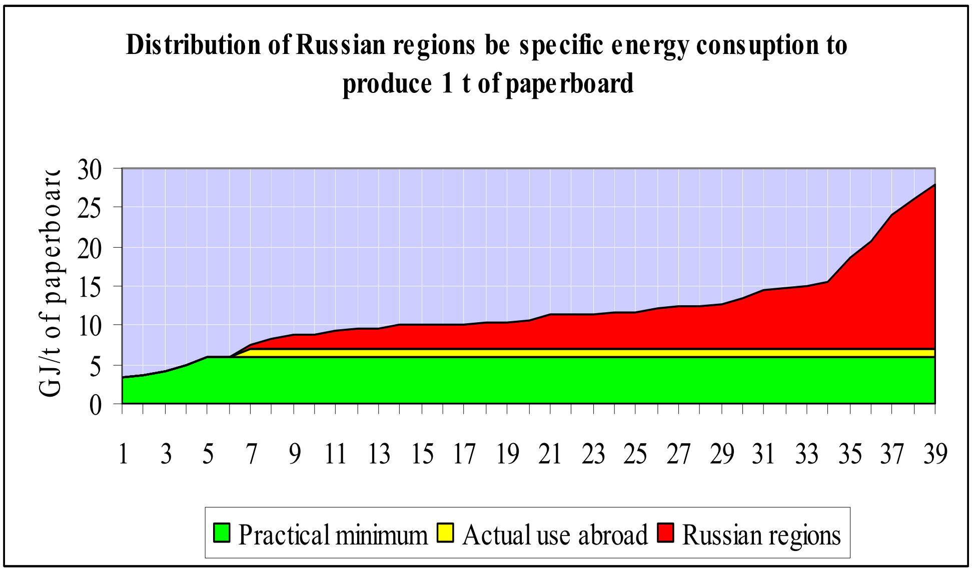

Figure 8.31. SECs in Russian paperboard production

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[70] E. Worrell, N. Martin, N. Angliani, D. Einstein, M. Khrushch, L. Price. Opportunities To Improve Energy Efficiency in The U.S. Pulp And Paper Industry, 2001.

[71] E. Worrell, M. Neelis, L. Price, et al. World best practice energy intensity values for selected industrial sectors. LBNL-62808. June 2007.

[72] Tracking industrial energy efficiency and CO2 emissions. OECD/IEA. Paris. 2007.

There are many opportunities to improve steam production and distribution efficiencies through better boiler maintenance, steam traps installation and monitoring, condensate return, detection and repair of leaks, flue gas heat recovery, etc. More intense utilization of waste paper provides another energy consumption reducing opportunity in the pulp and paper industry. It takes more energy to produce paper from waste paper, but it removes the energy demand for pulp production. This potential was assessed at 0.27 mtoe.

Total technical energy efficiency potential in pulp and paper making totals to 3.67 mtoe.

8.3.5. Cement production

Russian cement and clinker producers consumed 5.72 mtoe in 2005. There are two major products in the cement production industry: clinker and cement. Due to some additives to clinker, the clinker to cement ratio stays below 1: for China, India, Brazil it was 70-90%[73]. Blast furnace cement contains only 30% of clinker, substituted by blast-furnace slag. The statistical form "11-TER" reports the unrealistic 52% of clinker to cement ratio for Russia. So some integrated cement plants do not report separately SECs for clinker and cement production. This makes it difficult to assess the energy efficiency potential for this industry.

In Russian clinker production, the share of efficient dry method in 2005 (15%) appeared to be even lower, than in 1990 (18%). In Japan, the dry method is used to produce 100% of clinker, in South Korea and India 93%, in the U.S. 65%, and in West Europe 58%[74].

Efficient dry kilns incorporating pre-calcining plants and six-step pre-heaters consume only 3 GJ/t clinker[75], while wet kilns use 5.5-7 GJ/t abroad and up to 8.8 GJ/t in Russia. Therefore, no wonder SECs in Russian clinker production are much above the practical minimum and average use abroad (see Fig. 8.32). In 2000-2005, SEC for clinker production in Russia only went down by 2.6%. Importantly, in Russian cement production, natural gas constitutes 90% of fuel balance, while in the West coal is responsible for 80-95%. The technical potential in clinker production is assessed at 1.56 mtoe.

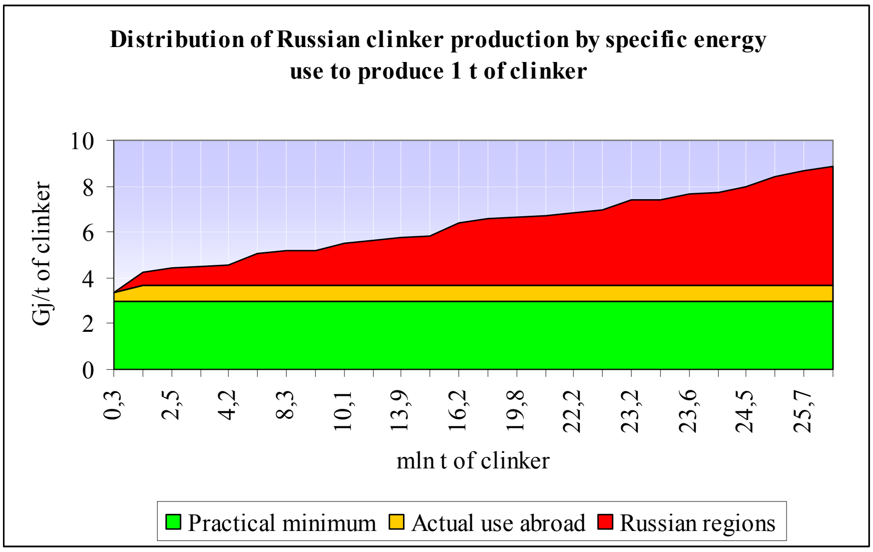

Figure 8.32. SECs in Russian clinker production

Practical minimum SEC for cement production, depending on the quality of cement, is 0,09-0.11 GJ/t. For Russian enterprises, where only data on energy use for grinding are available, it stays

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[73] Emission Baselines. Estimating the Unknown. Sustainable Development. OECD/IEA. 2000.

[74] Energy Technology Perspectives 2006.

[75] Ibid. and Martin, N. Angliani, D. Einstein, M. Khrushch, E. Worrell, L. Price. Opportunities To Improve Energy Efficiency in the U.S. Pulp And Paper Industry, 2001.

above 0.2. If energy consumption for both additives preparation and grinding is accounted for, the practical minimum SEC comes to 1 GJ/t.

Overall energy consumption in Russian cement and clinker production in 2005 was 5.76 mtoe; for 48.5 million t of cement produced the average SEC was 0.118 toe/t, or 76% above the average indicator for South Korea[76]. With this approach, the technical potential in the whole cement industry is 2.47 mtoe, of which 1.56 mtoe is allocated to clinker production.

Simple payback periods in Indian and the U.S. cement making industry for about half of the energy efficiency potential are below 3 years[77]. The other half includes transition to dry, semi-dry and semi-wet processes, conversion of long dry kilns to pre-heaters and pre-calcining plants, high efficiency grassfires. The investment demand to turn an existing plant from wet to dry process is estimated at 70-120 $US/toe of saved energy. So marginal investment costs in the most advanced and expensive cement making technologies are about $US 1,670 per 1 toe saved. With 6% and 12% discount rates, it yields CSEs of 130 and 214 $US/toe. So the whole technical potential is economically viable and a large part of it is market attractive.

8.3.6. Chemical products

The statistical form “11-TER” reports SECs for 12 chemical products: sulfur, synthetic ammonia, soda ash, hydrate of sodium, potassium, phosphatic manure; carbamide, ammonium nitrate, chemical fibers, plasticized for spirits, synthetic rubber, butyl and isobutyl alcohols. The 2005 energy consumption for the production of the above chemical products totaled to 8 mtoe.

In 2000-2005, SECs for chemical products were moving in different directions: they declined for chemical fibers (-41.8.%, the statistics is not very reliable), plasticize for spirits (-28.0%), synthetic rubber (-20.2%); potassium (-18.7%); ammonium nitrate (-15.0%); sulfur (-5.2%), soda ash (-5.1%); they were about stable for carbamide (-1.7%) and synthetic ammonia (-1.8%), but climbed up for hydrate of sodium (5.1%), butyl and isobutyl alcohols (7.3%), and phosphate fertilizers (76.9%).

Application of practical minimum and average use SECs from other countries is hampered by the mismatching of SECs for chemical products reported by Russian and foreign statistics and lack of comparable data on SECs for similar chemical products manufacturing abroad. In foreign literature, SECs for the following chemical products are often provided: petrochemical products – ethylene, propylene, butadiene, aromatics, PVC and others (absolutely not covered by the Russian statistics); ammonia, chlorine and sodium hydroxides[78]. For synthetic ammonia production SECs reported by the Russian statistics (2.45 GJ/t) are too far below the SECs reported by the international sources, practical minimum (28 GJ/t for natural gas use and 34 GJ/t for coal use), and the world average is 39.4 GJ/t. For urea, the situation is opposite: the Russian statistics gives 8.6 GJ/t SEC, while the data for the U.S. are 2.8 GJ/t[79]. So SECs provided are simply not comparable. There are some data on SEC for the best Indian soda ash production – 11.3 GJ/t (12.06 in Russia) –

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[76] Using energy and materials more efficiently: a precondition for sustainable development. Conference organized by Korea Resource Economics Association (KREA), Korea Energy Economics Institute (KEEI), Centre for Energy Policy and Economics (CEPE), ETH Zurich, Switzerland and Ecofys, Utrecht, the Netherlands. Seoul, Republic of Korea. September 21-22, 2006.

[77] J. Sathaye, L. Price, S. Can, D. Fridley. Assessment of Energy Use and Energy Savings Potential in Selected Industrial Sectors in India, 2005. Berkeley, CA: Lawrence Berkeley National Laboratory. 2005.

[78] Energy Technology Perspectives 2006; F. Coito, F. Powell, E. Worrell, L. Price, R. Friedmann. Case Study of the California Cement Industry, 2005. Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry; E. Worrell, C. Galitsky. Energy Efficiency Improvement Opportunities for Cement Making, 2004. An Energy Star Guide for Energy and Plant Managers. Berkeley, CA: Lawrence Berkeley National Laboratory. 2004.

[79] Ernst Worrell, Dian Phylipsen, Dan Einstein, Nathan Martin. Energy Use and Energy Intensity of the U.S. Chemical Industry, 2000. LBNL. 2000.

and on caustic soda production through membrane technology – 10.25 GJ/t[80] (16.39 GJ/t in Russia). So for caustic soda the potential is 0.05 mtoe.

Lack of foreign benchmarks leaves the only opportunity to benchmark with the best Russian practices. So the energy efficiency potential for the chemical industry was estimated by comparing the Russian average with the Russian best SECs[81]. For soda ash, the potential was estimated at 0.04 mtoe; for hydrate of sodium at 0.08 mtoe; for potassium at 0.07 mtoe; for phosphate fertilizers at 0.40 mtoe; for carbamide (urea) at 0.13 mtoe; for ammonium nitrate at 0.20 mtoe; for chemical fibers at 0.15 mtoe; for synthetic rubber at 0.88 mtoe; thus totaling (including caustic soda) to 2.45 mtoe, or about 31% of the 2005 energy consumption. An assumption was made, that for sulfur and synthetic ammonia 31% energy consumption reduction is also possible. That scales energy efficiency potential in the chemical industry up to 2.85 mtoe. Unfortunately, no data are available to estimate, which part of it is economically viable.

An alternative approach to the evaluation of the potential, similar to the one used above for ferrous metallurgy, is based on the investment plans analysis. It yields the potential of 1.85 mtoe broken down as follows: for soda ash 0.026 mtoe; for hydrate of sodium 0.026 mtoe; for potassium 0.07 mtoe; for phosphate fertilizers 0.09 mtoe; for carbamide (urea) 0.26 mtoe; for ammonium nitrate 0.51 mtoe; for chemical fibers 0.18 mtoe; for synthetic rubber 0.71 mtoe, for potash fertilizers 0.07 mtoe (see Table 8.7). During the evaluation of CSEs the following ancillary benefits were taken into account: additional 1,224 thousand t (9.8% over the 2005 level) ammonia production with 130 $US/t market price, generating $US 159 million additional turnover; additional 300 thousand t urea production with 110 $US/t market price, generating $US 33 million additional turnover; additional 75 thousand t hydrate of sodium production with 240 $US/t market price, generating $US 18 million additional turnover; additional 1,265 thousand t potassium chloride production with 113 $US/t market price, generating $US 143 million additional turnover; additional 464 thousand t synthetic rubber production with 1,600 $US/t market price, generating $US 724 million additional turnover. As a result, a large part of the energy conservation curve is characterized by negative CSEs (see Fig. 8.33). So at least 1.85 mtoe of the identified 2.85 mtoe technical potential in the chemical and petrochemical industry is economically viable and market attractive.

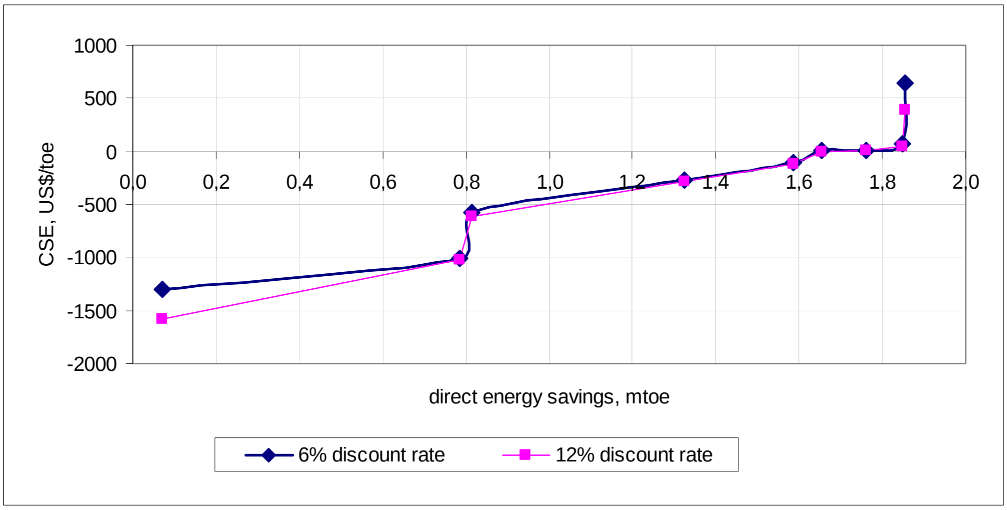

Figure 8.33. Energy conservation curves for Russian chemical and petrochemical industry estimated for 2005 based on the investment plans of Russian enterprises

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[80] Jayant Sathaye, Lynn Price, Stephane de la Rue du Can, David Fridley. Assessment of Energy Use and Energy Savings Potential in Selected Industrial Sectors in India, 2005. Berkeley, CA: Lawrence Berkeley National Laboratory. 2005.

[81] It was not done for sulfur, which is about exclusively produced in Astrakhan Oblast from sulfur rich natural gas and gas condensate, and so conditions are quite unique to be compared with other producers. Besides, the potential was not assessed for synthetic ammonia for high discrepancy in statistical data.

