GEOTHERMAL HEAT PUMP SYSTEMS OF HEAT SUPPLY (GHPS): OPERATING EXPERIENCE, TECHNICAL AND ECOLOGICAL ASPECTS OF RATIONAL INTEGRATION INTO POWER BALANCE OF RUSSIA

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KEY WORDS

The thermal pump, system of gathering low potential heat of a ground, thermowell.

ABSTRACT

The report is devoted to the geothermal heat pump systems of heat supply (GHPS) using low potential thermal energy of a ground of superficial layers of the Earth. In the report the natural data on efficiency of long-term operation in soil - climatic conditions of the Russian Federation **of real** objects equipped GHPS, created on technology of JSC " INSOLAR-INVEST " are submitted.
The second part of the report is devoted to technical and ecological aspects of rational integration GHPS in power balance of Russia. Results of analytical researches and « numerical experiments » are submitted according to efficiency of various circuit decisions of integration GHPS in structure of the centralized system of power supply prevailing in the country. Results of researches and a technique of definition of an ecological component in tariffs for the traditional power resources, taking into account the costs of municipal budgets connected to environmental contamination by products of its (organic) fuel of combustion are resulted.

1. INTRODUCTION

Efficiency of use of energy is some kind of the indicator of scientific and technical and economic potential of the society, allowing to estimate a level of its development. Comparison of parameters energy effective with the advanced countries shows economy of Russia, that specific power consumption of our total internal product (gross national product) in some times higher, than in the advanced countries. So, the level energy consumption counting upon unit of comparable gross national product of Russia approximately in 4 times is higher, than in the USA - the country with high installed power per employee of production of goods, sphere of services and a life. The consumption level of the electric power counting upon unit of comparable gross national product in Russia is higher, than in the USA in 2,5 time, Germany and Japan in 3,6 times. All this testifies to significant reserves of economy of power resources in Russia which scales can be estimated approximately in 40-50 % from a level of consumed fuel and energy.
The heat supply with the help of thermal pumps concerns to one of the most perspective directions in area энергосбережения and receives all greater distribution to the world.
For the first time the heat pump system has been offered in 1852 by lord Calvin, but their real application began only in XX century. The practical embodiment heat pump installations (ТНУ) was carried out in parallel with development of the refrigerating technics{technical equipment} close under technical decisions to ТНУ: reliability of machines raised, cost was reduced, the technology of operation of systems with application ТНУ was fulfilled.
The energy crisis of the seventieth years has a powerful spur to development ТНУ. So, for example, in the USA during this period the volume of manufacture of thermal pumps has trebled

and has reached a level of 300 thousand pieces in year, and the common number working ТНУ totals millions pieces. In the eightieth years the level of production and applications ТНУ was stabilized, and then again started to grow from the wave energy save and ecological tendencies of the further development of global power. In Russia, unfortunately, only individual objects equipped with heat pump systems of heat supply (ТСТ) which examples are submitted in this report today are maintained.

2. THE ENERGY EFFECTIVE BUILDINGS EQUIPPED WITH GEOTHERMAL HEAT PUMP SYSTEMS OF THE HEAT SUPPLY

2.1. Demonstration complex "ECOPARK-FILI"

In 1994-1997 for demonstration in natural conditions of operation of new "non-conventional" technologies of life-support of objects of an infrastructure of city parks, in Moscow, in territory of Recreation park "FILI", to the address of B.Filevskaja the street, h.22 have been created demonstration complex "ECOPARK" FILI " (Fig. 1.). The complex has been created by JSC " INSOLAR-INVEST " with assistance park "FILI" and Ministry of Science and Technology of the Russian Federation.



Fig. 1. Demonstration complex "ECOPARK FILI"

Today in the majority of city parks up to inadmissible limits air, the ground and green plantings are polluted. In many parks are maintained низкоэффективные out-of-date local boiler-houses with high emission of polluting substances in an atmosphere. Existing engineering networks, as a rule, are in an emergency condition. The decision of these problems, is connected by traditional way to significant capital investments, and 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, specificity of operational loadings on cultural - leisure objects (seasonal prevalence of operation of attractions, zones of entertainments, objects of a public catering, etc.) opens ample opportunities for use in life-support systems of the mentioned objects of a solar energy as, in most cases peaks of intensity of falling solar radiation and operational loadings on objects synchronize. Use of a solar energy, as in the transformed kind (for example, photo-electric installations and batteries), and in "direct", for example, in solar collectors, allows to provide with the electric power and a heat small independent attractions, boothes, cafe and other objects of a park infrastructure.

The demonstration complex includes technical buildings and two office buildings such as the "Snail", entered in operation, accordingly, in 1994 and in 1997. The General area of buildings of a complex of 1000 m2. The complex is placed in territory by the area 1 ha.

