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Geothermal Heat Pump Systems of Heat Supply (GHPS): Operational Experience, Technical and Ecological Aspects in Russia

G.P. Vasiljev

JSC "INSOLAR-INVEST", B. Filevskaja Street h. 32. builds 3. Moscow, Russia

e-mail: vassiliev@co.ru

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ABSTRACT

This paper is devoted to the geothermal heat pump system of heat supply (GHPS) using the low grade thermal energy stored in the first 100 metres or so of the Earth. Data on the efficiency of long-term operation in the ground and climatic conditions of the Russian Federation **of real** buildings fitted with GHPS, installed by JSC " INSOLAR-INVEST " are submitted.

The second part of the paper is devoted to the technical and ecological aspects of the rational integration of GHPS into the power balance of Russia. Results of analytical research and numerical experiments are submitted based on the efficiency of various network decisions regarding the integration of GHPS into the structure of the centralized system of power supply prevailing in the country. Results of research and a method for defining the environmental component in tariffs for traditional power resources, that takes into account the costs to municipal budgets of environmental contamination from fossil fuel combustion are presented.

1. INTRODUCTION

Efficiency of use of energy is an indicator of the scientific, technical and economic potential of a society, allowing an estimate to be made of its level of development. Comparison of parameters related to energy effectiveness with the advanced countries shows that in the economy of Russia, specific power consumption of our total internal product (gross national product) in several times higher, than in the advanced countries. The level of energy consumption per unit of comparable gross national product of Russia is approximately 4 times higher than in the USA - the country with high installed power per employeefor production of goods, and supply of services. Similarly, the figures are 2.5 and 3.6 times higher than for Germany and Japan respectively. All this suggests that savings of at least 40-50% in energy consumption could be made in Russia.

Heat supply through the use of thermal heat pumps is one of the most promising directions in the area of energysaving and is currently receiving greater attention throughout the world.

Historically the heat pump was first offered in 1852 by Lord Kelvin, but their real application began only in the 20th century. The practical evolution of heat pump installations was carried out in parallel with the development of refrigeration technology, improvements in reliability, and cost reduction.

The energy crisis of the 70's was a powerful spur to development HPS. For example, in the USA during this period the volume of manufacture of thermal heat pumps trebled and reached a level of 300 thousand pieces a year, with the number installed HPS totaling millions pieces. In the 80's the level of production and application HPS stabilized, and then again started to grow due to both environmental and energy conservation initiatives. In Russia, unfortunately, only a handful of individual buildings have been equipped with heat pump systems of heat supply (HPS) a few examples of which are described in this paper.

2. ENERGY EFFICIENT BUILDINGS EQUIPPED WITH GEOTHERMAL HEAT PUMP SYSTEMS

2.1 Demonstration complex "ECOPARK-FILI"

In 1994-1997 in order to demonstrate the use of non-conventional energy technologies for buildings under normal operating conditions, the recreation park complex “ECOPARK FILI” was established (Figure 1).This is located at B.Filevskaja Street, h.22, Moscow. It was created by JSC

" INSOLAR-INVEST " with the assistance of park "FILI" and the Ministry of Science and Technology of the Russian Federation.

Fig 1

Today in the majority of city parks inadmissible limits of air, ground and vegetation pollution exist. Many parks have low potential out-of-date local boiler-houses emitting high levels of atmospheric pollution. Existing engineering networks, as a rule, are in a very poor state of maintainance. The cause of these problems, is related to the traditional way of thinking regarding significant capital investments, but in many parks (for example, forest parks) it is simply impossible, in connection with ecological consequences of manufacture of works on a lining of engineering networks.

At the same time, the specific operational thermal loads on cultural leisure buildings (seasonal prevalence of operation of attractions, zones of entertainments, buildings for public catering, etc.) offers ample opportunities for the use of solar energy as, in most cases the peak of intensity of falling solar radiation and the operational loads of the buildings coincide. Use of solar energy, as in the transformed kind (for example, photo-electric installations and batteries), and in "direct", for example, in solar collectors, allows for the provision of electric power and heat to small independent attractions, booths, cafes and other buildings found in a park infrastructure.

The demonstration complex includes technical buildings and two office buildings such as the "Snail", commissioned in 1994 and in 1997. The total area of the buildings in the complex is 1000 m2. The complex is situated in an overall area of one hectare.

On buildings of a complex the following experimental systems and the equipment are established:

Automated heat pump systems of heat supply (ATNU) using low grade thermal energy of shallow ground . These systems supply equip both buildings such as "Snail". (HPS) They include ground collectors for gathering up to 40kWth of low grade heat from the ground connected to 4 heat pump installations ATNU-15 (of Russian manufacture) (Fig. 2.) which yield a total heat output of 60 kWth;

- Wind- energy installations with a rated capacity of 1-5 kWt;

Photoelectric installations with a peak capacity 2 kWt.

The photoelectric and wind installations partially supply the internal and external lighting requirements of the buildings.