Table 8.7. The costs of energy efficiency measures and technologies and rating energy efficiency measures and technologies in the chemical and petrochemical industry (discount factor 0.12)

Measures	Number of facilities	Facilities' productivity (average)	Specific capital investment	Overall capital investment, $US million	Additional operational costs (+) or benefits (-)	The cost of saved energy	Energy savings
Ammonia production equipment renovation and upgrade to increase individual productivity of ammonia units from 1,360 to 1,500 t/day	Renovation of 9 ammonia producing units	1,360 thou. t of ammonia	$US 17 million/unit	**153**	159,1	-292.3	513.05
Carbamide production equipment renovation and upgrade to increase individual productivity of carbamide units	Renovation of 10 carbamide producing units	300 thou. t of carbamide	$US 4.6 million/unit	**46.7**	33	-115.9	260.82
Caustic soda production equipment renovation and upgrade and application of membrane and diaphragm technologies	Renovation of 2 process lines	170-200 thou. t of caustic soda	$US 9.8-11.5 million/process line	**19.6**	17.95	-630.1	26.6
Introduction of carbon bisulphide-free technology of producing cotton-like cellulose textile fiber	Installation of 13 process lines	7 thou. t of fiber	$US 96.2 thou./process line	**1.25**	0	1.1	68.8
Introduction of energy efficient and environmental friendly technology to produce polyurethane yarn from polymer melt	Installation of 150 complexes	40 t of polymer	$US 246.2 thou./complex	**36.2**	0	304.0	7.3
Secondary energy resource utilization (flash steam recovery)	Installation of 10 heat recovery units (ejectors or compressors)	1 heat recovery unit per process line with 14-18 thou. t of yarn capacity	$US 650 thou./unit	**6.5**	0	34.3	86.3
Renovation and upgrade of phosphate fertilizers production equipment and installation of fluidized-bed grain-mill dryers	Installation of 22 grain-mill dryers	130 thou. t of fertilizers	$US 2.3 million/dryer	**49.3**	0	3.7	105.1
Renovation and upgrade of potassic fertilizers (potash chloride) production equipment	Renovation of 23 process lines	275 thou. t of potash	$US 17.2 million/ process line	**396.5**	742.4	-1,023.8	715.2
Renovation and upgrade of synthetic rubber production equipment	Renovation of 5 process lines	240 thou. t of rubber	$US 35 million/ process line	**169.2**	142.9	-1,680.8	70.9

Source: data from investment and production programs of the RF chemical and petrochemical plants (OAO "Uralkaliy", OAO "Nizhnekamskneftechim", AO "Voskresenskiye mineral fertilizers").

8.3.7. Light and food industries

Other products, for which SECs are statistically reported in Russia, include: textile products (cotton, flax, wool, and silk), leather footwear, meat products, sugar and bread. Altogether, they consume 4.1 mtoe, of which heat (mainly, steam) is 1.8 mtoe. Due to a better facilities load, the SECs in textile industry in 2000-2005 was improved by 129.6% for cotton textile, 17.9% for flax textile, 14.9 % for wool textile, 17% for silk textile, and 43.7% for leather footwear. For meat products, SEC went down by 30%. In sugar-beet processing, the SEC went up by 4%, in sugar lumping it was up by 22%, and in the production of final sugar product it went down by 20%.

Providing SECs for light and food industries is a quite difficult task, for the products manufactured are very diverse and for the variation in production cycles completeness. So again, the potential was estimates based on the comparison of Russian average SECs with the average for several Russian best regions. Only meat and bread production was considered (see Fig. 8.34 and 8.35).

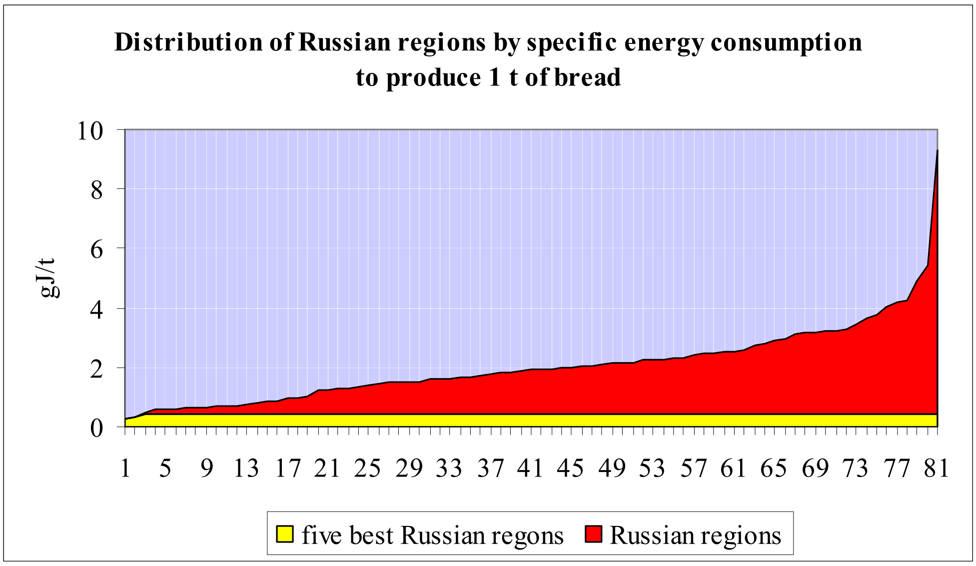

Figure 8.34. SECs in Russian bread production

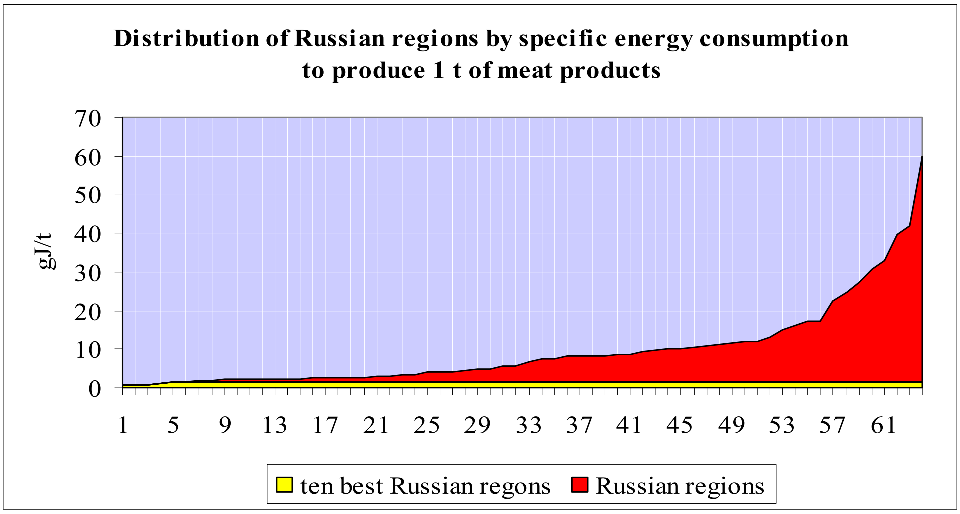

Figure 8.35. SECs in the production of meat products in Russia

The selected approach allowed it to assess the potential in bread making at 0.9 mtoe and in the production of meat products at 0.55 mtoe. If 30% savings are assumed for sugar making, textile and leather, the potential comes to 2.12 mtoe, or 52% of overall consumption.

As to the cost of saved energy in light and food industries, CENEf's experience shows that a large part of it may be implemented at net negative costs, even if 2002 energy prices are used in calculations, with the marginal costs for electricity savings approaching 13 U.S. cents per 1 kWh[82], which could be 2010 average tariff for many Russian regions.

8.3.8. Cross-cutting industrial technologies

8.3.8.1. Oxygen

Oxygen is produced in many industries, but primarily in metallurgy. Oxygen production consumes 0.89 mtoe of final energy, mainly electricity. The energy efficiency potential was evaluated through the comparison with 10 Russian best regions and equals 0.39 mtoe (see Fig. 8.36).

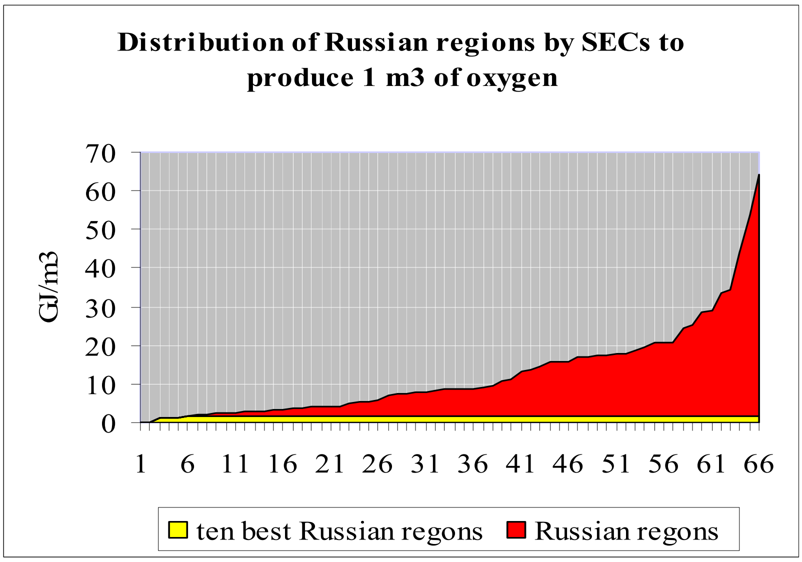

Figure 8.36. SECs in Russian oxygen production

8.3.8.2. Compressed air

Another cross-cutting technology is production and use of compressed air, which consumed in 2005 0.71 mtoe of final energy, mainly electricity. It is the most expensive form of energy used in mining and manufacturing with end-use energy efficiency of only 10-15%. There are three major sources of savings: improving the efficiency of compressed air generation; reduction of leaks in distribution systems (20-30%); and improving end-use efficiency and compressor heat recovery (80-93% of electricity used by compressors are converted into heat, 50-90% of which may be recovered).

Altogether, these measures may bring 30 to 50% savings at the U.S. enterprises[83], and even more at the Russian plants. Compressed air generation efficiency improvement may bring 0.3 mtoe savings. 20% leakage reduction will bring another 0.08 mtoe. Assuming 30% heat recovery from large compressors, the potential totals to 0.48 mtoe. Such improvements pay back in less than 3 years.

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[82] Energy Efficiency Guidelines for the Food Industry. German energy agency and the Center for Energy Efficiency. Moscow, 2002, p. 160.

[83] Improving Compressed Air Systems Performance: A Sourcebook for Industry, 2003. U.S. Department of Energy, Lawrence Berkeley National Laboratory, Resource Dynamics Corporation. U.S. Department of Energy. 2004; A. McKane, B. Madaris. The Compressed Air Challenge: Making A Difference for US Industry, 2003. LBNL. 2003.

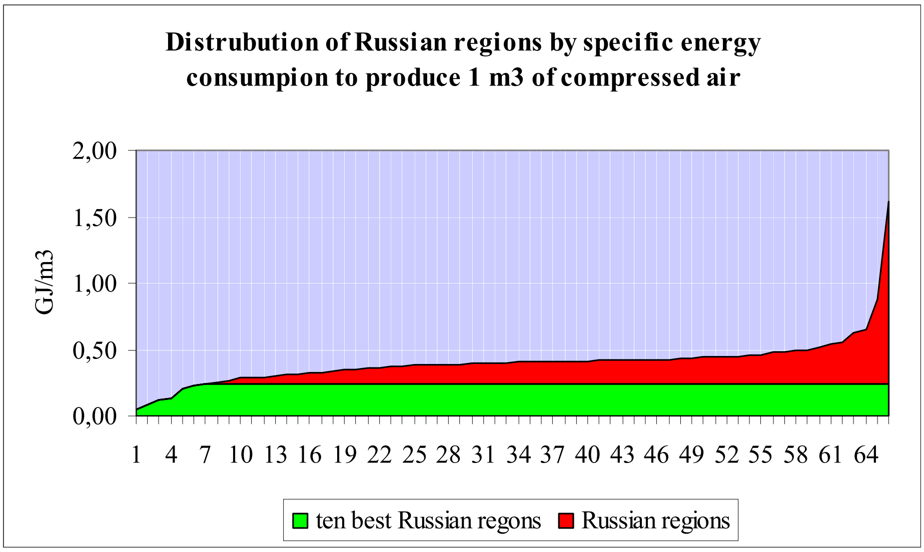

Figure 8.37. SECs in Russian compressed air generation

8.3.8.3. Steam distribution and consumption

Industry uses much of heat in the form of steam and hot water. Industrial heat generation technologies were considered above. Here only heat (hot water and steam) distribution and consumption processes are addressed. In Russia, steam consumption is poorly metered, steam distribution systems are poorly insulated, controlled and maintained, often there are no steam traps or condensate return systems installed, or they don't operate.

Low-cost optimization and renovation of steam use allows it to reduce steam demand by 31-48% and pays back in less than 1 year[84]. At a typical Russian industrial plant, such low cost savings bring over 30% reduction of steam demand[85] with a payback of less than 1 year. The same goes for industrial hot water use. It was assumed, that there is a 50% potential for heat use reduction in heat use in "other industries", thus totaling to 4.34 mtoe.

A special exercise was made to assess the costs of steam use efficiency improvements in 5 industries: pulp&paper; food; wood processing; textile; and cement and clinker production. The following sets of measures were considered: renovation of on-site steam boilers and optimal load operation of boilers (application of fuel combustion management and automation systems); installation of pressure controls in steam heat networks (steam pipelines); renovation of pipelines and thermal insulation in steam heat networks (steam and condensate pipelines); commissioning of new condensate collection and return systems (installation of condensate pipelines, condensate pumps, collection tanks, and steam traps); renovation (replacement) of steam traps in on-site condensate collection and return systems; utilization of secondary energy resources (heat recovery) for technology process and/or heat supply purposes. The highest CSEs were estimated with 12% discount rate equal to 25 $US/toe. So the whole potential to improve steam generation, distribution and consumption systems is cost effective.

8.3.8.4. Electric motors

Electric motors are responsible for approximately 70% of overall industrial electricity consumption (excluding electricity directly used in production process). In petroleum refining or food industry, it may be responsible for 80% of overall electricity consumption, mainly for pumping. If 70% proportion is applied to electricity use in "other industries" (in the industries considered above, this

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[84] Ernst Worrell, Christina Galitsky. Energy Efficiency Improvement in the Petroleum Refining Industry, 2005. Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry.

[85] Energy Efficiency Guidelines for the Food Industry.

potential has already been dealt with), 1.94 mtoe of final electricity use may be attributed to motor systems.

The structure of potential savings to be achieved through motors renovation and optimization include: elimination of motors oversizing (1-2%); installation of high efficiency motors (8%), adjustable speed drives (20-50%); operation and maintenance (2-7%); totaling to 31-67%[86]. 41 electric motor efficiency improvement projects conducted in the U.S. brought 23% electricity savings[87]. Another study of 13 U.S. plants representing various industries assessed this potential at 33%. For Russian "other industries", 50% savings potential was assumed, or 0.97 mtoe, achieved through electric motors renovation and optimization systems. All this technical potential is cost-effective. In India, the implementation of the motors efficiency programs brought the savings of only 1-2 US cents/kWh[88]. In Russia, it is not more than 1-5 US cents/kWh[89]. Another example is 28% electricity consumption reduction with a less than 0.5 years payback in China[90].

8.4. Agriculture and fishery

Of 6.2 mtoe agricultural energy consumption in 2005 about 50% (3 mtoe) are liquid fuels used for tractors and other machinery (bulldozers, lifting equipment, trucks, etc.). Ministry of agriculture reports 4.4 million t of diesel and 1.6 million t of gasoline supplied to agricultural companies. Not all this fuel is used for agricultural production purposes. In the recent 10 years, the cultivated area shrank by 17%, while the number of tractors halved.

Diesel fuel used by tractors per 1 ha of cultivated land went down by 8% in 2002-2005. In Russia, SEC per 1 ha of tillage is reported to stand at 0.175-0.196 toe compared to 0.098 mtoe in the USA[91]. So the potential to improve diesel fuel use per hectare is 50%. This evaluation is supported by the following facts: in 2006, 72% of tractors and 62% of combine harvesters were expected to have been in operation for more than 10 years; low reliability of tractors in use (three times below the standard); oversized tractors, which is determined by the shortage of tractors with appropriate range of power rating[92]. Modern diesel engines in tractors and other machines are 10-15% more efficient, than those presently in use[93]. Energy efficiency potential (for liquid fuels) in agriculture totals to 1.5 mtoe.