On buildings of a complex the following experimental systems and the equipment are established:
Automated the heat pump systems of heat supply (TCT) using low potential thermal energy of superficial layers of the Earth. These systems equip both buildings such as "Snail". TCT include systems of gathering low potential heat of a ground the general{common} capacity of 40 kWt and 4 heat pump installations АТНУ-15 (the Russian manufacture) (a Fig. 2.) the common heat productivity 60 kW;

- Wind- energy installations by the common capacity of 1-5 kW;
- Photo-electric installations by the common capacity 2 kW - peak. From photo-electric and wind- energy installations partial electrosupply of internal and external illumination of objects of a complex is carried out.

Results of monitoring of a thermal mode heat pump systems of a heat supply and buildings as a whole are submitted in table 1. That fact is rather essential, that at an estimation of power efficiency of buildings of a complex all power inputs of buildings were taken into account: energy spent for heating, hot water supply, illumination, both office equipment and household needs. Last line of table 1 annual specific consumption of power resources counting upon 1 m2 of the heated area, characteristic for position existing today in housing and communal services is resulted.

Table 1. Results of monitoring of a thermal mode heat pump systems of a heat supply and buildings

THE NAME OF PARAMETERS	UNITS OF MEASUREMENTS	THE BUILDING 1	THE BUILDING 2
Resistance to heat transfer of external protecting designs - Walls; - Windows.	м^2*oC/ Wt	 1,2 0,4	 3,0 0,4
Annual current consumption ,including on: -illumination and household needs; - Hot water supply; - Heating.	MWt*h in one year	143,5 48,0 16,0 79,5	49,8 18,0 12,0 19,8
Specific consumption of power resources counting upon 1 m2/ one year	кWt*h/ м^2 in one year	478	166
Specific consumption of power resources counting upon 1 m2/ one year	Кг с.f./ м^2 in one year	59	20
Specific consumption of power resources counting upon 1 m2 of the heated area one year in housing and communal services	Кг с.f./ м^2 in one year	100	

2.2. Energy effective rural school in the Yaroslavl area

In September, 1998 in village Filippovo of area Ljubimskogo of the Yaroslavl area the rural school equipped with heat pump system for heat supply (TCT) has been entered into operation. Actually it is the rural school first in Russia equipped with heat pump system for heat supply, using low potential warm a ground of superficial layers of the Earth (See Fig. 2). The technology of a heat supply of school has been developed by JSC " INSOLAR-INVEST ", the heat pump

equipment has been made and mounted « The Rybinsk factory of instrument making », designing of school is carried out by JSC «Iyroslavgragdanproect» .



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

The building of school represents a two-storeyed brick structure from a silicate brick area ~ of 2000 m2 in volume ~ of 6900 m3 with thickness of walls 640-680 mm, the area window and doorways ~230 m2 and ~ 20 m2 accordingly. The building has a technical underground and a roof with garret overlapping{blocking}. School it is located on surburb village Filippovo approximately in 100 km from Yaroslavl also it is designed for 162 pupils and 20 teachers. In table 2 settlement loadings on life-support systems of school are resulted.

Table 2. Settlement loadings on life-support systems of school

THE NAME OF PARAMETER	QUANTITY
Settlement heat loss buildings, кW.	**130**
The daily average charge of thermal energy of hot water supply, кWh.	**162**
The peak hour charge of hot water, м^3/h.	**1,1**
Brought to a building of school electric capacity, кW.	**96**

The major factor, which has actually determined technology of a heat supply and configuration TCT of school, significant deficiency of free electric capacity in the afternoon day was. At designing as alternative TCT the direct electroheating comparable to thermal pumps on ecological parameters was considered. However, electroheating could not be applied in connection with deficiency of 40 kWt, the brought electric capacity. In a result, the system of a heat supply as much as possible entered in the daily schedule of a power consumption of school, and using electric capacities liberated in the night and the night tariff for the electric power for accumulation of thermal energy in water tanks – accumulators.

As a source of thermal energy of low potential for evaporators of thermal pumps the ground of superficial layers of the Earth is used.

TCT it is located in separately worth building of thermal item which was earlier planned for accommodation of coal boiler-house. In the same building in a ground floor the refrigerating chamber for the school dining room, cooled from heat pump installations is placed. The heat pump system for a heat supply of school is maintained already during four cold seasons. Annually, before

the beginning of a cold season, experts «The Rybinsk factory of instrument making » spend out procedural works, and monthly during the heating period - control surveys of the working equipment. Besides the thermal unit is equipped with the instrumentation (thermal and electric counters) with which help constant monitoring operational modes TCT of school is conducted.