Results of monitoring the heat pump systems and the buildings as a whole are submitted in Table 1. It is important that in estimating the energy efficiency of the buildings of a complex, all power inputs were taken into account: energy used for space heating, hot water supply, illumination, both office equipment and household needs. The last line of Table 1 shows the annual specific energy consumption per m2 of the heated area, characteristic for position existing today in housing and communal services is resulted.

Table 1.

PARAMETER	UNITS	BUILDING 1	BUILDING 2
Resistance to heat transfer of external protecting designs Walls; Windows.	m^2*oC/ W	 1,2 0,4	 3,0 0,4
Annual current consumption ,including : Illumination and household needs; Hot water supply; Heating.	MW*h in per annum	143,5 48,0 16,0 79,5	49,8 18,0 12,0 19,8
Specific consumption of power resources per m2/ per annum	кW*h/m2 per annum	478	166
Specific consumption of power resources per m2/ per year	Кgc.f./m2 per annum	59	20
Specific consumption of power resources per m2 of the heated area per year in housing and communal services	Кgc.f./ m2 per annum	100	

Fig 2. Energy effective rural school in the Iyaroslavl area.

Table 2.

PARAMETER	
Design Heat loss of buildings kW	**130**
The daily average charge of thermal energy of hot water supply, kWh.	**162**
The peak hour charge of hot water, m^3/h.	**1,1**
Installed electric capacity, kW.	**96**

Table 3.

THE NAME OF PARAMETERS	October 5, 2001– on November 4, 2001	November 4, 2001- On March 23, 2002
1	**2**	**3**
The charge of electric power under the day time tariff, кWth.	10323	95250
The charge of electric power under the night time tariff, кWth.	11142	88560
It is made heat, кWth.	33348,8	244878,0
The total charge of the electric power , кWth.	21465,0	183810,0
The charge of the electric power on circulating pumps, кWth.	3485,0	16100,0
The total charge of the electric power on HW, кWth.	3000,0	15000,0
Quantity of the energy taken from a ground , кWth.	18368,8	92168,0
Economy of energy without taking into account HW, %.	45	31
Operating ratio of thermal capacity AHPS, shares of unit .(calculation on day time tariff).	0,44	0,8
Operating ratio of thermal capacity of HEWs AT , shares of unit .(calculation on night time tariff)	0,478	0,710
The electric power spent for a drive 8 AHPS+CP, кWt *h.	10339,0	113299,2
Factor of transformation *AHPS +CP (without HEWs AT), shares of unit.	3,23	2,16
Average for the period specific heat take off (quantity low potential heat removed) from 1 running metre of length earth heat exchanger –well, Wt/г.м.	182	126

2.2 Energy efficient rural school in the Yaroslavl area

In September, 1998 in the village of Filippovo in the Ljubimskogo area of the Yaroslavl region a rural school equipped with a heat pump system for heat supply (HPS) was commissioned . It is the first rural school in Russia equipped with a heat pump system for heat supply, using low grade heat from the shallow ground (See. Fig. 2). The technology for the heat supply to the school has been developed by JSC " INSOLAR-INVEST ", the heat pump equipment has been made and installed by the Rybinsk factory of instrument making , and the design of the school was carried out by JSC «Yaroslavgragdanproect» .

The school building is a two-storeyed brick structure built from silicate brick with an area ~ of 2000 m2 and a volume ~ of 6900 m3. The thickness of the walls is 640-680 mm, the area of window and doorways ~230 m2 and ~ 20 m2 respectively . The building has a underground plant room. The school is located in the surburbs of Filippovo village approximately 100 km from Yaroslavl and is designed for

162 pupils and 20 teachers. In table 2 the energy requirements of the building services of the school are given.

The major factor which determined the technology of the heat supply and configuration heat pump of the school, was a significant deficiency of local electric capacity in the afternoon. At the design stage heat pump the use of direct electric heating was compared to using thermal heat pumps on ecological grounds. However, direct electroheating could not be applied because of a deficiency of 40 kW in installed capacity. As a result the heat supply system makes use of a combination of storage tanks and low rate night tariffs to provided hot water storage. As in addition ground source heat pumps are used to provide additional thermal energy which significantly reduce the requirement for installed electrical capacity.The heat pump is located separately in a plant room which was earlier planned for accommodation of coal boiler-house. In the same building on the ground floor the refrigerating chamber for the school dining room, cooled from the heat pump installation is placed. The heat pump system for the heat supply of the school has already been operational during four cold seasons. Annually, before the beginning of a cold season, experts from the The Rybinsk carry out maintenance checks, and then monthly during the heating period they inspect the operation of the working equipment. In addition the thermal unit is equipped with instrumentation (thermal and electric meters) which help with the constant monitoring of the operational mode HPS of the school.

In table 3 some results of the monitoring of operation TCT of the school for the heating period 2001-2002 г.г are submitted.

In Table 3 the following marks :AHPS - automated heat pump installations are applied;

CP - circulating pumps; AT - tanks - accumulators; HW-hot water supply; HEW – heating resistance tanks of the accumulators, working in a night mode.