In recent years, substantial energy efficiency improvements were achieved in agricultural electricity use: in 2002-2005 alone, electricity intensity went down by 30%, mainly due to the reduction of energy equipment. In 1995-2003, the number of food processing units went down by 57%; food distributors by 58%; milk cooling reservoirs by 38%; milking machines by 48%; dunk-removing transporters by 55%. For stationary sources agricultural energy use the Russian statistics reports only on the following activities: greenhouse heating, with winter greenhouses shown separately (1 mtoe), and pumping water for irrigation and water drainage (1.64 billion kWh or 0.14 mtoe). In 2000-2005 SECs went up by 45% in irrigation, and by 11% in greenhouse heating, but declined by 7% in winter greenhouse heating and by 75% in melioration.

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[86] Worrell, Christina Galitsky. Energy Efficiency Improvement in the Petroleum Refining Industry, 2005.

[87] R. Lung, A. McKane, M. Olzewsky. Industrial Motor System Optimization Projects in the US: An Impact Study, 2003. LBNL. 2003.

[88] J. Sathaye, L. Price, S. Can, D. Fridley. Assessment of Energy Use and Energy Savings Potential in Selected Industrial Sectors in India, 2005.

[89] Energy Efficiency Guidelines for the Food Industry.

[90] R. Williams, A. McKane, Z. Guijn, S. Nadel, J. Peters, V. Tutterow. The Chinese Motor System Optimization Experience: Developing a Template for a National Program, 2005. EEMODS. 2005.

[91] A. Konovalov. Energy efficiency in the agriculture. Kursk Oblast Energy Efficiency Fund.

[92] Presentation by A.A. Mikhalev, Stats-secretary – First deputy RF minister of agriculture, at the scientific session "Technical progress in Russia's agro-industrial complex – the strategy of technological production of agricultural output until 2010". October 13-14, 2003.

[93] Energy Technology Perspectives 2006. p. 308.

An assumption was made, that a 50% reduction of heat consumption (reduction of greenhouse heat losses due to the application of modern glazing technologies) and a 50% reduction of power consumption are possible in agriculture.

There is a potential for a larger use of renewable energy, including biomass, biogas and biofuel in the agricultural sector, especially for drying processes and hot water production. These options are not considered in his paper. Fishing was not considered in this paper either for its negligible energy consumption.

8.5. Construction

In 2005, energy consumption in the constriction sector was 1.7 mtoe, which basically refers to the elevating construction machines and elevating equipment, compressors operation and lighting of the construction sites. When it comes to energy efficiency in the construction sector, researchers basically focus on buildings, rather than on the construction process. This makes it difficult to assess the energy efficiency potential in the construction; therefore, this sector, which is only responsible for around 0.3% of overall primary energy use, was simply skipped from the analysis.

8.6. Transportation

8.6.1. Energy efficiency potential in transportation

Russian transportation was responsible for 25% of final energy consumption and 15% of primary energy consumption in 2005 (see Table 8.9). It is the fifth largest energy consuming sector after heat and electricity generation, manufacturing, and residential sectors. Within the transportation sector, road transportation takes the lead in energy consumption, followed by gas transportation. The large contribution of the latter explains why the share of petroleum products in the Russian transport energy mix is just 57% versus, say, 97% in the OECD countries in 2005[94].

Modal mix in freight transportation in Russia is dominated by pipeline transport followed by rail transportation. Transportation of energy (coal, crude oil and petroleum products, gas and other fuels) is responsible for 40-45% of overall energy consumption by transportation sector. In passenger transportation (personal cars excluded), rail transportation dominates, followed by buses and air transport.

Many problems arise when attempting to assess energy efficiency potential in transportation in any country[95]. In Russia, like elsewhere, the constraints include: shortage of both statistical information and special studies on energy use in transport (especially personal) and contradictory information on some indicators, like transport vehicles stock, freight turnover, average mileage, pipeline leakages, etc. Importantly, power and heat generation by transportation companies is shown in electricity and heat potential evaluation in the sections above.

Overall final energy efficiency potential in transportation was assessed at 38.3 mtoe, or 41% of 2005 use (see Tables 8.8). A large part of it (36.4 mtoe) falls into the economic potential category, and about 32 mtoe into the market potential category.

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[94] Energy Balances for OECD countries. 2004-2005. OECD/IEA. 2007 Edition.

[95] Transport and infrastructure. Chapter 5. S. K. Ribeiro and Sh. Kobayashi coordinating lead authors. Fourth Assessment Report of the IPCC WG III. 2007; Energy Technology Perspectives 2006.

Table 8.8. Technical energy efficiency potential in transportation, 2005 (mtoe)

	Petroleum products	Gas	Electricity	Heat	Total
Rail	0.50		0.54		1.04
Other			0.30	0.30	0.60
Oil pipelines			0.63		0.63
Gas pipelines		14.95	0.20	0.09	15.24
Water	0.26				0.26
Road	18.89				18.89
Aviation	1.64				1.64
Total transport	**21.29**	**14.95**	**1.67**	**0.39**	**38.30**

Source: Estimated by CENEf

8.6.2. Pipeline transportation

Pipeline transportation consumes 36.7 mtoe (37% of overall transportation energy use) to move natural gas for 1,623 trillion m^3-km, crude oil for 853 billion t-km, and petroleum products for 19 billion t-km[96]. Over 9% of the whole domestic natural gas use (about 41 billion m^3) is spent at gas compressor stations to transport natural gas to both domestic consumers and to the country border for export.

For 2000-2005, statistics reports growing SEC (mainly electricity) intensity of crude oil transportation by 76% and of petroleum products by 22%; while SEC for gas transportation was relatively stable. So energy consumption in this sector grows faster, than freight turnover. Alternative statistical sources disagree on SEC consumption in pipeline transportation by 5-25%.

Natural gas transportation losses are even more uncertain. According to the recent study by Wuppertal Institute, total CH_4 emissions from the Russian natural gas export network are about 0.7% of the total amount of transported gas[97]. For the pipelines, this study comes up with the following losses estimates: 379 million m^3 of leaks; 44 million m^3 of breakdowns, and 585 million m^3 of maintenance& repairs. In addition, compressor energy losses include: leaks – 1,814 million m^3 and operation related emissions – 214 million m^3. All these losses total to 3 billion m^3. The IEA reports, that for 2004 overall CH_4 emissions from long-distance transportation systems, including compressor stations, was 6.2 billion m^3, and from distribution network 5.3 billion m^3 more[98].

Russian Federal Statistics Service does not publish data on gas transportation through the gas distribution system. According to “Gasprom”, there are over 200 gas distribution companies in Russia running 460 thousand km (or 575 thousand km, according to the IEA) of gas distribution systems with over 300 billion m^3 gas transportation (or over 380 billion m^3, according to the IEA for 2004). About 40% of all this gas is supplied through medium- and low pressure networks, for which gas losses are evaluated at 1.4-3% of transported gas (4.2-11.4 billion m^3). Thus, the IEA estimate for the distribution system is closer to the lower boundary of the uncertainty range. Statistically, distribution losses are accounted for as consumption and are allocated for different sectors.

“Gasprom” estimates the loss reduction and energy use reduction potential in the gas transportation system through low- and medium-cost measures alone at up to 10 billion m^3, or 8.06 mtoe. These measures include: replacing old power generators at compressor stations with 24-28% efficiency with new gas turbines with 32-36% efficiency; enhancing efficiency of compressors and pumps; reducing leaks through improved insulation of valves, etc., at pipelines and compressor stations.

CENEf’s estimate of the energy efficiency potential in gas transportation system is higher. Replacing the inefficient equipment stock in place with most advanced equipment brings SEC

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[96] Source: “11-TER” statistical form for 2005. Rosstat (2006).

[97] Greenhouse Gas Emissions from the Russian Natural Gas Export Pipeline System. Wuppertal Institute for Climate, Environment and Energy in cooperation with Max-Plank-Institute for Germany. Mainz. February 2005.

[98] IEA: Optimising Russian Natural Gas -- Reform and Climate Policy. 2006. www.iea.org/potential/

reduction between 0.25-0.20 kgoe/kWh and 0.14 kgoe/kWh, thus reducing gas consumption by 37.5%, or by 12.3 mtoe (15.2 billion m^3). The marginal specific investment costs for such measures are 1,805-2,406 $US/toe. With 6% discount rate and 7.8% capital recovery factor, the CSE is 144-187 $US/toe, or 116-151 $US/1,000 m^3, which is below the export price of 170-236 $US/1,000 m^3 expected by the RF Ministry of economic development and trade and below expected domestic gas price. About 90% of compressors with the total capacity over 37 GW need to be replaced to implement this potential. Total investments are in the range of $US 22.2-29.6 billion. But those investments may not be considered as incremental investments due to the fact that many of those compressors have expired lifetime and have to be replaced anyway.

Affordable measures to reduce natural gas transportation losses are numerous, including installation of systems to “catch” the leaking gas when the compressors are not in operation and low gas emission pneumatic devices (for continuous pneumatic pumping systems); audits and maintenance of valves and the pipeline surfaces; installation of low gas emission pneumatic devices (for periodic pneumatic pumping systems) and sealing rod on alternate/reciprocal compressors; installation of dry seals on rotary compressors and installation of separators on the associated gas reservoirs; replacement of compressed air equipment of compressor stations. According to the US EPA assessments based on the U.S. practices, such measures may reduce losses by 50%[99]. “Gasprom” estimates the loss reduction potential in its long-distance transportation network to 2015 at 2.6 billion m^3 for the mains and 1.08 billion m3 for the distribution systems totaling to 3.68 billion m^3 with the following incremental capital costs: installation of systems to catch the gas when the compressors are switched off (10.8 $US/toe); purchase of mobile compressor stations (5.4 $US/toe); improved insulation of valves, etc. at pipelines and compression stations (21.1 $US/toe). These CSE numbers are much in line with the US EPA estimates.

For the half of this potential “Gasprom” provides data on incremental capital costs, based on which CSE can be assessed, which are much below the expected natural gas price, and so make at least this part of the potential cost-effective both for the society and “Gasprom”[100]. The incremental investment demand to implement this potential is only $US 200 million. Expanding this estimate to the whole 3.68 billion m3 (2.96 mtoe) loss reduction under the assumption that the second half of it requires 4 times more incremental capital costs, one would get the overall investment demand of nearly $US 1 billion.

The overall potential to reduce both own use by transmission and distribution pipelines losses is 14.95 mtoe, or 46% of presently used and lost gas at gas transportation system, and would take $US 23-30 billion to explore.

As mentioned above, statistically reported SECs for oil pipeline transportation (95% of produced oil is transported by pipelines) went up in 2000-2005 by 76%. Electricity consumption increased 2.7-fold, and the turnover by only 61%, so SEC grew up by 65%. For petroleum products pipelines, SEC in 2005 were 22% above those in 2000. According to industry energy managers, a large part of this growth resulted from a higher velocity of oil and products pumping through the overloaded pipeline system. In 2006, after the pipeline system was expanded, some SEC reduction (by 10%) was observed. Mere getting back from the 2005 to 2000 SECs would bring around 0.4 mtoe savings. In addition, in 2000 there was much room for energy efficiency improvement. The potential to reduce energy intensity through advanced pumps application and improved quality of the internal pipes surface may be estimated at 1.36 billion kWh, or 0.23 mtoe. So the potential is 0.63 mtoe of electricity alone.

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[99] www.epa.gov/methane/pdfs/macc_analysis.pdf

[100] R.O. Samsonov, V.N. Bashkin, G.S. Akopova. Application of new technologies in the gas industry to reduce geoenvironmental risks and enter the GHG markets. A presentation at the international workshop “Kyoto Protocol: carbon market opportunities for Russian companies”. Moscow, 2007. http://www.carbon-project.ru/text/37363461

8.6.3. Railroad transportation

Railroad transport accounts for about 7 mtoe of final energy consumption, of which 2.85 mtoe is diesel fuel and 3.88 mtoe electricity (with 82% coming for electric traction). Statistics reports the SEC improvement for electric traction per t-km: in 2005 it was at the 2000 level, while for other uses dropped by 24%.

Some progress in SEC reduction due to a better railroad system load and management was compensated by the growing equipment wear: 60% of energy equipment and 65-73% of railroad vehicles with expired lifetimes were still in operation. This provides a large potential for efficiency improvement in the sector.

Growing electricity and diesel fuel prices make the management of the Railroad System ("Rossiyskiye Zhelezhyie Dorogi") aware of the need to improve energy efficiency. It has plans to reduce SECs by 2010 by 3.5-4.5% for electricity consumption per brutto-t-km and by 6% for fuel consumption per brutto-t-km. By 2020, the goals are more ambitious: corresponding reduction by 10-12% for electric traction, 13-18% for diesel traction, and 20-25% for general railroad system operation needs. This is expected to be achieved through the following measures: renovation of worn equipment park with new generation of locomotives with reduced aerodynamic resistance, lower train weight, regenerative breaking and higher efficiency propulsion systems (efficiency gains by 10-15%)[101]; higher locomotive capacity use factor, application of more efficient driving and dispatching technologies (5%), and IT management systems (up to 10 %); renovation of railroad electric equipment with expired lifetime to reduce losses by 10%, replacement of bi-metal bearer cables with copper ones (10-15% loss reduction), application of parallel joints sectioning stands (10-20% loss reduction), additional traction substations (nearly 4-fold loss reduction), new generation of rectifier and inverting elements (10-12% loss reduction); switching from diesel to AC electricity (1.6-1.8-fold energy use reduction).

The technical energy efficiency potential in railroad transportation was assessed at 3.7-4.4 billion kWh of electricity and 0.36-0.5 million t of diesel fuel. The greater part of it is no-cost. Replacement and renovation of worn locomotive stock and other equipment is essential for further service providing and profit-making. The replacement with new models brings embodied energy efficiency even without any energy efficiency policy, simply due to the fact that new railroad vehicles are more energy efficient. The implementation of this potential will take time due to high capital intensity of the renovation process. About 7,000 passenger and freight electric locomotives are to be replaced. New electric locomotives cost over 30 million rubles, and a passenger electric train 110 million rubles. In addition, 2,800 diesel locomotives are to be replaced at the cost of 40-60 million rubles each. Thus this program, which aims at providing transportation services, rather than at achieving energy savings, totals to $US 20-25 billion, and efficiency gains come as a side effect.

Other investments, including both energy efficiency improvements and contributing to better system productivity, are: installation of 4,000 IT management systems (additional $US 215 million in cost); replacement of diesel engines at 1,300 locomotives, replacement of injection systems at 800 engines; installation of fuel meters at the total cost of $US 420-450 million[102]. So energy efficiency

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[101] Reduction of train weight is an effective way to reduce energy consumption. Aluminum car bodies, lightweight bodies and lighter propulsion equipment are proven weight reduction measures. Regenerative brakes have been used in railways for three decades, but with limited applications. The research in energy storage device onboard or trackside is progressing in several countries. Lithium/ion batteries, ultracapacitors and flywheels are candidate energy storage devices. Recent research on rail propulsion focused on superconducting on-board transformers and permanent magnet synchronous traction motors. Apart from the above technologies mainly for electric trains, there are several promising technologies for diesel switchers, including common rail injection system and hybridization/on-board use of braking energy in diesel-electric vehicles (see the web site of the International Union of Railways). See Transport and infrastructure. Chapter 5. S. K. Ribeiro and Sh. Kobayashi coordinating lead authors.. Fourth Assessment Report of the IPCC WG III. 2007; Energy Technology Perspectives 2006.