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

Table 3. Results of monitoring of operation TCT of school

THE NAME OF PARAMETERS	On October 5, 2001– on November 4, 2001	On 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 ГВ, 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 ГВ, %.	45	31
Operating ratio of thermal capacity АТНУ, shares of unit .(calculation on day time tariff).	0,44	0,8
Operating ratio of thermal capacity of ТЭНs БА , shares of unit .(calculation on night time tariff)	0,478	0,710
The electric power spent for a drive 8АТНУ+ЦН, кWt *h.	10339,0	113299,2
Factor of transformation *АТНУ +ЦН (without ТЭНs БА), 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/r.м.	182	126

In table 3 the following marks :АТНУ - automated heat pump installations are applied; ЦН - circulating pumps; БА - tanks - accumulators; ГВ-hot water supply; ТЭН – heating resistance tanks of the accumulators, working in a night mode.
Apparently from the data submitted in table 2, the heat pump system of a heat supply of school provides economy of energy from 30 up to 45 % that has allowed to save for four years of operation about 60 tons of conditional fuel.

2.3. Energy effective the habitable house in Moscow in microdistrict Nikulino-2

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

The purpose of the project was creation, natural approbation and the subsequent introduction in housing construction of city of the newest technologies and the equipment, **power inputs** providing, at least, **double decrease on operation of an available housing.** Here it is necessary to note, that the project has started in 1998 in this connection, the expected economy of energy was estimated in comparison with the buildings constructed on working on that moment МГСН 2.01.94, and corresponding to requirements the first (1) of a stage of transition of a new level of a heat-shielding of external protecting designs.

A base series for realization of the project had been chose a typical series of apartment houses of 111-355 Ministries of Defence of Russia, as most full meeting the requirements energy effective, 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. MO it is developed by 53 Central project institute of the Ministry of Defence of Russia and it is coordinated when due hereunder for mass construction in territory of the Russian Federation.

Experimental energy effective the habitable house (see. the Fig. 3) have been constructed and entered into operation in 2001 to the address: Moscow, microdistrict Nikulino-2, street of Academician Anokhin, д. 62 also 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 heater 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 threefold glass in wooden bindings in accordance with GOST 16289-80.

System of heating-two-pipe .

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

The account *of the charge* of thermal energy on heating - the common on a building and every apartment.

Recycling of heat of exhaust air of systems of ventilation - through a heater with use heat pumps installations (ТНУ) of system of hot water supply.

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

System of hot water supply (ГВ):

The basic - independent heat pump with use low potential heat of a ground and ventilating emissions of a building, with tanks accumulators of hot water;

Duplicating - centralized - from ЦТП.

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

The account of the charge of hot water - the common on a building and every apartment.

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



Fig. 3. Experimental energy effective the habitable house in microdistrict Nikulino-2

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Fig. 4.Heat pump of the heat supply system

Results of the project «Energy effective experimental the habitable house in micro-district «Nikulino-2» are tabulated 6 and are submitted as comparison of some design and experimentally received actual parameters of the basic sections of power passports of a base apartment house and energy effective constructed.

Table 4. Results of the project «Energy effective experimental the habitable house in microdistrict «Nikulino-2»

THE 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. The resulted resistance to a heat transfer:						
- Walls;	R^r_w	м2 °C/Wt	2,56	2,56	3,28	3,28
- Windows and balcony doors;	R^r_F	м2 °C/Wt	0,55	0,55	0,6	0,6
- Coverings, attics overlappings (blockings);	R^r_c	м2 °C/Wt	3,30	3,3	4,39	4,39
- Overlappings (blockings) above cellars and undergrounds ;	R^r_f	м2 °C/Wt	2,80	2,8	4,27	4,27
- Overlappings (blockings) above providings and under bay windows.	R^r_f	м2 °C/Wt	-	-	1,63	1,63
2.2. The resulted factor of a heat transfer of a building.	K^r_m	Wt/(м2 °C)	0,72	0,75	0,496	0,496
3. Power loadings of a building						
3.1 Power consumption of systems engineering The equipment:						
- heating;	N_o	KWt	362,5	388,6	379	370
- ГВС with heat pumps installations (ТНУ);					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 the electric drive)	$N_Д$	KWt	-	-		11
3.2. Average daily charges:						
- 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