From the data submitted in Table 2, the heat pump system for heat supply of the school provides energy efficiencies of 30 to 45 % which has allowed, over four years of operation, the saving of about 60 tons of conventional fuel.

2.3 Energy efficient house in Moscow in microdistrict Nikulino-2

The project « Energy efficient house in microdistrict Nikulino-2 » has been realized in 1998-2002 by the Ministry of Defence of the Russian Federation together with the Government of Moscow, the Ministry of Industry and Science of Russia, JSC " INSOLAR-INVEST" and association AVOK in scheme called " The Long-term program of energy saving in Moscow ", authorized by the joint decision of the Government of Moscow and the Ministry of Science and Technology of the Russian Federation № 36-RP-6 from January, 15, 1998.

The purpose of the project was the creation, natural approbation and the subsequent introduction into housing construction of the city the newest technologies and equipment, **which would decrease by at least a factor of two the power inputs required compared to exisiting housing.** It is necessary to note, that the project started in 1998 and the expected economy of energy was estimated in comparison with buildings being constructed at that time МГСН 2.01.94, which were being fitted with new levels of insulation as part of the first stage of transition in energy efficiency.**As a base series** for realization of the project a typical series of apartment houses of 111-355 Ministries of Defence of Russia was chosen as best representing the requirements of energy efficiency , from the point of view of architectural and space-planning decisions. A standard project of inhabited large-panel houses and the block - sections of a series 111-355. MD it was developed by 53 Central project institute of the Ministry of Defence of Russia and it is planned to be used for mass construction throughout the territory of the Russian Federation.

An experimental energy efficient house (see. the Fig. 3) has been constructed and entered into operation in 2001 at h. 62 Academician Anokhin Street, Nikulino-2, Moscow. It has the following basic characteristics.

External protecting designs 3-layer ferro-concrete panels thickness of 350 and 400 mm on discrete connections ДС. The external layer thickness of 80 mm from heavy concrete γ = 2400 kg / m3; an internal layer from heavy concrete γ = 2400 kg / m3, a layer of a insulation thickness of 150 mm from polifoam ПСБ-35 (25) GOST 15588-86*.

End: a "cold" attic with a flat roof.

Windows and balcony doors with triple glazing in wooden frames in accordance with GOST 16289-80.

System of heating-twopipe .

Regulation heat transfer heating devices - by means of temperature regulators "Danfos" on convectors. Regulation of system of heating - central and on every apartment.

Metering of the thermal energy used both on the whole building and on every apartment.

Recycling of heat of exhaust air of systems of ventilation - through the use of heat recovery heat pumps to provide hot water supply.

System of ventilation - mechanical exhaust with natural inflow through autoadjustable air intake devices.

System of hot water supply (HW):

The basic - independent ground coupled heat pump and ventilating emissions of a building, with accumulator tanks of hot water;

Duplicating system --- centralized --- from Central heat point

Type of system - one-zoned with installation of regulators of pressure such as КFRD.

The metering of the charge of hot water - the both on the building and every apartment.

The photograph of the heat pump systems GV is submitted in Figure 4.

Results of the project are given in Table 4 and submitted as a comparison of some design and experimentally received actual parameters of the basic sections of power passports of a base apartment house and of the actual energy effective house as constructed .

Fig. 3. Experimental energy efficient house in microdistrict Nikulino-2

Fig. 4.Heat pump of the heat supply system.

Table 4

BASIC CHARACTERISTICS AND PARAMETERS	**MARK**	**UNIT OF MEASUREMENT**	**THE BASE HOUSE**		**ENERGY EFFECTIVE HOUSE**	
			THE PROJECT	**EXPERIMENT**	**THE PROJECT**	**EXPERIMENT**
1	**2**	**3**	**4**	**5**	**6**	**7**
2.A level of heat –shielding of external protecting desings						
2.1 Resistance to a heat transfer:						
- Walls;	R^r_w	м2 ^{o}C/Wt	2,56	2,56	3,28	3,28
- Windows and balcony doors;	R^r_F	м2 ^{o}C/Wt	0,55	0,55	0,6	0,6
- Coverings, attics overlappings (blockings);	R^r_c	м2 ^{o}C/Wt	3,30	3,3	4,39	4,39
- Overlappings (blockings) above cellars and undergrounds ;	R^r_f	м2 ^{o}C/Wt	2,80	2,8	4,27	4,27
- Overlappings (blockings) above prodrivings and under bay windows.	R^r_f	м2 ^{o}C/Wt	-	-	1,63	1,63
2.2. Overall heat transfer factor	K^r_m	Wt/(м2 ^{o}C)	0,72	0,75	0,496	0,496
3. Power loadings of a building						
3.1 Power consumption						
The equipment:						
- heating;	N_o	KWt	362,5	388,6	379	370
- HW with heat pumps installations (HPI);					90	83
- hot water supply;	$N_{гв}$	KWt	453,6	723,3	-	-
- electrosupply;	$N_э$	KWt	474,0	474,0	474	474
- other systems (fans, electric drive)	$N_Д$	KWt	-	-		11
3.2. Average daily consumption :						
- natural gas ;	$Q_{пг}$	м^3/daily	-		-	
- cold water;	$Q_{хв}$	м^3/daily	135,5	21,73	135	