[102] Assessed based on A.V. Kotelnikov (VNIIZhT). Russia's railroads energy strategy. OAO RZhD, 2007. Moscow.

investment demand is $US 635-665 million. If 25% of the potential is attributed to specific energy efficiency measures, specific capital investment to save 1 toe is $US 1,970, with 6% discount rate and 25 years service, capital recovery factor is 7.8%, and CSE even with no account of other benefits, is 154 $US/toe, which is much below both 2007 and expected 2010 diesel and electricity prices. So the major part of the technical potential comes at no-cost or is cost-effective.

8.6.4. Road transport

In 2005, road transportation consumed about 48 mtoe. It is a fast-growing energy consuming sector driven by dynamic personal fleet growth (car population escalated by 26% in 2000-2005) at the expense of public transport (the number of large city and inter-city buses fell down by 28%, small buses excluded). Average nameplate efficiency of Russian-made cars is about equal to that of foreign models of similar class: lower engine efficiency is compensated by lower car power, lower comfort (no air conditioners) or lower safety features. So the growing share of foreign-made cars or foreign car models assembled in Russia on the Russian roads does not significantly influence average car fleet SEC (about 11 liters per 100 km).

There are no data to allocate fuel consumption by types of road vehicles: cars, trucks, buses, which makes it difficult to develop a reliable energy efficiency potential assessment. There are also no statistically reported SECs for different vehicle groups in Russia. Based on expert opinions, CENEf assessed them as follows: personal cars 10-12 liters/100 km; light trucks 29-33 liters/100 km; buses 41-55 liters/100 km; heavy trucks 31-34 liters/100 km.

Hybrid electric drive vehicles bring fuel savings between 7-8% and 30-50% (full hybrid in an urban setting), which is up to 5.5 l/100 km, or half of average fuel consumption by Russian vehicles (11 l/100 km). IEA reports that SEC for advanced gasoline- and diesel-fired vehicles with progressive engine downsizing, stoichiomenric combustion and increased use of variable valve control reaches 5.4-9.7 and 4.2-7.5 l/100 km[103]. According to the IPCC WG III Fourth Assessment Report, there are the following additional options to improve energy efficiency of road transportation: vehicle weight reduction, including the reduction of engine size; more efficient internal combustion engine; direct fuel injection; 6-speed automatic and continuously variable transmission; friction reduction, etc[104].

Based on such data the technical potential to improve energy efficiency of all gasoline-driven light duty vehicles is assessed at 17 mtoe. Average incremental costs of hybrid car is $US 3,000-5,000 per car (i.e. Honda Civic Hybrid or Toyota Prius[105]). With 12,000 km average annual traveled distance it saves 660 liters per year. So with 6% discount rate and 10 years car lifetime, the CSE is 0.81 $US/l, which is above the present gasoline price of 0.75 $US/l, but below expected 2010 price over 1 $US/l. So the whole technical potential becomes an economic potential. With a 12% discount rate, CSE is 1.07 $US/l and may be not cost-effective for those who travel less than 12,000 km a year. With an assumption that 40% of car owners usually drive more than that, the market potential comes down to 3.88 mtoe.

Diesel hybrid buses currently running in New York city have a 45% higher in-service fuel efficiency compared to conventional diesel buses[106]. The potential to replace diesel fuel-fired city buses with hybrid ones was also estimated. Average travel distance of a Russian bus is 56-60 thousand km per year with SEC 40 l/100 km fuel efficiency. The overall bus stock (98,750 units) was corrected for 25% of private buses in operation. 45% SEC reduction brings 0.86 mtoe savings. A modern hybrid bus costs $US 0.5 million versus $US 0.14 million for a regular Russian-made one; thus incremental

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[103] Energy Technology Perspectives 2006. pp. 297, 309.

[104] IPCC, 2007: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge. University Press, Cambridge, United Kingdom and New York, NY, USA.

[105] C. Difiglio. Reducing the growth of motor vehicles CO2 emissions through 2050: efficiency, low-emission fuels and advanced technologies. U.S. Department of Energy. Erice Seminars on Planetary Emergencies. August 20, 2007; (2007): www.fueleconomy.gov .

[106] Barnitt, R., Chandler, K.:NYCT Hybrid and CNG Transit Buses. TR, NREL. 2006.

costs are $US 0.36 million per bus. Annual fuel savings are 10,800 liters of diesel fuel. So with 6% discount rate and 10 years useful lifetime, the CSE is 4.6 $US/l, which makes this part of potential not cost-effective.

At to the trucks, evaluation of the potential is difficult for considerable variation in weight and carrying capacity, as well as types of cargo and distances traveled. In addition, trucks normally do not have fuel efficiency standards. WG III Third Assessment Report "Mitigation" estimates the potential to improve trucks diesel engines efficiency from 24% to 45% and argues for hybridization as an attractive option for medium-sized trucks with short distances. According to the U.S. estimates, new heavy-duty vehicles can bring 18-24% savings at a cost about 5,000-7,000 $US per unit[107]. Reduced aerodynamic resistance could yield in from 5% (currently) up to 20% fuel savings for heavy trucks (tractor trailers) accompanied by energy efficient tires (+3-6%).

If 20% efficiency gain is chosen with 35,000 km per year mileage and 35 l/100 km fuel efficiency, one truck saves 2,450 liters of diesel fuel with annualized costs (6% discount rate and 10 years lifetime) of $US 816, or 0.33 $US/l, which is much below the present diesel fuel both wholesale and retail prices. Russian statistics reports 9.5 mtoe of diesel fuel consumption by road transport. Assuming 75% of that is used by trucks, the savings are 1.43 mtoe.

Smart traffic management systems may significantly reduce fuel burnt in traffic jams. Transport mode switch in favor of public transportation is another option. Bus Rapid Transit mode share increase from 0 to 10% allows for 8% reduction of fuel consumption at the cost of 4.5 $US/GJ.

According to the assessments by Moscow Government Transportation Department, energy saving potential in urban electric vehicles (trams and trolleys alone) resulting from the transportation infrastructure renovation (partial replacement of power networks, cables, contact-line supports, electric transformers, etc.) equals 10-12% of their total energy use. On the national scale, trams and trolleys consumed about 2.9 billion kWh, or 0.25 mtoe in 2005. So the technical energy efficiency potential of these measures is 0.02-0.30 mtoe. No cost estimates of these measures are available. The energy efficiency potential hidden in the management of subway systems is at least same large[108].

8.6.5. Aviation and water transportation

Aviation consumes 4.1 mtoe of energy (primarily, kerosene) and is a fast-growing energy consuming sector. Shipping consumes another 0.87 mtoe. This study does not focus on assessing energy efficiency potential for these two sectors. With a high wear of both plane and ship fleets, it was assumed that replacing them with new models would allow for 40% and 30% SECs reduction respectively. WG III Third Assessment Report "Mitigation" estimates the potential to improve energy efficiency in aviation by 40% through improving both engine performance and aerodynamics. For water transport, it is possible to achieve 42% efficiency of diesel engines versus the present 27-30% in Russia. So the potential is about 30%. According to the WG III Fourth Assessment Report "Mitigation", the efficiency potential is up to 40%.

8.7. Buildings

Russian residential, public, and commercial buildings in 2005 were responsible for 144.5 mtoe of final energy use (34%) and for 360 mtoe of primary energy (55% of overall primary energy consumption).

The technical energy efficiency potential in buildings was assessed at 68.6 mtoe (see Table 8.9). The largest potential is evaluated for residential buildings. A larger part of it (67%) can be implemented through the reduction of district heating use for space heating and hot water. About 85% of the

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[107] Energy Saving through Improved Fuel Economy for Heavy Duty Trucks" performed by the American Council for an Energy-Efficient Economy on request of National Commission on Energy Policy in 2004.

[108] www.tacisinfo.ru/brochure/transp/uprav_m.htm

technical potential is economically viable, 72% is market attractive with the 2010 energy prices and 49% with the 2007 prices.

Table 8.9. Evaluation of the energy efficiency potential in buildings (mtoe)

Type of power station	2005 consumption level	Technical potential	Economic potential	Economic potential with Kyoto	Market potential, 2010 prices	Market potential, 2007 prices
Total buildings	**144.54**	**68.61**	**58.59**	**58.65**	**49.70**	**33.32**
Coal	2.89	0.58	0.00	0.00	0.00	0.00
Petroleum products	0.99	0.20	0.00	0.00	0.00	0.00
Natural gas	38.60	13.28	13.28	13.28	13.28	10.23
Other solid fuels	0.98	0.20	0.00	0.00	0.00	0.00
Electricity	18.57	8.42	8.42	8.42	8.42	5.02
Heat	82.51	45.94	36.89	36.95	28.00	18.07
Residential buildings	**108.24**	**53.42**	**44.78**	**44.78**	**37.98**	**24.53**
Coal	2.83	0.57				
Petroleum products	0.91	0.18				
Natural gas	27.18	10.16	10.16	10.16	10.16	7.11
Other solid fuels	0.94	0.19				
Electricity	9.37	3.82	3.82	3.82	3.82	2.82
Heat	67.02	38.50	30.80	30.80	24.00	14.60
Public and commercial buildings	**36.31**	**15.20**	**13.81**	**13.87**	**11.72**	**8.79**
Coal	0.06	0.01				
Petroleum products	0.08	0.02				
Natural gas	11.43	3.12	3.12	3.12	3.12	3.12
Other solid fuels	0.04	0.01				
Electricity	9.20	4.60	4.60	4.60	4.60	2.20
Heat	15.50	7.44	6.09	6.15	4.00	3.47

Source: CENEf's estimates

8.7.1. Residential buildings

8.7.1.1. Residential sector energy end-use structure

Residential sector is the second largest final energy end-user after manufacturing. In 2005, it consumed 108 mtoe. No direct statistical data are available to split residential energy consumption by end-uses. CENEf has made a special assessment based on some indirect data on equipment saturation rates, shares of dwellings equipped with district heating, hot water, natural gas, floor based electric ranges, as well as on some data for SECs for residential energy equipment and appliances (see Table 8.10). More surveys are needed to improve the knowledge on residential energy use structure in Russia.

Table 8.10. Residential sector energy end-use structure, 2005 (mtoe)

	Coal	Petroleum products	Gas	Other solid fuels	Electricity	Heat	Total
Heating	2.47		12.05	0.76	0.79	46.68	62.94
Hot water	0.36	0.18	5.71	0.18	0.36	20.34	26.94
Cooking		0.73	9.42		0.57		10.72
Lighting					2.81		2.81
Appliances					4.84		4.84
Total	**2.83**	**0.91**	**27.18**	**0.94**	**9.37**	**67.02**	**108.25**

Source: CENEf's estimates. Residential energy consumption was split by processes using data on the availability of energy services, equipment saturation, consumption norms fixed in several methodological documents in use, to estimate average gas-, heat- and electricity consumption.

Space heating is the leading energy end-user (58%), followed by hot water (25%), cooking (10%), lighting (2.6%), and appliances (4.5%)[109]. The share of appliances in electricity consumption stands at 52% and corresponds very well to similar shares in many other countries[110].

Importantly, natural gas and electricity are used for space heating not only in locations with decentralized heat supply, but also to meet minimum sanitary requirements for indoor comfort in settlements where heat supply systems fails to provide good quality services. So improving the efficiency of both district heating and buildings would allow for not only district heat, but also some electricity and natural gas, savings. Shortage of natural gas for domestic consumption recently led to a large-scale use of electric heating in suburban single-family houses. The less natural gas is technically available to connect new single-family houses, the higher is electricity consumption for space heating. The same could be said about hot water, but with a much wider geographic coverage: summertime 2-3 weeks' hot water cut-offs for district heating networks maintenance force residents to use electricity and natural gas to produce hot water for sanitary use (they still have to pay for domestic hot water supply).

8.7.1.2. Heat use efficiency potential

8.7.1.2.1 Space heating

Space heating is responsible for 58% of overall energy consumption in residential buildings with district heating systems serving three quarters of dwellings. Distribution of Russian residential buildings by energy efficiency levels is extremely uneven. A small part of buildings erected after 2000 in compliance with the new Building Codes meet modern thermal performance and heat efficiency requirements (see the green zone in Fig. 8.38)[111]. But the majority of existing buildings have quite low parameters of space heating efficiency. The following average SECs for space heating were assessed depending on the year of construction: built before 1990 (0.23 Gcal/m2/year); built in 1991-2000 and recently renovated (0.13 Gcal/m2/year); built after 2000 (0.09 Gcal/m2/year)[112].

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[109] This structure is quite close to the one reported for the IEA-11 for 1973 (space heating – 67%; water heating – 16%; cooking – 5%; lighting – 3%, and appliances – 9%, rather than to 1998 data. See Energy Technology Perspectives 2006. p. 333.

[110] Tools and Methods for Integrated Resource Planning. Joel N. Swicher, Gilberto de Martino Jannuzzi, Robert Y. Redlinger, UNEP Collaborating Centre of Energy and Environment. Riso National Laboratory, 1997, p. 38. IEA. Energy Technology Perspective 2006. p. 333.

[111] The German Building Codes demand specific energy end-use for space heating in the range between 40 and 96 kWh/m2/year with base heat supply system. A similar indicator specified in the Russian Building Codes adjusted for German climate conditions is 55-105 kWh/m2/year. So the German Codes have stricter requirements: by 20-27% for multi-family apartment buildings and by 9-10% for single-family houses. See V.A. Ilichev, Yu.A. Matrosov, G.L. Osipov. Energy efficient future of Russia's building sector. "Building techniques Bulletin", No. 8, 2005, pp. 56-61.

[112] The distribution was developed based on the data on residential buildings in several Russian cities where CENEf had developed energy efficiency programs (Kostroma, Zheleznogorsk, Izhevsk, Yuzhno-Sakhalinsk, Cheliabinks, Berezniki, Lipetzk, just to name a few).

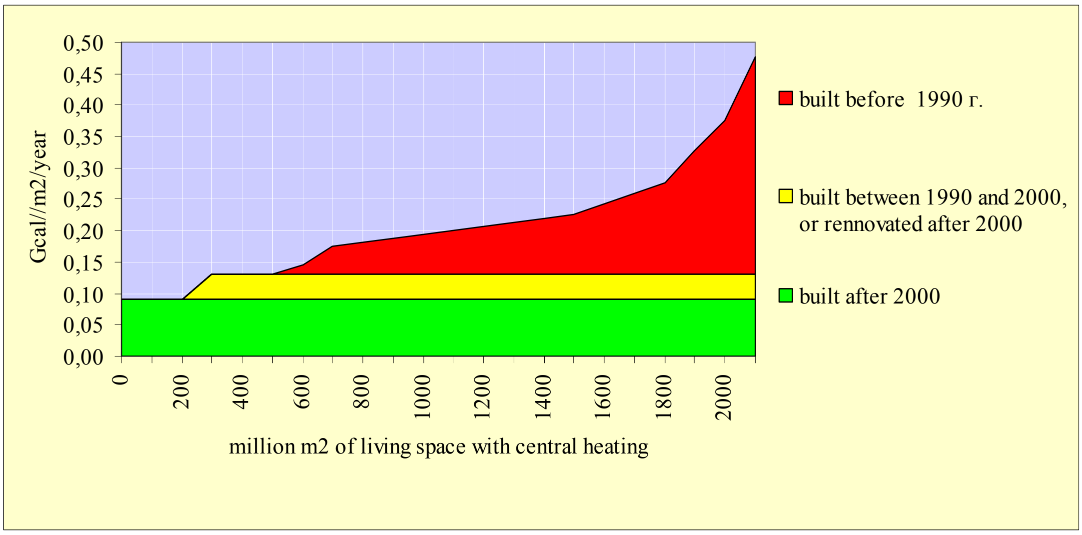

Figure 8.38. Distribution of residential buildings with an access to district heating by specific heat consumption for space heating

Space heating efficiency potential in residential buildings can be assessed through comparing average SEC (per m2/year) to the best one in the new construction (with an assumption that all houses are replaced overnight), or through comparing the present value with the SEC of the building after renovation (with an assumption that all old buildings are renovated overnight).