4. Parameters of power consumption of a building						
4.1. Annual charges of power resources on building (inhabited part of a building):						
-thermal energy on heating in cold and transitive the periods of year;	Q^{r}_{h}	MWt*h/year	1059	1008	577	560
- thermal energy on 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:						
- on common house illumination ;	$Э_{о}$	MWt h/year	62,03	47,5	62	62
- in apartments;	$Э_{к}$	MWt h/year	323,8	203,4	324	324
- on the power (force) equipment and ТНУ,	$Э_{с}$	MWt h/year	182,5	27,3	384	430
- on water supply and the water drain;	$Э_{в}$	MWt h/year	195,5	195,0	195	166
- on heating;	$Э_{отопл}$	MWt h/year	51,2	51,2	51	51
- natural gas.	-	M^3/year	-	-	-	-
4.2. Specific annual charges power resources counting Upon 1 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 consumption of a building (the generalized parameter of the annual charge of fuel and energy resources counting upon 1 $м^2$ of the area of apartments)	q^{y}	KWt*h/ (м2*year)	448,6	333,4	220	242
		кг у.т./ $м^2$*year	55,1	40,9	27	30
ECONOMY of ENERGY in comparison with the base house (project)		**%**	**0**	**-**	**50**	**45,5**

3.ТЕХНИЧЕСКИЕ AND ECOLOGICAL ASPECTS OF RATIONAL INTEGRATION (GHPS) IN POWER BALANCE OF RUSSIA

Let's consider opportunities of integration GHPS in existing power supply systems by the example of municipal economy of Moscow. Today the basic fuel of system of power supply of Moscow is natural gas. The city annually consumes 29 billion cub meters of natural gas. Thus Moscow is superfluous region on manufacture of electric energy. Up to 20 % of developed electric energy the capital transfers to the Federal wholesale market electric capacities (Federal Wholesale Electric Power Market) and in the Moscow area. In table 1 the integrated estimation of potential of non-conventional energy sources is submitted from the point of view of their possible contribution to power balance of city. In a basis of the settlement data submitted in table 5., the following basic data and assumptions:

- A housing fund of Moscow - 180 mil.sq. meters or 40 thousand apartment houses;
- Quantity of inhabitants 10 million person;
- For recycling a solar energy on a roof of each of apartment houses solar collectors are established by the area of 300 sq. meters;

The potential of energy discharge of ventilator was determined at the rate of its recyclings within 6000 hours per one year;

- Sewer drains of city are accepted 400 litres on the person in day with cooling in system of recycling on 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.

Table 5. An energy potential of non-conventional sources

THE NAME of the ENERGY SOURCE	Billion . кWt*h In one year	The 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	140	45,6
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	40	13,0
TOTAL on item 2.	307	100

The data submitted in table 5 evidently show, that the potential of non-conventional energy sources is high enough, and they can quite replace with success a significant part of traditional power resources in city power balance. Besides the serious advantage, the new technologies of life-support using non-conventional renewed energy sources, is not only their power efficiency, but also their ecological "cleanliness". Today in territory of city up to inadmissible limits air, the ground and green plantings are polluted. In many areas are maintained low effective boiler-houses with high emission of polluting substances in an atmosphere. Existing engineering networks, as a rule, are not in very good condition. The decision 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 OS " Mosenergo ". Extent of thermal highways makes 2387,12 km, including water. 2349,66 km and steam 37.46 km. The attached thermal loading of consumers has made to the beginning 200130485,1 Gкal/h. The technological charge (losses) on transfer of thermal energy in 2001 has made 8,74 %.

In table 6 the heat supply structure from thermal power station, and in table 7 electric balance of the Moscow region is resulted.

Table 6. The heat supply structure from thermal power station

THERMAL INPUT FROM THERMAL POWER OF THE MOSCOW REGION IN 2001 Y.		
THE NAME OF THE PARAMETER	**UNITS OF MEASUREMENTS**	**QUANTITY**
Extent of thermal highways	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

Таблица 7. electric balance of the Moscow region

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

In table 8 are submitted existing and perspective (the developments of city authorized by the General plan) thermal and electric loadings of Moscow.

Table. 8 Existing and perspective thermal and electric loadings of Moscow

NAME OF 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 thermal and electric balances of the Moscow region submitted in tables of the given unit, it is possible to draw a conclusion **that the structure of manufacture and consumption of energy in Moscow region is not rational:**