- hot water.	$Q_{гв}$	м^3/daily	35,0	17,8,0	35	30
4Power consumption of a building						
4.1. Annual charges of power resources on building (inhabited part of a building):						
-thermal energy for heating in cold and transitive periods of year;	Q^r_h	MWt*h/year	1059	1008	577	560
- thermal energy for hot water supply ;	$Q_{гв}$	MWt*h/year	1061	650	-	-
- thermal energy of other systems (separately);	-	MWt*h/year	-	-	-	-
- electric energy;	Э	MWt h/year	814,3	524,4	1016	1033
Including:						
- common house illumination ;	$Э_o$	MWt h/year	62,03	47,5	62	62
- in apartments;	$Э_к$	MWt h/year	323,8	203,4	324	324
- for the power (force) equipment and HPI,	$Э_c$	MWt h/year	182,5	27,3	384	430
- for water supply and the water drain;	$Э_в$	MWt h/year	195,5	195,0	195	166
- for heating;	$Э_{отопл}$	MWt h/year	51,2	51,2	51	51
4.2. Specific annual charges power resources Per m2 of the area of apartments:						
-thermal energy on heating in cold and transitive the periods of year;	q^y_h	кWt*h/м2 year	162	154	87,6	85,0
- thermal energy on hot water supply ;	$Q_{гв}$	кWt*h/м2 year	162,1	99,3	-	-
- thermal energy of other systems (separately);	-	кWt*h/м2 year	-		-	-
- electric energy;	$Q_э$	кWt h/м^2 year	124,5	80,1	132,4	157
Specific operational power consuption of a building (the generalized parameter of the annual charge of fuel and energy resources per m2 of the area of apartments)	q^y	KWt*h/ (м2*year) кг у.т./ м^2*year	448,6 55,1	333,4 40,9	220 27	242 30
ENERGY SAVING in comparison with the base house (project)		**%**	**0**	**-**	**50**	**45,5**

3.TECHNICAL AND ECOLOGICAL ASPECTS OF THE RATIONAL INTEGRATION OF GHPS INTO THE POWER BALANCE OF RUSSIA

We consider the opportunities presented by the possible integration of GHPS into the existing power supply systems by using the example of the municipal economy of Moscow. Today the basic fuel for the system of power supply of Moscow is natural gas. The city annually consumes 29 billion m3 of natural gas. Moscow is a net exporter of electric energy With up to 20% of developed electric energy being transferred from the capital to the Federal wholesale market.In Table 5 the integrated estimated potential of nonconventional energy sources is presented from the point of view of their possible contribution to power balance of city. The figures presented in Table 5 are based on the following data and assumptions:

- Housingstock of Moscow - 180 mill.sq. meters or 40 thousand apartment houses;
- Number of inhabitants -10 million person;
- For using solar energy on a roof of each of apartment or house solar collectors are established by the area of 300 sq. meters;

The potential of energy recovered from ventilation discharge was determined at the rate of its recyclings over 6000 hours per year;

Sewer drains of city accept 400 litres per person per day with cooling in the system of recycling of 5 degrees, time of use of 6000 hours per year;

- Cooling water in system of recycling of heat of the river of Moscow - 1 degree, amount of hours of use - 6000 hours per year.

The data submitted in Table 5 shows that the potential of nonconventional energy sources is high , and they could displace a significant part of the traditional power resources in the city's power balance. The serious advantage, of the new technologies using nonconventional renewable energy sources, is not only their power efficiency, but also their ecological "cleanliness". Today in the area of the city up inadmissible limits of air, ground and vegetation pollution are occurring. In many areas there are low efficiency boiler-houses with high emissions of polluting substances. Existing engineering networks, as a rule, are not in very good condition. The cause of these problems is connected by traditional way to significant investments from the city budget, and sometimes it is simply impossible, in connection with ecological and technical consequences of manufacture of works on a lining or reconstruction of engineering networks.

The basic supplier of thermal and electric energy to consumers of the Moscow region is JSC" Mosenergo ". The extent of thermal distribution thermal highway is 2387,12 km, including water. 2349,66 km and steam. 37,46 km. The connected thermal loading of consumers at the beginning of 2001 was 30485,1 Gcal/h. The heat transfer losses in 2001 was made 8,74 %.

In Table 6. the structure termo input from thermal power station, and in Table 7 the electric balance of the Moscow region is presented.

In Table 8 the existing and future (developments of city authorized by the General plan) thermal and electric loadings of Moscow are presented.