In the first case, the world best energy efficient buildings, such as passive houses or “near zero or zero energy houses”[113], can be theoretically selected for reference, bringing energy efficiency potential for space heating nearly to 100% of current use[114]. But passive houses are mostly suitable for detached single-family houses. In Russia, where urban population living in multi-family buildings dominates, they are applicable on a limited scale (mostly for suburban cottages). Reallocation of people to passive houses would then require rebuilding the whole urban infrastructure. The assessments below use the best multi-family buildings presently under construction in Russia for benchmarking.

For the first approach, it is important to check, whether additional heating efficiency adds up any cost for builders, and if it does, then how much. To answer this question, the data on designs of 28 new building types presently under construction in Moscow were collected. The SECs for heating (in kWh per m^2) were compared against the construction costs per m^2. No correlation was identified (see Fig. 8.39). So the answer to the question above is “no”: no additional costs are required to erect more efficient buildings, and all other factors, such as the number of floors, building geometry and orientation, the costs of materials, labor costs, etc., are responsible for the difference in the construction costs.

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[113] They require no energy procurement for space heating, using only heat released by inhabitants and appliances.

[114] One of such all electric houses has been in operation in the U.S. since 2002. Its daily electricity bill is only $US 0.82 ($US 0.45 for heating and cooling) versus $US 4-5 for a conventional house. Energy Technology Perspective 2006. p. 338.

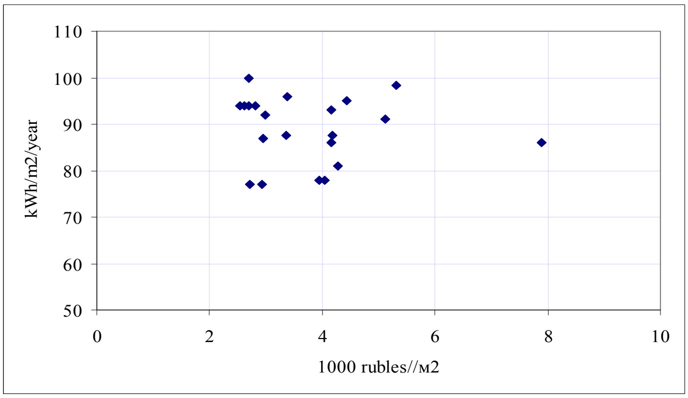

Figure 8.39. Relationship between residential buildings construction costs and specific energy consumption for new types of buildings under construction in Moscow in accordance with the 1999 Building Codes (only construction costs are included in the analysis; no land acquisition or grid connection costs are taken into account)

Of 28 multi-family many-stored building designs considered, the best ones consume only 77 kWh/m2/year versus 229 kWh/m2/year the country average. With this approach, the technical potential for Russia may be evaluated at 41.8 mtoe, including 31.3 mtoe in district heating. Only 0.5% of residential buildings are demolished in Russia annually, so even if it doubles, natural decommissioning of inefficient housing stock will take a century.

"Shaving off" the red and yellow zones in Fig. 8.38 is possible through buildings renovation measures, which, at reasonable costs, can bring 35-60% savings. It is more practical to consider the technical potential in the rehabilitation of existing housing stock, than overnight replacement of all buildings with new, most efficient ones. For such assessment, all buildings connected to district heating (2,364 million m2[115]) were split by four categories: built before 1990 (74.1%); in 1991-2000 (14.2%); after 2000 (6.5%); and recently renovated (5.2%). If all buildings built before 1990 are renovated with approaching average 0.13 Gcal/m2/year efficiency, the technical potential to improve space heating efficiency equals 16.9 mtoe. This number should be adjusted to reduced electricity and natural gas consumption for space heating in houses with district heating. Assuming that district heating failures are responsible for 10% of gas and electricity use for space heating purposes, additional savings of 0.08 mtoe of electricity and 0.12 mtoe of natural gas may be achieved, bringing the lower potential estimate to 17.1 mtoe. So depending on the approach used, the potential in space heating varies from 17.1 to 41.8 mtoe. For calculations below the average technical potential for space heating was taken at 25 mtoe.

Lack of adequate capital repair expenses and lack of energy efficiency motivation during capital repairs block the implementation of this potential. Importantly, at least 60% of energy efficiency potential in residential buildings lies with collective use systems, while 40% is achievable in flats. There are institutional options (for example, development of ESCO business) for the identification of a beneficiary for residential energy efficiency improvements, and for the harmonization of households' interests. Moreover, the money saved through municipal utility resource procurement may become an important source of funds for capital repairs of residential buildings.

8.7.1.2.2 Hot water

Hot water is the second largest end-user in the housing sector. Specific energy consumption for hot water supply is normally accounted for on a liters-per-capita basis. In this paper, SEC expressed in Gcal/per capita/year was used. For buildings erected after 2000 this SEC is 0.0774 Gcal/per capita; for those built in 1991-2000 – 1.135 Gcal/per capita; for recently renovated – 1.723 Gcal/per capita; for those built before 1991 – 2.597 Gcal/per capita (see Fig. 8.40). Bringing all hot water SEC to the best benchmark provides 13.13 mtoe technical potential (49% of present use).

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[115] Russian statistical yearbook. 2006.

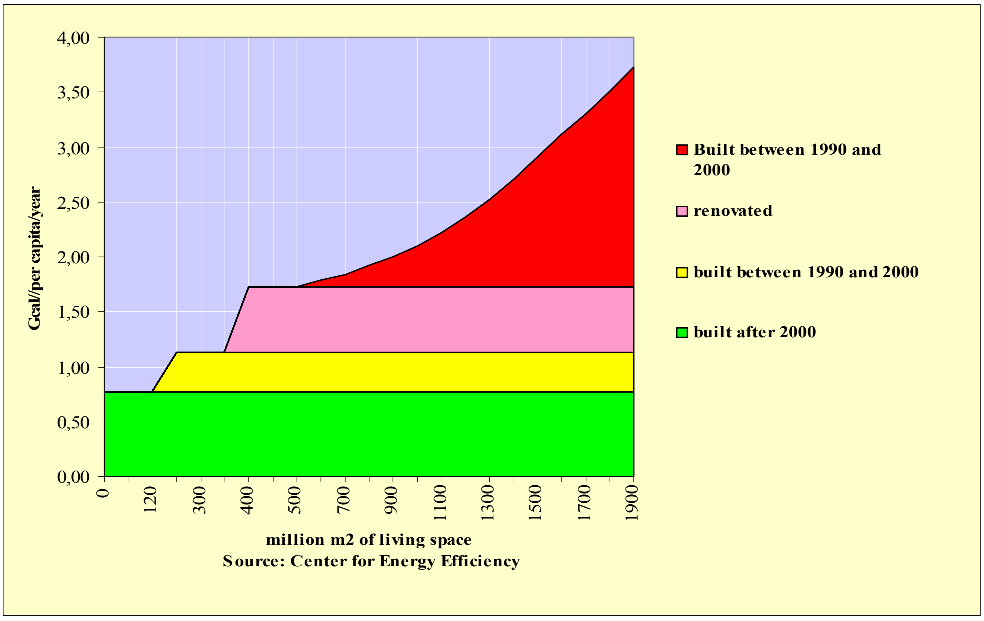

Figure 8.40. Distribution of residential buildings with an access to district heating by specific heat consumption for hot water supply

The number of households equipped with hot water meters in Russia is growing every year. Just this measure alone allows for 30-40% average savings of hot water. In reality, as CENEf studies have shown, hot water consumption habits and patterns are quite conservative, so these savings only partly are determined by improved consumer behavior and replacement of water using devices, but basically they are just an indication, that actual heat losses in heat transmission and distribution systems are much higher, than reported. So these losses are billed to residents who have no hot water meters, but in fact, this heat was never delivered to them. In this study, such losses were dealt with in the section on heat networks losses. Nevertheless, as detailed studies made for several Russian cities show, there still is a way to halve hot water energy use without sacrificing any sanitary needs, with 12% potential hidden in collective use systems (water temperature and pressure regulation, hot water pipes insulation, etc.) and the rest 38% located in dwellings[116]. If such approach is used, then the technical potential also equals 13.4 mtoe, thus proving the reliability of the assessment.

8.7.1.2.3 Cost curves for space- and water heating efficiency potential

There are multiple measures to improve efficiency of space and water heating while renovating existing buildings. The measure costs depend on whether one family is doing the job (so retail prices for materials and equipment are used) or the whole building is renovated by a housing company (benefiting from wholesale prices). The effects to a large degree depend on the specific building characteristics and climate zone (the same measure implemented in Norilsk city with over 11,000 degree-days brings 3-4 times larger effect, than in Astrakhan with its 3,000 degree-days).

The figure below shows the energy efficiency cost curve developed for Zheleznogorsk city with about 100 thousand residents (see Fig. 8.41)[117]. With expected 2010 heat price, only two measures are not cost-effective with 6% discount rate. When 12% discount rate is applied, the rating of

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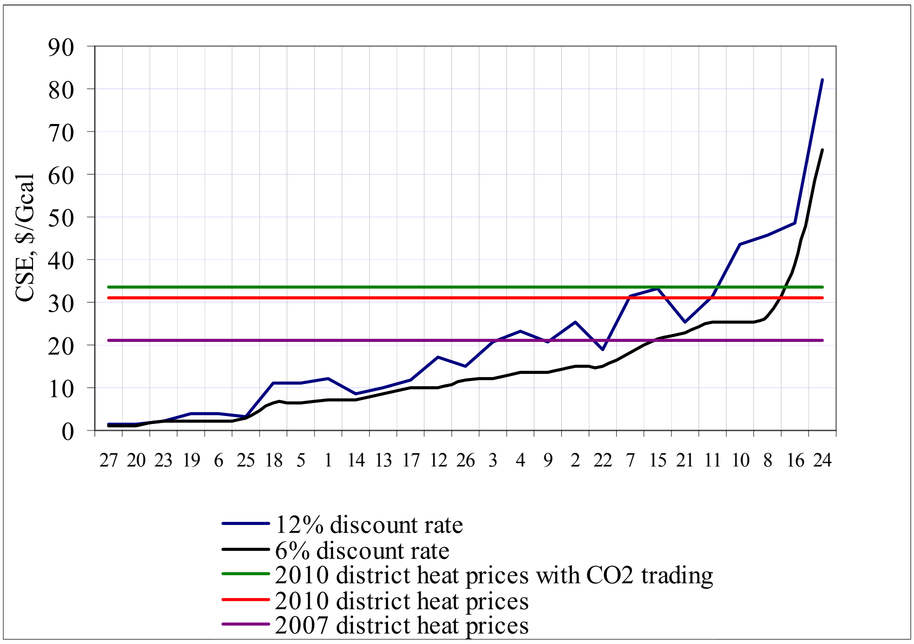
[116] V. Papushkin, T. Tasenko, I. Bashmakov and others. Reliable, Energy Efficient Municipal Utility Services. UNDP, M. 2005.

[117] Zhelesnogorsk has 6,600 heating degree-days, which is fixed in the Building codes; this is twice as many as in Rostov-on-Don, but only half of what is reported for Norilsk city. In Moscow, this index is 5,027. Therefore, the data on the effects for Zhelesnogorsk should be downsized before being extrapolated for the rest of the Russian Federation; some measures related to the insulation of exterior walls may become not cost-effective.

measures by CSE changes, and 5 measures are then not market attractive. When CO_2 emission trading is accounted for in heat price, the list of energy efficient measures does not change much. The CSE for installation of thermostatic valves at radiators and some exterior insulation techniques are above the heat price even after adjusting for CO_2 emission quotas trade.



1	Insulation of basement from the inner side
2	Insulation of basement ceiling
3	Insulation of the floor (1st floor)
4	Insulation of floor on the logs
5	Insulation of attic floor
6	Insulation of exterior walls from the inner side
7	Insulation of exterior walls with mineral wool and thin plaster
8	Insulation of exterior walls with thermo-insulating slabs
9	Insulation of walls from the exterior side with molded board lining
10	Insulation of exterior walls with mineral wool and plastic or aluminum siding
11	Installation of heat mirrors behind radiators
12	Insulation of flat roof
13	Insulation of windows (doors) + elimination of gaps between window (door) frame and the wall
14	Insulation of windows (installation of heat reflecting films)
15	Insulation of energy efficient windows
16	Installation of ceiling-mounted ventilators (casablanka fans)
17	Insulation of in-house DHW pipes
18	Restoration of re-circulation in the DHW system
19	Hydropneumatic cleaning of heating pipelines and radiators
20	Installation of efficient faucets
21	Installation of water meters in flats
22	Installation of heat meters in buildings
23	Installation of balancing valves at the buildings inputs
24	Installation of thermostatic valves at radiators
25	Replacing hydroelevators with circulating pumps and control system
26	Installation of individual heat points
27	DHW temperature control unit upgrade in open-type district heating systems

Figure 8.41. Energy conservation curves for district heating in Russian residential buildings

Total space and water heating reduction potential in residential buildings is assessed at 38.5 mtoe (see Table 8.11 and Fig. 8.42). With expected 2010 average heat prices and carbon trading, the economic potential scales down to 30.8 mtoe, and the market potential - to 24 mtoe. But with the 2007 heat prices the market potential is only 14.6 mtoe.

Table 8.11. Energy efficiency potential in residential buildings: space and water heating

Measures	Technical potential		Total incremental costs	CSE (dr=6%)	CSE (dr=12%)
	Million Gcal	%	$US million	$US/toe	$US/toe
Efficient windows	50,00	13	3929	408.68	627.56
Wall insulation (ventilated facade technology)	115,38	30	5239	681.08	1163.85
Radiator heat mirrors	11,54	3	8	7.25	9.44
Window heat reflecting films	46,15	12	174	37.74	49.16
Doors weather stripping	26,92	7	145	53.80	64.35
Others	50,00	13	268	63.24	97.11
Efficient faucets	65,38	17	1417	216.69	276.48
Insulation of indoor DHW pipes	26,92	5	32	16.77	21.85
Total	**384,59**	**100**	**11212**		

Source: CENEf's estimates

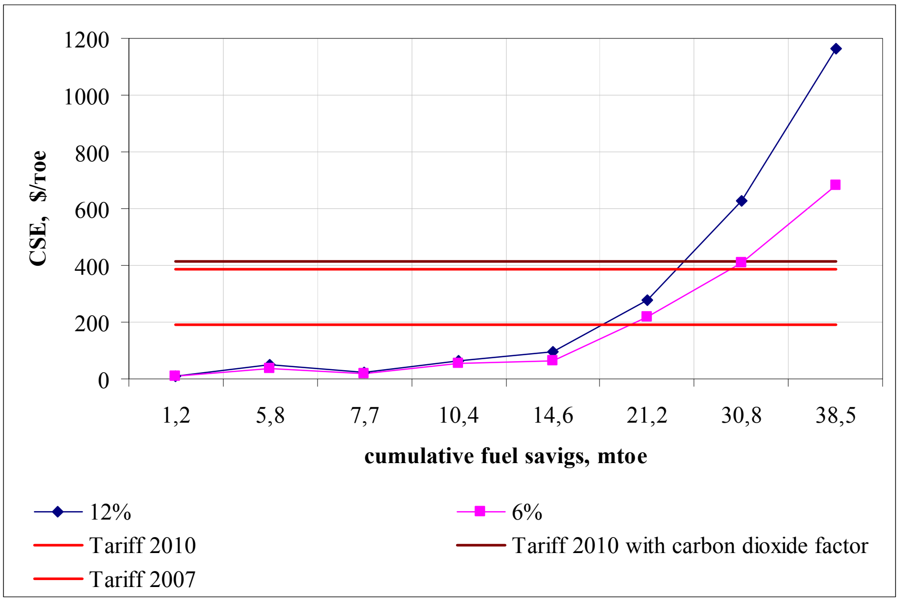


Figure 8.42. Heat for space heating and hot water savings cost curve

In this sector, part of the improvements is to be financed by residents who have a much higher discount rate (33-50%). If an assumption is made that residential energy efficiency improvements are financed by both separate households (50%) and their associations or municipalities (another 50% with 12% discount rate), then the market potential is shrinking to 18 mtoe, or 47% of the technical potential (with expected 2010 energy prices).