First, about 50 % the capacities located in Moscow provide with electric energy not the Moscow consumers (the Moscow region and so forth). It results to that « ecologically dirty technology » manufactures of electric energy is carried out in Moscow, and the significant part of a non-polluting product: electric energy - is consumed outside city;
Second, about 12 % of thermal loading of city become covered due to direct burning primary fuel on RTS, instead of in the combined cycle.
Daily and seasonal schedules of power loadings of city are not sufficiently coordinated with power opportunities of the combined manufacture of thermal and electric energy.
Really, climatic features of Moscow are those, that the ratio of power resources necessary for city (power loadings of city) under authorized Recently general plan for development of Moscow will make: in 2005 electric loading of-12,8%, thermal loading of-87,2 %;-in 2020 - electric loading of-14,3 %, thermal loading of-85,7 %. Thus, technological opportunities energy generator the equipment on thermal power station are those, that in the combined cycle 40 % of electric energy and 60 % - thermal are developed approximately. In the long term, with introduction парогазовых stations (abroad they already for a long time work) this ratio will come nearer to 50/50, i.e. The thermal power station can develop 50 % of electric energy and 50 % thermal. In a result, the city is compelled (a difference between technological opportunities of the combined cycle and actual electric loading of city) to give a part of developed electric energy in European Economic Community (integrated power grid) that results to that ecologically we carry out not so pure technology of burning of organic fuel in territory of city, and a non-polluting product - the electric power, we deliver for limits of city in European Economic Community. Clearly, that this situation needs to be corrected, and possible ways of its correction can be:
Application of the new power technologies using non-conventional energy sources;
New tariff politics of city on power resources.
In figure 5 the possible circuit of integration of thermal pumps in system of power supply of objects of municipal economy is submitted. The offered variant of a heat supply of Moscow with use heat pump systems of heat supply (TCT) assumes use for a drive of thermal pumps 5000 MWt the established capacities of thermal power station on manufacture of the electric power. Apparently from the figure 5, the offered circuit provides economy of 60 % of primary fuel.
In table 9 results of the integrated technical and economic comparison of traditional and "heat pump" variants of a heat supply of Moscow in 2020 are submitted.
Technical and economic comparison of variants was spent at the following basic assumptions:

Cost of 1 ton of conditional fuel (т у.т.) it is accepted equal 100 $ the USA.

1.Capital investments in 1 kW of the established capacity traditional теплогенерирующего the equipment (RTS), individual gas boiler-houses and so forth) are accepted equal 100 $ the USA without taking into account капвложений in thermal networks;

2.Capital investments in 1 kWt of established thermal capacity TCT are accepted equal 250 $ the USA, switching 50 $ the USA in system of gathering low potential heat. **Thus fundamental investment in TCT are provided without costs for the city budget only due to investors of builded and reconstructed objects.**

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

4.At carrying out of calculations the winter mode with duration of the heating period of 5000 hours was considered only, thus average thermal loading both on traditional heat generating equipment, and on TCT was accepted equal 0,5 from the settlement loadings resulted in the table.