Table 5. An energy potential of nonconventional sources

ENERGY SOURCE	**Billion . кWt*h In one year**	**SHARE IN POWER BALANCE of CITY,%**
1.TRADITIONAL POWER RESOURCES		
Natural gas	290	96
Black oil	8,7	2,7
Coal	4,3	1,3
TOTAL on item 1.	303,0	100
Including:		
Electric energy	80	26,4
Thermal energy	223	73,6
2. NONCONVENTIONAL POWER RESOURCES		
Solar energy	12,0	4,0
Energy of ventilating emissions of inhabited and public buildings.	27,0	8,8
Waste heat of sewer drains	40	13,0
Waste heat of underground.	4,0	1,2
Recycling low potential heat of the river of Moscow.	84	27,4
Ground of superficial layers of the Earth	140	45,6
TOTAL on item 2.	307	100

Table 6.

THERMAL INPUT FROM THERMAL POWER OF THE MOSCOW REGION IN 2001 Y.		
THE NAME OF THE PARAMETER	**UNITS OF MEASUREMENTS**	**QUANTITY**
Extent of heat transmission system	км	2 387,12
The thermal loading of consumers attached to thermal power station by the beginning of 2001.	MWt	35454,1
The technological charge (losses) on transfer energy.	**%**	8,74
Useful throughput of heat to the consumer	mill.кWt*h	78386,2
Own consumption, including: Moscow The Moscow area	mill.кWt*h	78 386,2 73996,5 4389,6

Table 7.

ELECTRIC BALANCE OF THE MOSCOW REGION OF 2001 Y.		
THE NAME OF THE PARAMETER	**UNITS OF MEASUREMENTS**	**QUANTITY**
Manufacture of the electric power	mill.кWt*h	71 352,6
The charge on own needs	mill.кWt*h	5 613,9
The technological charge	mill.кWt*h	9 148,3
Industrial needs	mill.кWt*h	2 766,5
Purchase from blocks-stations	mill.кWt*h	130,3
Useful throughput of the electric power	mill.кWt*h	53 954,2
Own consumption, including: Moscow The Moscow area	mill.кWt*h	54 087,5 29 866,9 24 220,6
Reception from FWEPM (Federal Wholesale Electric Power Market)	mill.кWt*h	133,3

Table 8

TECHNICS – ECONOMIC PARAMETERS	1999 г	A VARIANT GENERAL PLAN for 2020 y.
Electric loading, MWt	6700	9500
Thermal loading, MWt	44900	57200
Share of electric loading, %	13	14

Having analysed the data on loadings and the structures of the thermal and electric balances of the the Moscow region, it is possible to draw a conclusion **that the structure of manufacture and consumption of energy in Moscow region is not rational:**

-Firstly, about 50 % of the capacities located in Moscow do not supply electric energy to Moscow consumers (the Moscow region and so forth). Thus ecologically damaging manufacture of electric energy is carried out in Moscow, while a significant part of the non-polluting product: electric energy - is consumed outside the city;

-Secondly, about 12 % of the thermal load of the city is delivered through direct burning of primary fuel on Region Power Station, instead of using the combined cycle;

-Thirdly, daily and seasonal schedules of power loadings of the city are not sufficiently coordinated with power opportunities offered by the combined manufacture of thermal and electric energy.

The power resources necessary for the city under a recently authorized general plan for the development of Moscow are as follows:

2005 :electric loading -12,8%, thermal loading -87,2 %;

2020 - electric loading -14,3 %, thermal loading -85,7 %.

Energy generation equipment on thermal power station using the combined cycle currently deliver ~40 % of electric energy and 60 % - thermal. In the long term, with the introduction of new power stations (they already exist in other countries) this ratio will come nearer to 50/50, i.e. the thermal power station can develop 50 % of electric energy and 50 % thermal. The result of this will be that the city will be compelled to give part of its electric energy to European Economic Community (integrated power grid). This will again mean that Moscow will be burdened with ecologically damaging generation of electricity, while other areas of the European Community will benefit from using “clean” electricity exported from the city. Clearly, this situation needs to be corrected, and possible ways of its correction can be:

Application of the new power technologies using nonconventional energy sources;

New tariff politics of city on power resources.

In Table 9. results of the integrated technical and economic comparison of traditional and "heat pump" variants of heat supply for Moscow in 2020 are submitted.

This comparison of was carried out using the following basic assumptions:

1. Cost of 1 ton of conditional fuel US $100 .

2. Capital investment in 1 kW of the conventional equipment (District Heat Station, individual gas boiler-houses and so forth US$100 without taking into account capital investments in thermal networks;

3 Capital investmentsin 1 kWt of thermal capacity HPS – US$ 250 switching US$ 50 in system of gathering low potential heat.

Thus fundamental investment in HPS are provided without costs for the city budget only due to investors of built and reconstructed objects.