Experience in energy efficiency programs development for more than 50 Russian municipalities shows, that average investment cost to reduce space heating energy use through the renovation of residential houses is 700-1,000 $US/toe. So renovation of 88% of the living space of Russian residential houses bringing 39 mtoe in savings would cost $US 27-39 billion. A large part of this investment will be directed to the replacement of worn construction elements and equipment to prolong the building lifetime. Only $US 11-13 billion can be allocated as energy efficiency incremental costs.

8.7.1.3. Electricity

Compared to other countries, Russian residential sector is not listed among large electricity consumers: it is responsible for only 11.6% of overall electricity consumption in 2005. This consumption can be broken down by electric space heating (0.79 mtoe); hot water (0.36 mtoe); cooking (0.57 mtoe); lighting (2.81 mtoe); and electric appliances (4.84 mtoe).

To evaluate residential electricity efficiency potential, all households were split into three groups: the best (1% of the population), average (80%), and the worst (19%)[118]. These groups differ very much in their per capita electricity consumption (see Fig. 8.43). Comparing the best, average, and the worst monthly consumption, the technical energy efficiency potential in the residential sector can be assessed at 50 billion kWh (4.3 mtoe). Serious barriers to the implementation of this potential include lack of information and behavioral stereotypes. In Moscow, replacement of an incandescent lamp with a CFL pays back in 3-4 months; however, incandescent lamps dominate in the lighting systems. At the same time, in China, incandescent lamps have become a rarity.

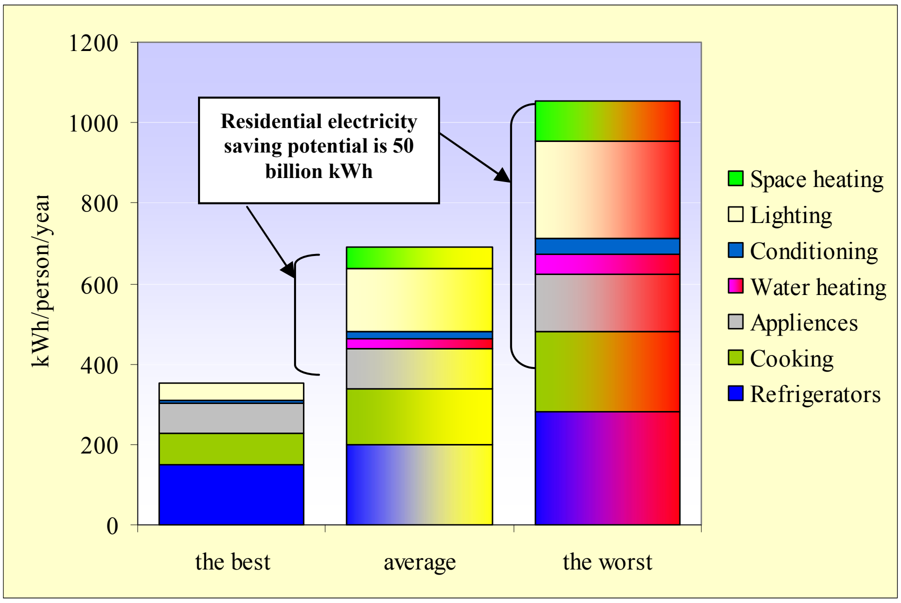


Figure 8.43. Electricity saving potential in residential buildings

More detailed element-by-element assessments of the technical potential were made (see Table 8.12) to reveal the technical potential of 43.5 billion kWh (3.74 mtoe). All of it is cost-effective with expected 2010 electricity price, and a large part of it is cost-effective even with 50% discount rate (see Fig. 8.44). CO_2-markup has a small impact on the cost-effective potential, because its value is small (59.6 $US/toe), or about 5% of expected 2010 electricity price. The market potential with the 2007 prices stays at 2.82 mtoe.

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[118] No survey data are available for such split; so it is an entirely intuitive estimate of CENEf experts.

Table 8.12. Energy efficiency potential in residential buildings: electricity

	Annual consumption	Minimal possible consumption	Technical potential		CSE (dr=6%)	CSE (dr=12%)	CSE (dr=50%)
	Billion kWh	Billion kWh	Billion kWh	% reduction	$US/toe	$US/toe	$US/toe
Space heating	9.19	6.83	2.36	25.7	188.19	268.36	915.97
Hot water	4.15	2.02	2.13	51.9	0.70	1.08	4.04
Cooking	6.64	4.71	1.93	29.1	1.36	1.95	6.64
Lighting	32.68	6.91	25.77	78.8	7.58	10.05	28.19
Appliances	56.29	43.07	12.55	23.5			
Refrigerators and freezers	20.11	15.54	4.57	22.7	24.06	34.31	117.12
Washers	13.71	11.51	2.20	16.1	720.15	1,026.93	3,505.13
VT and video	12.83	9.40	3.44	26.8	6.80	9.70	33.10
Air conditioners	2.52	1.35	0.99	42.3	5.43	7.07	20.32
Other appliances	7.29	5.27	2.02	27.7	7.58	10.05	28.19
Total	**108.95**	**63.53**	**43.77**	**40.7**			

Source: CENEf's estimates. The technical potential was assessed as a difference between the minimal possible consumption and the 2005 consumption. The minimal possible consumption was assessed based on the application of most advanced appliances presently available in the market, given the level of comfort provided and the structure and number of residents fixed as the 2005 level. CSE were assessed based on the incremental costs of new appliances and lighting systems.

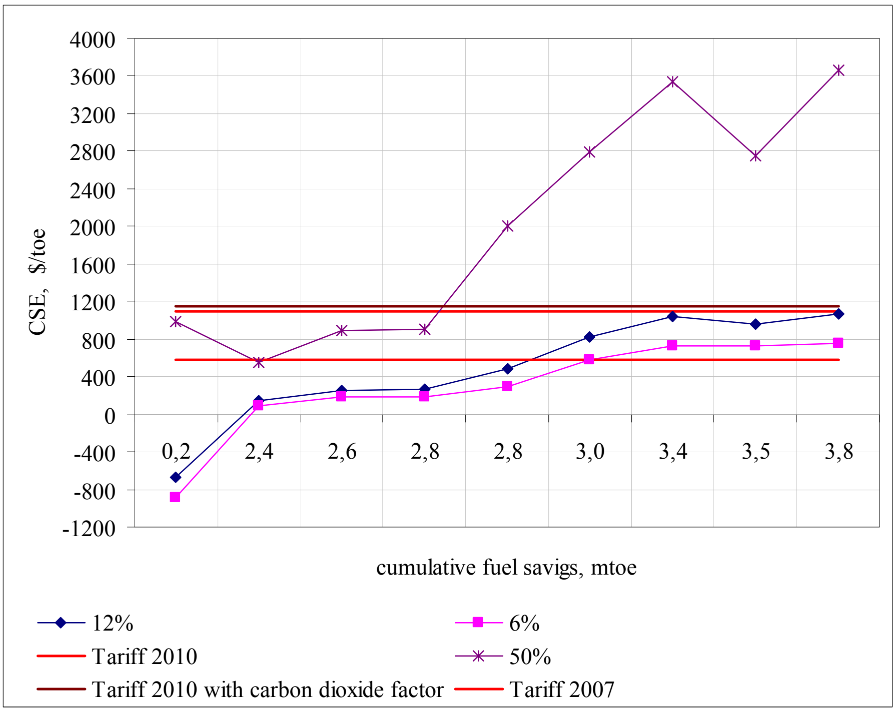

Figure 8.44. Residential electricity cost saving curve

A special analysis was made to find out if additional efficiency of refrigerators available in the Russian retail market adds up any additional cost (see Fig. 8.45). The conclusion is: there is no statically meaningful correlation between the SEC and purchase price. So additional efficiency is sort of "a free lunch" for smaller refrigerators. For larger models, the result was quite surprising: more efficient models cost less. So for refrigerators there are no incremental costs to get a more efficient unit from the market; the price is determined by other factors. In the U.S., in 1974-2002 average refrigerator price went down 2.7-fold (despite the 25% volume increase), while the efficiency improved 3.3-fold[119]. A similar conclusion may be made for most electric appliances. So it is hardly possible to estimate incremental costs for highly efficient electric devices.

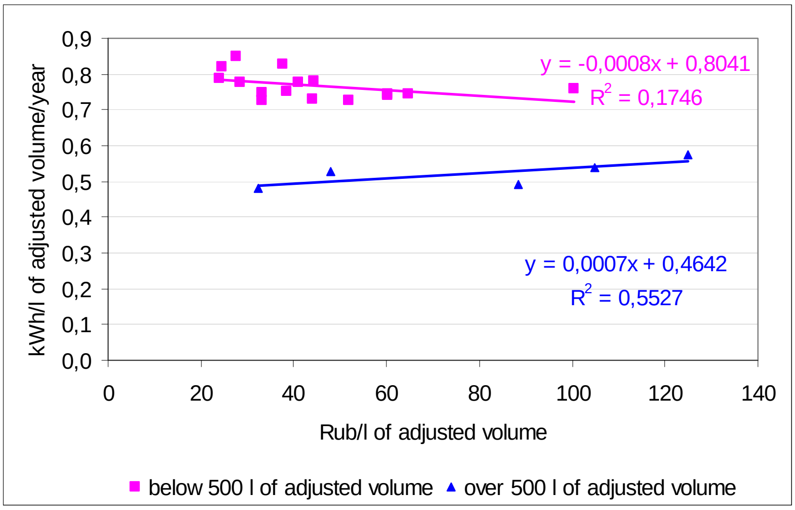

Figure 8.45. Relationship between refrigerator purchase cost (per unit of adjusted volume) and energy consumption (per unit of adjusted volume)

8.7.1.4. Natural gas and other fuels

Gas is the second largest energy resource used in the residential sector. Gas consumption in 2005 is estimated at 27.2 mtoe, of which a larger part was used for space heating (12.2 mtoe), and the rest for cooking (9.4 mtoe) and hot water supply (5.5 mtoe). The technical potential was assessed based on the minimal specific gas consumption of modern small condensing gas boilers (with minimal 0.09 m3 gas consumption to generate 1 kWh of heat[120]) and amounted to 2.54 mtoe for space heating (17%) and 2.48 mtoe for hot water (36%). Efficient gas stoves may generate 5.02 mtoe savings (43%). Thus, the total technical potential of the replacement of outdated equipment with efficient models is estimated at 22%, or 3.12 mtoe, all of which is cost-effective with expected 2010 natural gas price.

Other fuels are responsible for 4.3% of overall energy consumption (4.7 mtoe) in the residential sector and are used mainly for space heating, hot water preparation (coal and fuel wood), and for cooking (LPG). It was assumed that the technical potential is 20%, so energy savings amount to approximately 0.94 mtoe.

8.7.2. Public and commercial buildings

No data on public and commercial buildings total floor space, or floor space broken down by types of buildings (educational and health care facilities, restaurants, trade etc.) are available from the Russian statistics. CENEf estimated the total floor space at approximately 700-740 million m2. This estimate was based on the extrapolation of the housing space to public and commercial buildings space in other countries[121], as well as on the Russian Building Codes requirement that, if no construction documentation is available, public building energy consumption be taken at 25% above the value for residential buildings. About half of this total floor space is the share of public buildings. These buildings differ very much in the functions performed, so are hard to compare in terms of energy efficiency. Data for schools are probably the most comparable of all.

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[119] A.H. Rosenfeld. Managing climate change. Erice Seminars on Planetary Emergencies. August 20, 2007.

[120] www.framoss-volga.ru.

[121] Indicators of Energy Use and Efficiency: Understanding the link between energy and human activity. OECD/IEA. 1997. p. 174.

Public buildings are a large energy consumer. In 2005, about $US 2.6 billion were spent for energy services to 20,000 federal buildings alone. Energy bills of all Russian public buildings (including regional and municipal buildings) in 2006 exceeded $US 10 billion.

The space heating efficiency potential of public buildings is 45%. The experience in many Russian regions shows, that the technical space heating efficiency potential is 80% for educational institutions and 60% for health care facilities. Installation of meters and hot water end-use efficiency measures can bring 20-80% savings. Engineering analysis allowed it to estimate the technical potential of electricity savings in public buildings at 48%.

Public agencies purchase municipal utility services, rather than comfort (which is measured by other criteria and parameters). Paying public agencies' energy bills does not automatically bring comfort to the required standard. Lighting systems in many schools have never been replaced since their commissioning some 40 or 50 years ago; although they consume a lot of energy, illumination is often low, and the schoolchildren get weak-eyed. An audit of a Moscow school building showed, that despite the fact that lighting was responsible for 74% of the overall electricity consumption, there was practically no classroom, where sanitary illumination requirements were met. Comfort problems are also caused both by under- and over-heating. Installation of meters does not guarantee, that the required amount of resources will be provided and billed for. As the experience of Rostov-on-Don shows, regular over-heating results in 36% excessive heat costs, which are to be covered from the municipal budget. Municipality also covers the under-heating costs (additional electricity consumption for space heating). In other words, violation of comfort parameters always results in excessive costs.

Reduced comfort may result both from insufficient financing to cover energy bills and from the buildings wear, including the wear of the engineering infrastructure, and a lack of professional maintenance. Even addressing financial problems does not remove the factors determining inadequate comfort level. In the current situation, when the energy resources are procured, rather than comfort, the risks of inadequate comfort level persist.

Average time in operation for Rostov-on-Don school buildings and health care facilities audited by CENEf is 59 years. For Russia as a whole, there are no data on the distribution of public buildings by their time in operation; however, it is clear, that at least 80% of public buildings were built before 1980, i.e. are in operation for more than 25 years, and their thermal performance and engineering infrastructure need significant improvements and capital repair. In many buildings, windows and interpanel joints are in a highly unsatisfactory shape. The list may be continued.

Further wear of public buildings and engineering infrastructure will require considerable investment in their maintenance, at the same time it will not allow for the ensuring the required comfort parameters. Capital repair investment is estimated at least at $US 25 billion. The budget is unable to provide such financing. However, without these funds, the budget expenses under "municipal utility services" and "current repair" budget lines will be growing. Emergencies and cut-offs may become considerably more frequent, while the comfort parameters may erode further.

Public investment demand may significantly decrease with the launch of the public-private partnership mechanisms, which help finance renovation through savings. To reduce the burden on the budget, revolving schemes may be used to finance energy efficiency projects. They make the problem not so acute, although do not remove it.

According to the available estimates, public monetary savings potential through energy- and water efficiency improvements in public buildings accounts to $US 3.5-5.0 billion, including at least $US 1.2 billion per annum in 2006 prices in federal buildings alone. The effectiveness of energy efficiency measures will additionally increase in the coming years due to the electricity and natural gas tariffs growth, which is faster, than the inflation rate.

Implementation of energy efficiency measures is also important for the balancing electricity capacity demand and supply with the view of current electric capacity and natural gas shortage at domestic market. Given electric capacity deficit, many energy systems do not cut off social facilities. However, the contribution of public facilities to the electricity peak load and capacity deficit is 2-3 times larger, than their share in the overall electricity consumption. The specific feature of public buildings is that their base electricity-, water-, and heat consumption takes place exactly during the peak hours and the peak months. The marginal cost of electricity supplied to a public agency from 1 kW peak electric capacity built for $US 1,000-2,000 and running only at a 700 hours/year load is more than 5-10 rubles/kWh, which many-fold exceeds the tariff for public organizations. In other words, the tariffs for all other consumers need to be increased.