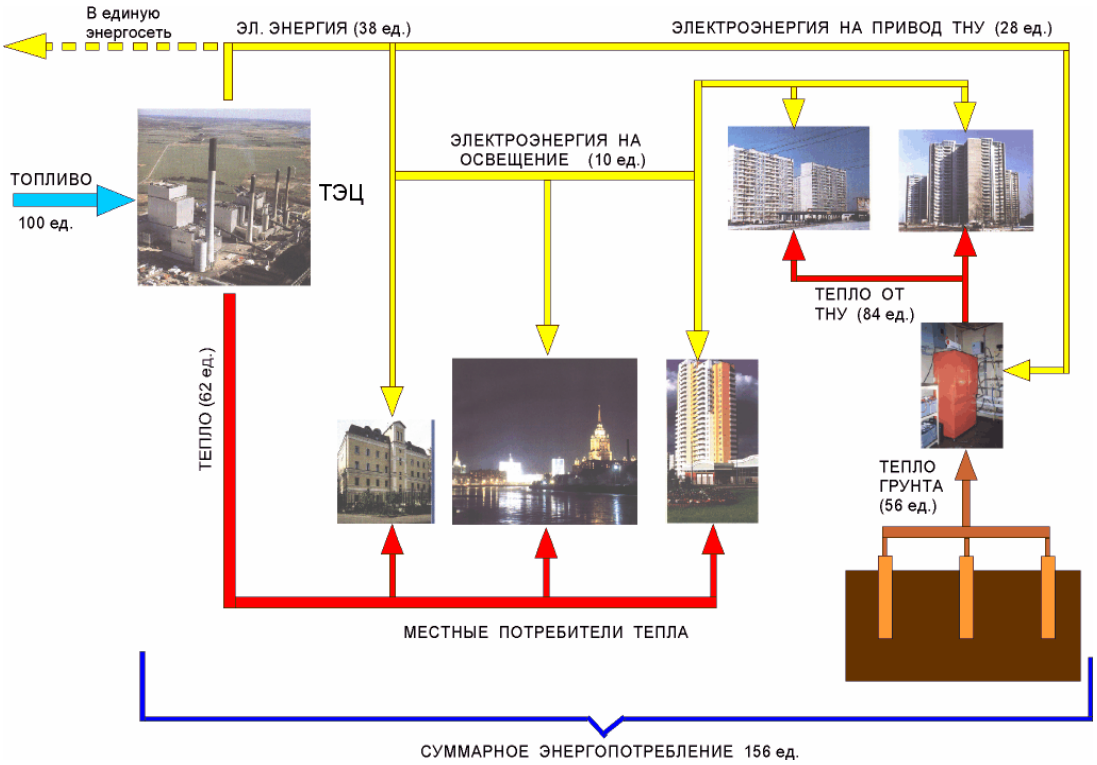


Fig. 5. Possible circuit of integration of thermal pumps

Table. 9 integrated technical and economic comparison

NAME OF TECHNICS – ECONOMIC PARAMETERS	VARIANT THE GENERAL PLAN	VARIANT TCT
1	**2**	**3**
1.Capacity of the established equipment , мWt:	**66 700**	**66 700**
- An electric equipment ,including:	**9 500**	**14 500**
- The heat pumps;	**-**	**5 000**
- The thermal equipment ,: including:	**57 200**	**57 200**
- The heat pumps.	**-**	**17 500**
2. Economy of power resources ,		
- in one million мWt*hours in one year;	**-**	**32,25**
- in one million tons of conditional fuel year	**-**	**3,84**
3. Capital investments in system of a heat supply , one mill. $ the USA:		
- From city sources (RTS), boiler and so forth) ;	**1230**	**-**
- From inappropriate sources in heat pump equipment (means of customers of objects).	**-**	**4375**
4. Economy of operational expenses in municipal economy on purchase of primery fuel , one million $ the USA on one year	**-**	**384**

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

In that, as to a tariff politics on power resources that, first of all it is necessary to note, that the most important lack of an existing tariff politics is that tariffs do not reflect technological essence of manufacture of energy, both on quality, and by amount. A subject of market relations on the amount of the consumed energy, and granting of capacity in determined time should is not simple. On the market of power services it should be given two kinds of power production:

а) An opportunity of use of the declared power capacity during certain time;

б) Amount of the consumed energy.

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

Lack of existing pricing consists that the price does not reflect quality of energy on time. So, if for boiler-house there is no basic difference when it is made warmly - in the summer or in the winter for thermal power station it is essentially various technologies. If in the summer for hot water supply it is possible to use the waste heat acting on градирни 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, an existing method of pricing on power resources full absence of the account in tariffs of ecological consequences of burning of organic fuel is.

At burning various kinds of traditional organic fuel in products of combustion different amount CO_2 is formed. So, at use of natural gas on 1 нм3 fuel 2 kg CO_2 are formed, and at burning black oil - 3 kg CO_2 on 1 kg of fuel.

Heating capacity of 1 thousand нм3 gas makes 9,239 MW*h energy, and 1 т black oil - 11,046 MW*h.

It is known, that 1 hectare of a wood absorbs for a year from 3 up to 5 tons of carbonic gas. Thus, 1 ha woods it is capable to swallow up in one year products of combustion of 1,5-2,5 thousand нм3 gas at which burning can be produced 13,9-23,1 MWt*h energy, or, at use as fuel of 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 reception 18 MWt*h (burning of 2,2 tons of conditional fuel) energy in one year (average on gas size) **the non-polluting way which is not providing processes of burning, on influence on an environment is equivalent to planting 1 га a "virtual" wood.**

Now we shall try to determine, how many there is a planting in Moscow 1 ha green plantings for what we shall take advantage of 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 in view of basic elements 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, shall accept compensation cost 1sq. meter of such "virtual" city wood of equal 10 % from MPOT or a today's price level of-10 roubles for 1 sq. meter. Then, compensation cost 1 ha a "virtual" city

wood will be equal 100000 roubles. Here it is necessary to note, that at definition of this cost the lowest quotations from authorized by the Government of Moscow which besides are reduced in 10 times as the "virtual" wood not in full replaces the true wood plantings (are absent recreational functions and so forth) are actually accepted.
It is obvious, that 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 received values of economic damage from environmental contamination at burning traditional fuel would be expedient for including **as an ecological component in tariffs for thermal energy by development of a stage the Project of new building objects in Moscow.**
For an illustration of 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 by the example of the hypothetical construction of new residential area of Moscow consisting from 1000 **(N)** of base residential buildings, with the common area of apartments (S_{com})-7 mill.sq.meter and settlement amount} of inhabitants - 300 thousand persons.
In table 10 the basic data used at carrying out of calculations are resulted. A part from them have been received from design specific cost indexes of system of power supply of experimental area "Kurkino".