4. The mid-annual factor of transformation HPS is accepted equal 3,5.

Table. 9

TECHNICS – ECONOMIC PARAMETER	VARIANT	VARIANT 2 HPS
1	**2**	**3**
1.Capacity of the established equipment , мWt: - Electric equipment ,including: - The heat pumps; - The thermal equipment ,: including: - The heat pumps. -тепловые насосы.	**66 700** **9 500** **-** **57 200** **-**	**66 700** **14 500** **5 000** **57 200** **17 500**
2. Economy of power resources , -million мWt*hours in one year; -million tons of conventional fuel year one year.	**-** **-**	**32,25** **3,84**
3. Capital investments in system of heat supply , million. US$: - from city sources (District Heat Station, boiler and so forth) ; - from out of budget sources in heat pump equipment (means of customers of buildings).	**1230** **-**	**-** **4375**
4. Saving of operational expenses in municipal economy on purchase of primary fuel , million US$ on one year эксплуатационных затрат в городском хозяйстве на приобретение первичного топлива, млн. $ США в год.	**-**	**384**

In carrying out of calculations of the winter mode, the duration of the heating period of 5000 hours was considered used , thus the average thermal loading both on traditional heat giving out equipment, and on HPS was accepted as being 0,5 from the loadings given in Table 4.

Thus, the introduction of the technologies using thermal heat pumps, in the municipal economy of Moscow will allow to provide a necessary gain till 2020 capacities due to out of budget sources means , not increasing thus of consumption of primary fuel (natural gas).

TARIFF STRATEGIES

The most important lack of an existing tariff strategy is that current fuel tariffs do not reflect the technological essence of manufacture of energy, both on quality, and by amount. The subject of market effects on the amount of the consumed energy, and the delivery of capacity at a determined time is not simple. In the market of power services two kinds of power production should be catered for:

a) An opportunity for the use of declared power capacity at a given certain time;

b) Amount of consumed energy.

Thus methodologicalally there is no basic difference, on what kind of energy services - thermal or electric rendered.

The current pricing policy does not reflect quality of energy on time. So, for a boiler-house there is no basic difference as to when it is operated - in the summer or in the winter. If in the summer for hot water supply it is possible to use the waste heat acting on thermal power station , in the winter for heating habitation of fulfilled heat any more does not suffice, and it is necessary to spend additional primary energy sources. If in the summer warmly at thermal power station will not buy, it all the same warmly will throw out it in an environment, or will simply stop in the compelled reserve for the lack of thermal consumption. Besides for the sake of simplicity of calculations not concrete tariffs for characteristic modes of power supply, and the average, mid-annual tariffs on region today are determined. Though the mid-annual price of heat at thermal power station is lower than at boiler-house, all the same it does not stimulate industrial buyers of thermal energy to go on not burning fuel on the boiler-houses and under the mutually beneficial price to use waste heat from thermal power station.

The radical mistake in , the existing method of pricing of power resources is the absence from the tariffs of ecological consequences of burning fossil fuel.

Burning various kinds of traditional organic fuel yields different amounts of combustion products. use of natural gas on 1 normal м3 fuel, 2 kg CO_2 are formed, and in burning black oil - 3 kg CO_2 on 1 kg of fuel.

Heating capacity of 1 thousand normal m3 gas makes 9,239 MWt*h energy, and 1t black oil - 11,046 MWt*h.

It is known, that 1 hectare of a wood absorbs in a year from 3 to 5 tons of carbonic gas. Thus, 1 ha woods it is capable of swallowing up in one year products of combustion of 1,5-2,5 thousand normal м3 gas the burning of which can produce 13,9-23,1 MWt*h energy, or, using black oil, quantity{amount} CO_2 which will turn out at burning 1-1,7 т black oil, that in a power equivalent makes 11-18,4 MWt*h.

From here it is possible to draw a conclusion, that 18 MWt*h (burning of 2,2 tons of conventional fuel) energy in one year (average on gas quantity) **the non-polluting way which is not providing processes of burning, on influence on an environment is equivalent to planting 1 hectare a "virtual" wood.**

We shall try to determine, the value of planting 1 hectare of vegetation in Moscow based on the

« Technique of estimation of cost of green plantings and calculations of the size of damage and the losses caused by their damage and (or) destruction in territory of Moscow » authorized by the Order of Mayor of Moscow from May, 14, 1999 N 490-PM.

The valid regenerative cost of city woods and other natural vegetative communities is determined by considering basic elements of the natural ecological system . That is, natural vegetative communities are estimated, as uniform ecological system (a natural complex) through a cumulative cost estimation a layer ground and, actually vegetation: alive a cover, bushes and trees, and also expenses in which expenses enter: on protection of territory; on an accomplishment and cleaning of territory and to care of plantings.

Taking into account, that in our case there is a speech about "virtual" wood plantings received compensation cost 1 ha a "virtual" city wood actually and is economic benefit which receives municipal economy from reduction of environmental contamination by products of combustion of traditional organic fuel.