8.7.2.1. The structure of energy end-use in the public sector

Public sector is one of the key final energy users; it consumed 36.3 mtoe in 2005. District heat dominated in its energy consumption (42.7%), followed by natural gas (31,5%) and electricity (25,3%). Like with the residential sector, there are no statistical data which allow it to break down public energy consumption by end-uses. A special effort was made to make such breakdown based on some indirect data (see Table 8.13).

Table 8.13. The structure of energy end-use in the public sector, 2005 (mtoe)

	Coal	Petroleum products	Gas	Other solid fuels	Electricity	Heat	Total
Space heating	0.04		8.20	0.03	0.18	13.43	21.89
Hot water	0.02	0.03	0.41	0.01	0.03	2.07	2.56
Cooking		0.05	2.82		1.27		4.15
Lighting					3.12		3.12
Others					4.59		4.59
Total	**0.06**	**0.08**	**11.43**	**0.04**	**9.20**	**15.50**	**36.31**

Source: CENEf's estimates

Space heating energy consumption takes the lead (60.3%), followed by other use[122] (12.6%), cooking (11.4%) lighting (8.6%) and hot water (7.1%). Splitting results are pretty close to those for the U.S.[123].

8.7.2.2. District heat

District heating is responsible for 60% of public energy consumption in Russia (13.43 mtoe). No country-wide data is available on public buildings distribution by SEC for space heating. There are many types of public buildings performing different functions, including schools, hospitals, government buildings, shops, restaurants, sport facilities with very different profiles of energy use. It is hard to compare them in terms of SEC. But even buildings performing similar functions are very different in terms of SECs: for example, the best SEC for space heating in Rostov-on-Don schools is 8-fold lower, than the worst one, and for lighting the gap is an order of magnitude. The distribution was made by CENEf based on the data from its multiple projects to improve energy efficiency in the public sector.

Only a small part of public and commercial buildings were erected after 2000 in compliance with the new Building Codes to meet modern thermal performance and heat supply efficiency requirements (see the green zone in Fig. 8.46). The majority of existing buildings are quite old and

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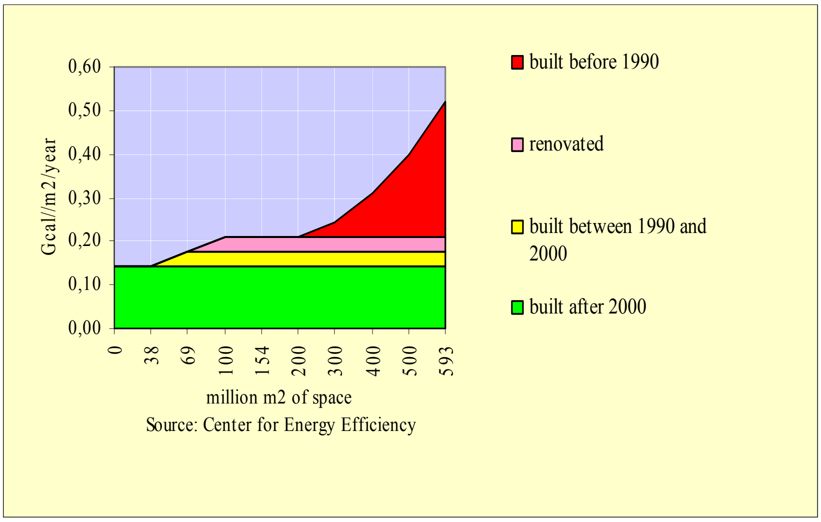
[122] Various electric appliances, such as motors, refrigerators, etc.

[123] Energy Efficiency in Buildings: Progress and Promise. Eric Hirst, Jeane Clinton, Howard Geller and Walter Croner. American Council for an Energy-Efficient Economy. Washington, D.C., p. 103. Energy Conservation Multi-Year Plan 1990-1994. August 1988. U.S. Department of Energy, Office of Conservation. Washington, D.C. 20585. p. 4-3.

inefficient. The following average SECs for space heating were assessed depending on the year of construction: built before 1990 (0.337 Gcal/m2/year); built in 1991-2000 (0.176 Gcal/m2/year); and recently renovated (0.210 Gcal/m2/year); built after 2000 (0.142 Gcal/m2/year).



Source: Center for Energy Efficiency

Figure 8.46. Distribution of public buildings by specific heat consumption for space heating

Space heating efficiency potential in public buildings can be assessed through comparing average SEC (per m2) with the best one in the new construction. This approach reveals the technical potential of 6.44 mtoe. The technical potential for hot water was estimated by a similar approach. For buildings erected after 2000, the SEC is 0.022 Gcal/m2; for those built in 1991-2000 – 0.027 Gcal/m2; for recently renovated – 0.032 Gcal/m2; for those built before 1991 – 0.052 Gcal/m2. Bringing all SEC for hot water to the best benchmark generates 1 mtoe of the technical potential.

Total district heating use reduction potential in public buildings equals 7.44 mtoe. With expected 2010 average heat prices and 6% discount rate, 6 mtoe are cost-effective, and with 12% discount rate and 2010 prices, the market potential shrinks to 4 mtoe and further down to 2.2 mtoe with the 2007 prices.

8.7.3. Electricity

Russia’s public and commercial sectors are close to the residential sector by the scale of electricity consumption (9.20 mtoe). It can be broken down by electric heating (0.18 mtoe); hot water (0.03 mtoe); cooking (1.27 mtoe); lighting (3.12 mtoe); and others end-uses (4.59 mtoe). The technical potential was assessed at 4.6 mtoe. All of it is cost-effective with expected 2010 electricity price and both 6% and 12% discount rates. With the 2007 prices market potential is downsized to 3.47 mtoe.

8.7.4. Natural gas and other fuels

Gas is the second largest energy source in the public sector. Gas consumption in 2005 is assessed at 11.43 mtoe, of which a larger part was used for space heating at own heat generators (8.20 mtoe), and the rest for cooking (2.82 mtoe) and hot water supply (0.41 mtoe). The technical potential of space heating was assessed based on the minimal specific gas consumption of modern condensing small boilers and amounted to 1.7 mtoe (or approximately 17%). The technical potential in the hot water is 0.14 mtoe (28%), and in cooking 1.27 mtoe (36%). Thus the overall technical potential of the replacement of outdated equipment with efficient models is estimated at 22%, or 3.12 mtoe. It is cost-effective with both 2007 and expected 2010 natural gas prices.

Other energy sources are responsible for only 0.5% of overall energy consumption (0.18 mtoe) in the public sector, and so the technical potential is insignificant. If we assume that it is 20%, then energy savings amount to approximately 0.04 mtoe.

9. Russian energy efficiency balance

9.1. The “map” of energy efficiency resource distribution

The findings of energy efficiency potential investigation are presented in two tables (see Table 9.1 and 9.2 below). Table 9.1 provides a “map” of energy efficiency potential distribution by the cells of integrated energy balance. The energy efficiency potential in the energy transformation sector presented in this table only accounts for technological improvements, given 2005 volumes of energy resource production and transformation, and not accounting for possible reduction of final energy use due to a full-scale implementation of the potential by energy end-users.

The largest energy efficiency potential is in the residential sector (53.4 mtoe), followed by manufacturing (41.5 mtoe), electricity generation (44.4 mtoe), transportation (38.3 mtoe), heat supply systems (31.2 mtoe), services sector (15.2 mtoe), and other sectors. In final energy use, the largest potential is in district heat savings (60.7 mtoe), followed by natural gas (38.2 mtoe), petroleum products (24.6 mtoe), and electricity (19.5 mtoe). In the energy sector, the largest potential is for natural gas (43.3 mtoe), district heat (losses reduction – 17.3 mtoe), and coal (10.8 mtoe).

Table 9.1. Assessment of Russia’s technical energy efficiency potential. Non-integrated approach (mtoe)

Energy consumption sector	2005 energy consumption	Technical potential	Coal	Petroleum products	Natural gas	Other solid fuels	Total fuels	Electricity	Heat
Use of associated gas					**12.09**		**12.09**		
Energy sector	**395.74**	**84.41**	**10.83**	**2.81**	**43.27**	**2.06**	**58.97**	**5.78**	**19.07**
Electricity generation*	**142.56**	**44.42**	**8.01**	**0.38**	**32.12**	**0.51**	**41.02**	**3.4**	
Condensing units	68.06	22.53	4.58	0.05	17.9	0	**22.53**	0	
CHPs (electricity)	63.15	17.91	3.43	0.27	13.7	0.51	**17.91**	0	
Diesel plants	1.66	0.58		0.06	0.52		**0.58**	0	
Electricity distribution losses	9.69	3.4					**0**	3.4	
Heat supply systems**	**212.38**	**31.24**	**2.76**	**0.69**	**7.92**	**1.45**	**12.82**	**1.12**	**17.3**
CHPs (heat)	63.20	2.42	0.53	0.12	1.29	0.48	**2.42**		
Boilers	124.93	11.52	2.23	0.57	6.63	0.97	**10.4**	1.12	
Heat distribution losses	24.25	17.3							17.3
Fuel production and transformation	**40.80**	**8.75**	**0.06**	**1.74**	**3.23**	**0.10**	**5.13**	**1.26**	**1.77**
Coal production and transformation	1.83	0.26	0.04	0.02	0.00		**0.06**	0.10	0.10
Oil production	8.69	1.75		0.09	0.55		**0.64**	0.82	0.29
Oil refining	20.60	4.8	0.02	1.63	1.77	0.10	**3.52**	0.21	1.07
Gas production and processing and losses	9.69	1.94			0.91		**0.91**	0.14	0.31
Final energy use***	**367.22**	**153,64**	**9,01**	**24,57**	**38,18**	**1,65**	**73,41**	**19,52**	**60,72**
Agriculture and forestry	**6.21**	**2,90**	**0,02**	**1,53**	**0,08**	**0,04**	**1,67**	**0,73**	**0,50**
Fishing	**0.04**								
Mining	**7.19**	**1.12**	**0.00**	**0.14**			**0.14**	**0.37**	**0.60**
Manufacturing	**109.54**	**41.49**	**8.41**	**1.19**	**9.86**	**1.40**	**20.87**	**7.72**	**12.90**
Coke production	3.62	2.41	1.68		0.02		**1.71**	0.09	0.61
Oxygen production	1.12	0.39						0.20	0.19
Compressed air production	0.75	0.38	0.02		0.06		**0.08**	0.27	0.03
Water pumping and treatment for industrial use	1.82	0.55			0.01		**0.01**	0.50	0.03
Pig iron	19.55	5.97	4.70		1.18		**5.88**	0.02	0.07
Open-hearth furnace	1.58	1.48		0.36	1.00	0.04	**1.39**	0.02	0.06
Basic oxygen furnace steel	0.35								
EAF steel	1.01	0.50			0.11		**0.11**	0.36	0.03

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Rolled steel	5.20	3.64	0.92	0.03	1.96		**2.91**	0.45	0.28
Steel pipes	0.72	0.18			0.12		**0.12**	0.03	0.03
Electroferroalloys	1.05	0.25	0.10				**0.10**	0.14	
Synthetic ammonia	0.73	0.23	0.00		0.09		**0.09**	0.06	0.08
Fertilizers and carbamide	2.15	0.42	0.00	0.01	0.06		**0.07**	0.07	0.28
Synthetic caoutchouc	2.88	0.71	0.00	0.05	0.08		**0.13**	0.07	0.52
Casting and metal works	1.08	0.32	0.02	0.01	0.21		**0.24**	0.05	0.03
Pulp	4.96	2.66	0.00	0.04		1.29	**1.33**	0.17	1.16
Paper	1.18	0.52					**0.00**	0.17	0.35
Paperboard	0.76	0.21					**0.00**	0.05	0.16
Cement and clinker	5.72	2.47	0.20	0.02	2.00		**2.23**	0.24	0.01
Meat	0.48	0.24			0.02		**0.02**	0.06	0.16
Bread	0.84	0.50	0.02	0.02	0.24	0.02	**0.30**	0.06	0.14
Other	51.97	16.51	0.74	0.66	2.70	0.05	**4.14**	3.69	8.68
Non-ferrous metallurgy		0.95					**0.00**	0.95	
Construction	**1.70**	**0.50**		0.20	0.01	0.01	**0.22**	**0.25**	**0.04**
Transport	**94.40**	**38,30**		**21,29**	**14,95**		**36,24**	**1,67**	**0,39**
Rail	6.97	1,04		0,50			**0,50**	0,54	
Other	1.94	0,60					**0,00**	0,30	0,30
Oil and pet. prod. pipelines	1.54	0,63					**0,00**	0,63	
Gas pipelines	34.06	15,24		0,00	14,95		**14,95**	0,20	0,09
Water	0.87	0,26		0,26			**0,26**		
Road	44.94	18,89		18,89			**18,89**		
Aviation	4.09	1,64		1,64			**1,64**		
Utilities	**3.61**	**0.72**		**0.01**			**0.02**	**0.36**	**0.34**
Services sector	**36.31**	**15.20**	**0.01**	**0.02**	**3.12**	**0.01**	**3.16**	**4.60**	**7.44**
Residential	**108.24**	**53.42**	**0.57**	**0.18**	**10.16**	**0.19**	**11.10**	**3.82**	**38.50**

*Energy inputs for electricity generation

** Fuel and electricity inputs for heat generation

***Excluding non-specified consumption and non-energy use.

Source: Center for Energy Efficiency

It is not possible to sum up final energy efficiency potential through the whole table. If the potential in final energy using sectors is implemented, less heat and electricity generation and fuel transformation is needed, so primary energy use in generation will be much lower, and the potential in heat and power generation, as well as in fuel transformation, is to be verified appropriately.

One way to evaluate the indirect effects of final energy consumption reduction is to multiply the vector of final energy use reduction ΔFE by matrix $(E\text{-}AE)^{-1}$ (see table 7.4) to estimate ΔPE – integral (direct plus indirect) energy savings. This operation yields 319 mtoe of energy efficiency potential, of which 165 mtoe (319-154) represents an indirect effect. This effect declines, as energy efficiency improvements are progressing in the energy sector.

Such approach, among other things, reduces volumes of heat generated by heat recovery units, as well as electricity generated by nuclear and hydropower plants. If these three items, which require no fuel and emit no CO_2, are kept stable at the 2005 level, the procedure of indirect effect evaluation turns into a two-step process. The first step: based on final energy consumption reduction (ΔFE) and assuming net energy export at the 2005 level, as well as frozen (2005) efficiency of energy sector processes (heat- and power generation, fuel production, processing, transmission and distribution), a new energy balance for 2005 was developed. This step allows it to identify a multiplication effect associated with final energy use reduction, which is assessed at 94 mtoe (653-406-153, see tables 7.1 and 9.2).