Table. 10. The basic data used at carrying out of calculations

THE NAME OF THE PARAMETER	UNITS OF MEASUREMENTS	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**
Settlement 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**
Settlement 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 , $k_э$.	**$USA**	**860**
Specific capital investments in 1 kW of electric capacity of thermal power station , $k_т$.	**$USA**	**112**
Specific capital investments in 1 kW of throughput of devices of electrosupply, **пэ.**	**$USA**	**209**
Specific capital investments in 1 kW of thermal networks, **птс.**	**$USA**	**60,00**
Specific capital investments at 1m3/hour of gas networks, **пгс.**	**$USA**	**313**
Cost of construction 1 м2 the heated area of base house, $C_б$.	**$USA /sq. м**	**500**

Ecological damage from environmental contamination at burning one т. у. т., $\mathbf{y_{экт}}$.	**$USA/т у т**	**0,00**
Specific cost (counting upon 1 sq.meter of the heated area) increases on 1sq.meter cover *oC/W the generalized resistance to a heat transfer ($\mathbf{R_{об}}$) a heat –shielding environment of building $\mathbf{C_{ут}}$ *).	**($USA/$_{м2от. пл}$)* W/ ($м^2_{оболочки}$*oC)**	**30,00**
The tariff for thermal energy , **Ст .**	**$USA/кWth**	**0,05**
The tariff for electric energy, **Сэл .**	**$USA/кWth**	**0,08**

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

In figure 6 results of the first numerical experiment as 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 its (house) of heat-shielding environment $R_{об}$ are submitted. Thus normative efficiency of capital investments $(Е_{нп})$ is accepted equal 10 % one year. In this experiment cost of energy carriers is accepted at perspective level $С_т$ **= 0,05 $USA/кWth**, and $С_{эл}$ **= 0,08 $USA/кWth.** The ecological damage from environmental contamination at burning one ton of conditional fuel $у_{экт}$ **is accepted equal 0**, and specific cost of increase on 1 $м2оболочки*град/Вт$ the generalized resistance to a heat transfer of a heat-shielding environment of building $С_{ут}$ **is accepted equal 30,0 ($USA/m2 $_{от.пл}$) * (W / (m2 $_{оболочки*оС}$).** The red line on schedules marks economically expedient generalized resistance to a heat transfer of a heat-shielding environment of a building at which resulted expenses **П** for construction and operation of 1 sq. meter of the heated area of a base house **minimal.**

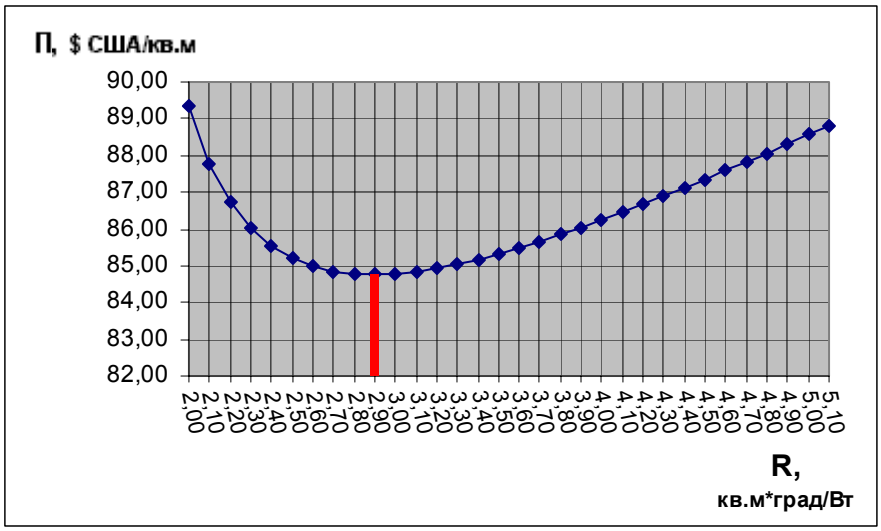


Fig. 6. Dependence of resulted expenses П on construction and operation of 1 sq. meter of the heated area of a base house from the generalized resistance to a heat transfer of heat-shielding environment $R_{об.}$

Experiment 1: $С_т$ **= 0,05 $USA/кWth**, $С_{эл}$ **= 0,08 $USA/кWth,** $у_{экт}$ **= 0,** $С_{ут}$ **= 30,0 ($USA/m2 $_{от.пл}$) * (Wt / (m2 $_{оболочки*оС}$).**

At carrying out of the second experiment the size of ecological damage from environmental contamination has been changed only at burning one ton of conditional fuel, $у_{экт,}$ which have been accepted equal **1450 $ USA / т.у.т. (see the formula 2.12)** Results of the second experiment are submitted in figure 7.