Thus, the economic damage from environmental contamination at burning one ton of conditional fuel can be determined as:

$у_{экт}$ = 100000/2,2 = 45500 rouble from 1 ton of the burnt conditional fuel

In recalculation on kWth:

$у_{экт}$ = 100000/18000 = 5,5 rouble from 1 кWt*h the burnt organic fuel

Or

0,18 $ the USA from 1 кWt*h the burnt organic fuel

The derived values of economic damage from environmental contamination from burning traditional fuel would be useful for including **as an ecological component in tariffs for thermal energy at the development stage of any new building Project in Moscow.**

For illustration of the influence of an ecological component in tariffs for thermal energy for a configuration of a complex city system of power supply + a building + a climate, numerical experiments have been carried out using the example of the hypothetical construction of a new residential area of Moscow consisting of 1000 **(N)** of base residential buildings, with the common area of apartments (S_{com})-7 mill.sq.meter and number of inhabitants - 300 thousand persons.

In Table 10 the basic data used in carrying out the calculations are given. Some of the data has been taken from design specific cost indexes of a system of power supply of the experimental area "Kurkino".

Table. 10.

PARAMETER	UNITS	QUANTITY (AMOUNT)
1	**2**	**3**
Quantity of base buildings in considered area, **N.**	**Buildings**	**1000**
The general area of Buildings , **S** $_{общ}$**.**	**Sq.m**	**7000000**
The area of a heat –shielding environment of a base house, $F_{об}$.	**Sq.m**	**5400**
Loading on system of ventilation of a base house , $q_{рв}$.	**kWt**	**270**
Settlement loading on system of hot water supply of a base house, $q_{ргв}$.	**kWt**	**560**
Loading on system of electrosupply of a base house , $q_{рэ}$.	**kWt**	**490**
Specific capital investments in 1 kW of electric capacity of thermal power station , $k_э$.	**$US**	**860**
Specific capital investments in 1 kW of electric capacity of thermal power station , $k_г$.	**$US**	**112**
Specific capital investments in 1 kW of throughput of devices of electrosupply, **пэ.**	**$US**	**209**
Specific capital investments in 1 kW of thermal networks, **птс.**	**$US**	**60,00**
Specific capital investments at 1m3/hour of gas networks, **пгс.**	**$US**	**313**
Cost of construction 1 м2 the heated area of base house, $C_б$.	**$US /m2**	**500**
Ecological damage from environmental contamination at burning one т. у. т.,$У_{экт}$.	**$US/conditional fuel**	**0,00**
Specific cost (counting upon 1 sq.meter of the heated area) increases on 1sq.meter cover *oC/W the generalized resistance to a heat transfer (R_{cover}) a heat –shielding environment of building $C_{ут}$ *).	**($US/$_{м2от. пл}$)* W/ ($m^2{}_{cover}$*oC)**	**30,00**
The tariff for thermal energy , **Ct .**	**$US/кWth**	**0,05**
The tariff for electric energy**, Cel .**	**$US/кWth**	**0,08**

) –depending on type of isolation of protections $C_{ут}$ can change in limits from 4 ($US/м^2 $_{от.пл}$) (Wt/(м^2 $_{cover}$*^{o}C) for multi-storey new construction up to 30 ($US/м^2 $_{от.пл}$)* (Wt/(m^2 $_{cover}$*^{o}C) – for reconstruction.

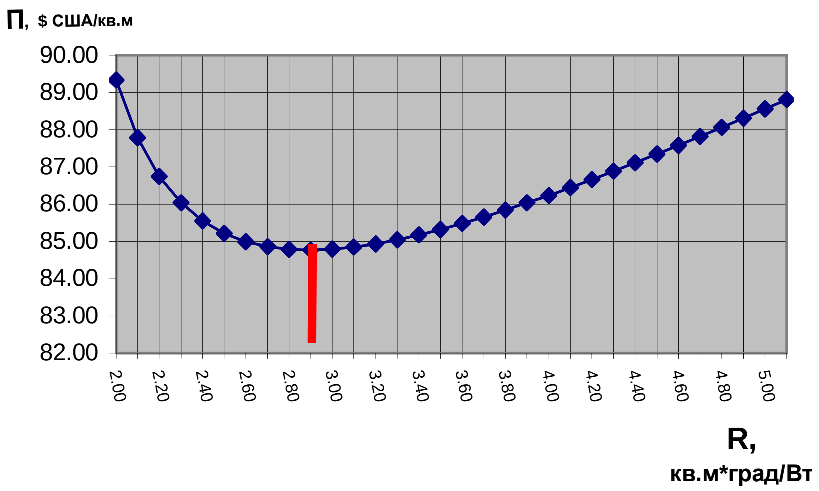

Fig. 5. Dependence of expenses П on construction and operation of 1 sq. meter of the heated area of a base house from the generalized resistance to a heat transfer of heat-shielding environment R $_{cover}$.