Table 9.2. Russian energy balance with implemented final energy use efficiency and the 2005-level efficiency of the energy sector (mtoe)

Energy consumption sector	**Coal**	**Crude oil**	**Petroleum products**	**Gas**	**Other solid fuels**	**Nuclear**	**Hydro**	**Electricity**	**Heat**	**Total**
TPES	**58.90**	**178.56**	**-96.05**	**203.58**	**8.03**	**38.82**	**15.05**	**-1.06**		**405.82**
Electricity generation	**-17.15**		**-1.87**	**-45.93**	**-1.68**	**-38.82**	**-15.05**	**55.27**		**-65.23**
Fossil fuels electr. plants	-10.67	0.00	-0.46	-22.87	-0.13			12.93		**-21.20**
CHP	-6.48	0.00	-1.23	-22.42	-1.54			13.72		**-17.95**
Diesel power stations	0.00	0.00	-0.18	-0.65	0.00			0.22		**-0.62**
Heat generation						-38.8	-15.1	28.4		**-25.47**
Fossil fuels electr. plants	**-21.83**	**-0.42**	**-6.61**	**-68.46**	**-3.31**			**-1.86**	**89.03**	**-13.45**
CHP	-0.90	0.00	-0.04	-1.92	-0.01			-0.08	2.70	**-0.24**
Other	-6.66	0.00	-1.27	-23.04	-1.58			-0.89	31.03	**-2.41**
Industrial boilers	0.00	0.00	0.00	0.00	0.00			0.00	0.00	**0.00**
District heating boilers	-7.40	-0.40	-3.68	-30.75	-1.08			-0.43	29.72	**-14.01**
Small boilers	-1.65	-0.02	-0.65	-5.37	-0.06			-0.08	6.22	**-1.60**
Fuel production and transformation	-5.22	0.00	-0.98	-7.38	-0.58			-0.38	11.56	**-2.98**
Coal and peat production and transformation									7.80	**7.80**
Oil production	**-2.22**	**-177.84**	**168.08**	**-12.08**	**-0.35**	**0.00**	**0.00**	**-14.34**	**-19.64**	**-58.39**
Oil refining	-0.17		-0.11					-0.44	-0.48	**-1.20**
Gas production and processing	0.00	-0.06	-0.33	-2.49				-3.73	-1.31	**-7.92**
Own use	-0.09	-174.38	168.52	-6.38	-0.35			-0.75	-3.84	**-17.27**
Distribution losses		-0.02		-3.21				-0.48	-1.08	**-4.79**
TFC	**17.70**	**0.31**	**63.55**	**77.10**	**2.68**			**38.01**	**69.39**	**268.74**

Source: Center for Energy Efficiency

At the second step, it was assumed that the efficiency of energy sector processes is improving, as discussed in Section 8, but all new technologies are only applied to the scale set in step one. A new energy balance for 2005 was developed, where all final energy savings for each cell were deducted from real 2005 energy use presented in the IFEB table (see Table 7.1).

Then the parameters for the energy sector were assessed first for reduced final energy demand, and then accounting for all possible technological advances in energy transformation. Thus the technical potential in the energy transformation sectors was adjusted downwards to account for lower coal, petroleum products, gas, electricity and heat demand. An assumption was made that heat generated by heat recovery units, as well as nuclear and hydro-electricity generation, keeps stable at the 2005 level. 2005 net energy export for each energy resource is also stable. Finally, the potential in the energy transformation sector was assessed by subtracting from the value in each cell of estimated new energy balance the corresponding real IFEB value for 2005. With this approach, savings in the energy transformation sector reflect both reduction in final energy use and technical improvements for energy generation and transformation. This procedure allows for the evaluation of efficiency improvements in the energy sector, which equal 46 mtoe (406-360, see tables 9.2 and 9.3). Depending on how statistical differences (see special line in table 7.1) are accounted, this procedure also gives an assessment of the potential equal to 293 mtoe.

Table 9.3. Russian energy balance with implemented final energy use efficiency and adjustments for improved efficiency of the energy sector (mtoe)

Energy consumption sector	**Coal**	**Crude oil**	**Petroleum products**	**Gas**	**Other solid fuels**	**Nuclear**	**Hydro**	**Electricity**	**Heat**	**Total**
TPES	**47.19**	**174.44**	**-96.05**	**174.08**	**7.43**	**38.82**	**15.05**	**-1.06**	**0.00**	**359.89**
Electricity generation	**-10.33**	**0.00**	**-1.21**	**-26.72**	**-1.61**	**-38.82**	**-15.05**	**50.48**		**-43.25**
Fossil fuels electr. plants	-5.26	0.00	-0.16	-9.14	-0.07			8.14		-6.48
CHP	-5.07	0.00	-0.92	-17.14	-1.54			13.72		-10.96
Diesel power stations			-0.12	-0.44	0.00			0.22		-0.35
Heat generation						-38.8	-15.1	28.41		-25.47
Fossil fuels electr. plants	**-17.95**	**-0.33**	**-5.10**	**-58.38**	**-2.79**	**0.00**	**0.00**	**-1.70**	**81.97**	**-4.28**
CHP	-0.82	0.00	-0.04	-1.75	-0.01	0.00	0.00	-0.07	2.47	**-0.22**
Other	-6.08	0.00	-1.16	-21.04	-1.45	0.00	0.00	-0.81	28.33	**-2.20**
Industrial boilers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
District heating boilers	-5.88	-0.32	-2.76	-25.41	-0.86	0.00	0.00	-0.39	27.14	**-8.48**
Small boilers	-1.24	-0.01	-0.46	-4.28	-0.04	0.00	0.00	-0.07	5.68	**-0.44**
Fuel production and transformation	-3.92	0.00	-0.70	-5.89	-0.44	0.00	0.00	-0.35	10.55	**-0.74**
Coal and peat production and transformation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.80	**7.80**
Oil production	**-1.21**	**-173.80**	**165.91**	**-11.88**	**-0.35**	**0.00**	**0.00**	**-9.71**	**-12.58**	**-43.61**
Oil refining	-0.15	0.00	-0.09	0.00	0.00	0.00	0.00	-0.37	-0.40	**-1.02**
Gas production and processing	0.00	-0.05	-0.27	-1.99	0.00	0.00	0.00	-2.99	-1.05	**-6.34**
Own use	-0.09	-172.05	166.27	-6.29	-0.35	0.00	0.00	-0.74	-3.79	**-17.04**
Distribution losses	0.00	-0.01	0.00	-2.57	0.00	0.00	0.00	-0.38	-0.87	**-3.83**
TFC	**17.70**	**0.31**	**63.55**	**77.10**	**2.68**			**38.01**	**69.39**	**268.74**

Source: Center for Energy Efficiency

Both steps allow it to integrate the potential and avoid double counting. The final outcome is presented in the format of primary energy savings. Based on this approach, the integrated technical energy efficiency potential was assessed at 282-293 mtoe, or 403-420 mtce, which is 43-45% of the 2005 primary energy consumption (see Table 9.2). With the elimination of gas flaring, the technical potential scales up to 294-305 mtoe (420-436 mtce), or 45-47% of 2005 TPES. Relationships of various factors in the final assessment of the energy efficiency potential are presented in Figure 2.1.

Implementation of this potential would allow it to reduce natural gas consumption by 194 mtoe (240 billion m3); coal consumption by 62.5 mtoe; petroleum products consumption by 35 mtoe; crude oil consumption by 2.5 mtoe, and other fuels consumption by about 7 mtoe.

The reduction of natural gas consumption originates partly from the reduction of final energy use (47 billion m3), but mostly from the reduction of heat generation (89 billion m3) and power generation (81 billion m3) and utilization of presently flared associated gas. Such reductions are only partly determined by more efficient gas use at power plants and boiler-houses, but mainly by improved efficiency of heat and electricity final use.

Table 9.4. **Assessment of Russia's technical energy efficiency potential. Primary energy (interrogated) approach (mtoe)**

Energy consumption sector	Coal	Crude oil	Petroleum products	Gas	Other solid fuels	Electricity	Heat	Total
TPES with the elimination of natural gas flaring	**58.34**	**2.50**	**34.65**	**192.09**	**6.92**			**294.50**
TPES	**58.34**	**2.50**	**34.65**	**180.00**	**6.92**			**282.41**
Electricity generation	**23.87**	**0.00**	**2.53**	**64.88**	**1.73**			**93.01**
Fossil fuels electricity plants	16.02		0.75	36.47	0.20			53.44
CHP	7.85		1.53	27.56	1.53			38.47
Diesel power stations			0.24	0.85				1.09
Heat generation	**23.31**	**0.46**	**7.38**	**71.02**	**3.47**	**1.82**		**107.45**
Fossil fuels electricity plants	0.88		0.04	1.88	0.01	0.08		2.88
CHP	6.50		1.24	22.51	1.55	0.87		32.67
Other								0.00
Industrial boilers	8.11	0.44	4.19	32.70	1.18	0.42		47.04
District heating boilers	1.88	0.02	0.76	5.87	0.07	0.08		8.67
Small boilers	5.94		1.15	8.06	0.66	0.37		16.19
Fuel production and transformation	**2.15**	**2.04**	**0.17**	**5.92**	**0.07**	**10.08**	**19.95**	**40.39**
Coal and peat production and transformation	0.12		0.07			0.30	0.32	0.81
Oil production	0.00	0.02	0.10	0.74		1.11	0.39	2.35
Oil refining	0.02			1.32	0.07	0.15	0.79	2.35
Gas production and processing		0.00		1.99		0.29	0.67	2.96
Own use						1.73		1.73
Distribution losses	2.02	2.02	0.00	1.88		6.49	17.78	30.18
TFC	**9.01**	**0.00**	**24.57**	**38.18**	**1.65**	**19.52**	**60.72**	**153.64**
Agriculture and forestry	**0.02**		**1.53**	**0.08**	**0.04**	**0.73**	**0.50**	**2.90**
Fishing								
Mining		**0.00**	**0.14**			**0.37**	**0.60**	**1.12**
Manufacturing	**8.41**		**1.19**	**9.86**	**1.40**	**7.72**	**12.90**	**41.49**
Coke production	1.68			0.02		0.09	0.61	**2.41**
Oxygen production						0.20	0.19	**0.39**
Compressed air production	0.02			0.06		0.27	0.03	**0.38**
Water pumping and treatment for industrial use	0.00			0.01		0.50	0.03	**0.55**
Pig iron	4.70			1.18		0.02	0.07	**5.97**
Open-hearth furnace			0.36	1.00	0.04	0.02	0.06	**1.48**
Basic oxygen furnace steel								
EAF steel	0.00		0.00	0.11		0.36	0.03	**0.50**
Rolled steel	0.92		0.03	1.96		0.45	0.28	**3.64**
Steel pipes				0.12		0.03	0.03	**0.18**
Electroferroalloys	0.10			0.00		0.14	0.00	**0.25**
Synthetic ammonia	0.00	0.00	0.00	0.09		0.06	0.08	**0.23**
Fertilizers and carbamide	0.00	0.00	0.01	0.06		0.07	0.28	**0.42**
Synthetic caoutchouc	0.00	0.00	0.05	0.08		0.07	0.52	**0.71**
Casting and metal works	0.02	0.00	0.01	0.21		0.05	0.03	**0.32**
Pulp			0.04		1.29	0.17	1.16	**2.66**
Paper				0.00		0.17	0.35	**0.52**
Paperboard				0.00		0.05	0.16	**0.21**
Cement and clinker	0.20		0.02	2.00		0.24	0.01	**2.47**
Meat	0.00		0.00	0.02		0.06	0.16	**0.24**
Bread	0.02		0.02	0.24	0.02	0.06	0.14	**0.50**
Other	0.74		0.66	2.70	0.05	3.69	8.68	**16.51**
Non-ferrous metallurgy						0.95		**0.95**

Energy consumption sector	**Coal**	**Crude oil**	**Petroleum products**	**Gas**	**Other solid fuels**	**Electricity**	**Heat**	**Total**
Construction	**0.00**		**0.20**	**0.01**	**0.01**	**0.25**	**0.04**	**0.50**
Transport and com.	**0.00**	**0.00**	**21.29**	**14.95**	**0.00**	**1.67**	**0.39**	**38.30**
Rail	0.00		0.50	0.00	0.00	0.54		**1.04**
Other	0.00		0.00	0.00	0.00	0.30	0.30	**0.60**
Oil and pet. prod. pipelines			0.00	0.00		0.63		**0.63**
Gas pipelines				14.95		0.20	0.09	**15.24**
Water	0.00		0.26					**0.26**
Road			18.89	0.00				**18.89**
Aviation	0.00		1.64					**1.64**
Utilities	**0.00**		**0.01**	**0.00**	**0.00**	**0.36**	**0.34**	**0.72**
Services sector	**0.01**		**0.02**	**3.12**	**0.01**	**4.60**	**7.44**	**15.20**
Residential	**0.57**		**0.18**	**10.16**	**0.19**	**3.82**	**38.50**	**53.42**

Source: Center for Energy Efficiency

9.2. Costs and benefits of exploiting Russian energy efficiency resources

As the analysis has shown, the economic potential is 215-227 mtoe with expected 2010 energy prices and CO_2 emission trading, while the market potential is about 190-210 mtoe.

It is really a challenge to identify capital incremental costs of the energy efficiency potential implementation. This difficulty originates from the fact that a large part of the equipment is to be replaced to let the systems perform their basic functions, and the new equipment is more energy efficient. So efficiency often comes as a "free lunch" at no additional cost. The numbers below were assessed with some precaution, and real incremental costs may be lower.

Incremental capital costs of implementing the energy efficiency potential were assessed at the following values: in power generation at about $US 106 billion; in district heating renovation at $US 27 billion; in the fuel processing and manufacturing sector at $US 35 billion; in mining and agriculture $US 4 billion more, in pipeline transportation at $US 23-30 billion; in automobiles at $US 100 billion; and in buildings at $US 25-50 billion, totaling to $US 321-352 billion. If automobile transport is not accounted for, the total comes down to 2005 $US 221-252 billion. With the use of flared associated gas it is $US 224-257 billion. Average specific incremental capital investments are 830-920 $US/toe. Russia's energy sector investment demand was estimated for 2005-2020 at about $US 1 trillion. Additional average energy supply costs are estimated at 1990-2740 $US/toe[124]. In other words, **1 toe of primary energy delivered to support economic growth generated by energy efficiency improvements requires on average 2-3 times less capital, than the same amount of energy delivered through additional supply options. If only cost-effective incremental investments in energy efficiency improvements are accounted for, this ratio scales up 4-6-fold.**

Russia's energy demand in 2005-2020 is expected to grow up by 350 mtoe in the "Inertia" scenario against only 109 mtoe in the "Efficiency" scenario[125]. The gap is 240 mtoe, which is about equal to the implementation of the whole 2005 economic potential at 2010 energy prices.

If the equivalent of natural gas consumption reduction is exported at the 200-230 $US/1000 m3 price, it may bring about $US 48-55 billion in additional export revenues. If accompanied by the

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[124] Russia's long-term economic development projections for 2007-2030 (scenarios). Russian Academy of Science, Institute for economic projections. Moscow, May 2007. A large part of investment in energy supply is required merely to keep current production levels.

[125] I. Bashmakov. Russia's energy sector: the inertia or the efficiency strategy? Voprosy ekonomiki. No. 8, 2007.

export of saved crude oil (9.4 mtoe) at 70 $US/barrel and saved petroleum products (34 mtoe), additional $US 24 billion will be generated. So lost petroleum and natural gas export revenues from non-implemented technical energy efficiency potential total to $US 72-79 billion per annum.

9.3. Top fifteen energy efficiency technologies to support

Screening the major technical options presented in the section above to implement the energy efficiency potential allowed for the identification of top 15 technologies capable of bringing huge energy savings at reasonable costs:

1. Combined cycle natural gas turbines;
2. Efficient gas boilers and clean coal-fired boilers;
3. Renovation of heat supply networks with partial decentralization of district heating systems in areas with low heat load densities;
4. Renovation of electric grids;
5. Improving oil refining technologies;
6. Improving gas transportation efficiency (gas compressors and other equipment to reduce leaks) and utilization of flared associated gas;
7. Dry and semi-dry clinker production technologies;
8. Pulverized coal injection technologies in blast furnaces and coke dry quenching technology;
9. Efficient electric motors;
10. Efficient steam transportation and steam systems;
11. Heat recovery, including heat pumps;
12. Hybrid automobiles;
13. Efficient windows and housing weatherization;
14. Efficient lighting;
15. Energy metering.

There is a need for special national policies to support the penetration of these technologies to the market.