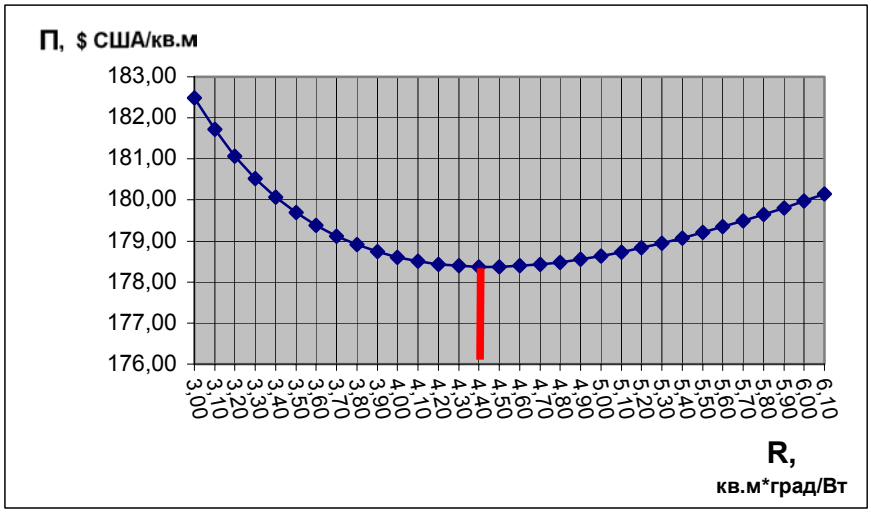


Fig. 7. Dependence of resulted expenses П on construction and operation of 1 sq. meter of the heated area of a base house from the generalized resistance to a heat transfer of heat-shielding environment $R_{об.}$

Experiment 2: $C_т$ = **0,05 $USA/кWth**, $C_{эл}$ **= 0,08 $USA/кWth**, $У_{экт}$ **= 1450 $ USA / т.у.т.**, $C_{ут}$ **= 30,0 ($USA/m2** $_{от.пл}$**) * (Wt / (m2** $_{оболочки*оС}$**).**

At carrying out of the third experiment was the variant completely similar to the second experiment with unique change is considered - half of thermal capacity was developed by thermal pumps with factor of transformation 3,5. Results of experiment are submitted in a Fig. 8.

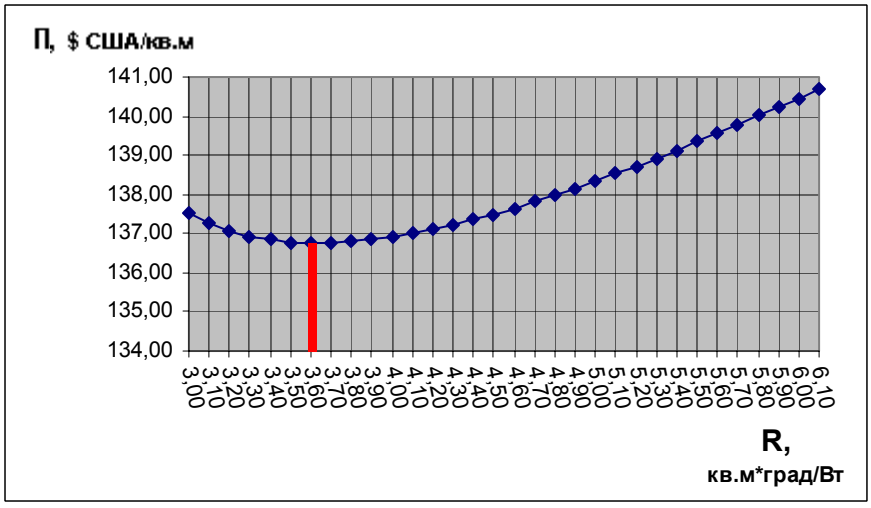


Fig. 8. Dependence of resulted expenses П on construction and operation of 1 sq. meter of the heated area of a base house from the generalized resistance to a heat transfer of heat-shielding environment $R_{об.}$

Experiment 2: $C_т$ = **0,05 $USA/кWth**, $C_{эл}$ = **0,08 $USA/кWth**, $У_{экт}$ **= 1450 $ USA / т.у.т.** $C_{ут}$ **= 30,0 ($USA/m2** $_{от.пл}$**) * (Wt / (m2** $_{оболочки*оС}$**).**

Thus, the submitted results of " numerical experiments » evidently enough testify that the account of an ecological component in tariffs for thermal energy by development of the FEASIBILITY REPORT of new technical equipment and projects of new building objects can

change in the cardinal image the relation to new energy effective technologies and the equipment, and first of all to the systems using non-conventional renewed energy sources.

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