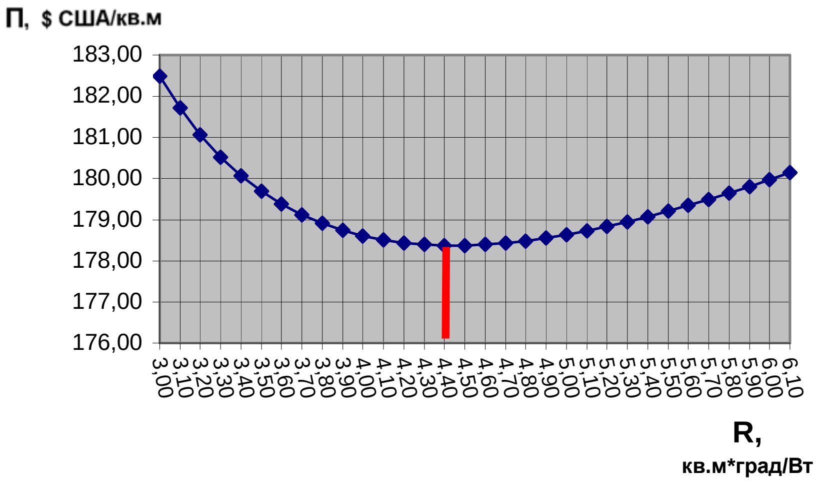

Fig. 6. Dependence of resulted expenses П on construction and operation of 1 sq. meter of the heated area of a base house from the generalized resistance to a heat transfer of heat-shielding environment $R_{cover.}$

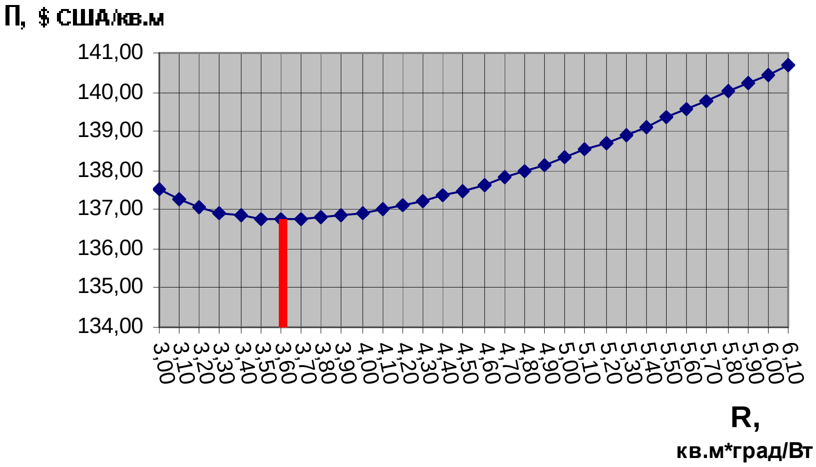

Fig. 7. Dependence of resulted expenses П on construction and operation of 1 sq. meter of the heated area of a base house from the generalized resistance to a heat transfer of heat-shielding environment using heat pumps to deliver thermal heat R $_{cover}$

In Figure 5 results of the first numerical experiment showing dependence of construction and operation costs of 1 sq. meter of the heated area of a base house on the overall generalized resistance to heat loss R_{ob} are submitted. Normal efficiency of capital investments $_{(Ен?п)}$ is accepted as being equal to 10 % one year. In this experiment the cost of energy carriers is accepted at perspective **Ct = 0,05 $US/kWth**, and **Cel = 0,08 $US/kWth.** The ecological damage from environmental contamination of burning one ton of conventional fuel **is taken as 0**, and the specific cost of increase on 1m^2 cover the generalized resistance to heat transfer of a heat-shielding environment of building $С_{ут}$ **is taken as 30,0 ($US/m2 $_{от.пл}$) * (W / (m2 $_{cover}$ ^{*o}C).** The red line on the graphs marks the point at which the overall resistance to heat transfer results in the minimum construction and operational costs.

Experiment 1: Ct = 0,05 $US/кWth, C_{el} = 0,08 $US/кWth, Уес= 0, Сут = 30,0 ($US/m^2 $_{от.пл}$) * (Wt / (m2 $_{cover}$*^{o}C).

In carrying out the second experiment the size of ecological damage from environmental contamination has been changed to reflect the environmental cost of burning one ton of conventional fuel, $_{Уэкт,}$ which is taken as **1450 $ US / т.у.т. (see the formula 2.12)** Results of the second experiment are shown in Figure 6.

Experiment 2: $C_{Т}$ = 0,05 $US/кWth, C_{el} = 0,08 $US/кWth, $У_{ест}$= 1450 $ US / т.у.т., $C_{ут}$ = 30,0 ($US/m2 $_{от.пл}$) * (Wt / (m^2 $_{cover}$*^{o}C).

In carrying out the third experiment the variant was completely similar to the second experiment with a unique change - half of the thermal capacity was developed by thermal heat pumps with an average COP of 3,5. Results of the experiment are submitted in Fig. 7.

Experiment 2:C_t = 0,05 $US/кWth,$C_{el}$ = 0,08 $US/кWth, $У_{ec}$= 1450 $ US / т.у.т. $C_{ут}$ = 30,0 ($US/m2 $_{от.пл}$) * (Wt / (m2 $_{cover}$*oC).

Thus, the results of the numerical experiments demostrate that taking into account an ecological component in tariffs for thermal energy can significantly change the potential impact of new energy efficient technologies when compared to the continued use of conventional fossil fuel technologies. and the equipment.

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