УДК662.621

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GEOTHERMAL ENERGY FOR HEAT PUMPS

Mazkur maqolada, yerning geotermal energetik resursidan foydalanuvchi issiqlik nasoslari ustida olib borilgan izlanishlar natijalari keltirib o'tilgan. O'zbekistonda xo'jalik sohasi eng yirik energiya iste'molchisi bo'lib, uning hisobiga mamlakatdagi umumiy energiya iste'molinig 41 % to'g'ri keladi. Xo'jalik sohasida energiya tejomkorligiga erishish bilan ulkan iqtisodiy va energetik samaradorlikka erishish mumkin. Hozirgi kunda, bu sohada iste'mol qilinayotgan issiqlik energiyasining 80 %, bino va inshoatlarning isitish tizimi va issiq suv bilan taminlash tizimlariga sarflanmoqda [1].

В статье рассматриваются результаты исследования тепловых насосов, использующих геотермальные источники энергии. Показано, что в жилищно-коммунальном хозяйстве потребляется 41 % энергии от общепотребляемого количества энергии по республике. Жилищно-коммунальное хозяйство, представляет собой самый большой и экономически эффективный потенциал для экономии энергии. В настоящее время 80 % тепловой энергии, потребляемой в данном секторе, затрачивается в отопительных системах и в системах горячего водоснабжения зданий.

In this statement, results of observation of heat pumps which use geothermal energy as a source of energy are shown. Energy consumption patterns of Uzbekistan reveal that buildings are the greatest energy consumer, consuming 41% of energy. Buildings represent the biggest and most cost-effective potential for energy savings. At present, heat use is responsible for almost 80% of the energy demand in houses for space heating and hot-water generation.

Recently, renewable energy application technology is becoming an interesting issue in the building sector. In particular, system using natural heat source such as ground heat is receiving great attention due to huge potential. Ground-source heat pump (GSHP) systems use the ground as a heat source to provide space heating and cooling as well as domestic hot-water. The GSHP technology can offer higher energy efficiency for air-conditioning compared to conventional air-conditioning (A/C) systems because the underground environment provides higher temperature for heating and lower temperature for cooling and experiences less temperature fluctuation than ambient air temperature change [2].

The energy from solar radiation and other atmospheric agents is continuously transferred to the surface of the Earth, which causes effects on its temperature in depths close to the surface. The observed soil temperature at various depths has been studied decades ago [3]. Since then, no new theoretical approaches in this field are found in literature, but obviously what has evolved with technological advancement are measuring systems and data processing. It is well known that the typical annual cycles of monthly average soil temperatures at the surface and at depths close to the surface, follow a pattern of easy fit to a simple harmonic.

But, as the depth increases annual fluctuations in soil temperature are diminishing and it is getting closer to the annual average of the place. In the real world, and for a practical case, in depths between the surface and about 10 m, the temperature of the soil varies depending on the depth and anything that disturbs the type, compactness and uniformity of the ground and of course moisture or groundwater (anything that changes the ground thermal conductivity).

There has been evaluation soil temperature at different depth for Tashkent region climate conditions using numerical modeling [4] and results are shown in Fig1.

The Fig1. illustrates the monthly average temperature of soil at five different points relatively surface and ambient temperature. It is easy to see that the deeper into ground the less effect of ambient temperature to soil temperature and approximately deeper than 10 m the temperature of the soil almost the same all over the year (without fluctuations).

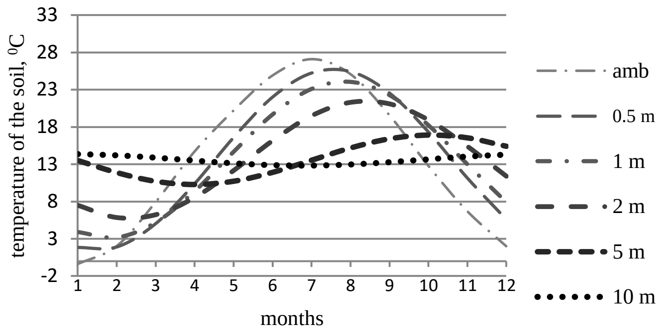

Fig1. Temperature of the soil at different depth

A heat pump (HP) is a thermal installation that is based on a reverse Carnot thermodynamic cycle (consumes drive energy and produces a thermal effect). Any HP moves (pumps) heat from a source with low temperature to a source with a high temperature, consuming the drive energy. The heat consumer is recommended to be associated with a cold consumer. This can be performed with either a reversible (heating–cooling) or a double effect system. In cooling mode, a heat pump operates exactly like central air-conditioning.

All heat pump systems are consisted of four main parts, they are compressor, condenser, expansion valve and evaporator and the process of elevating low temperature heat to high and transferring it indoors involves a cycle of evaporation, compression, condensation, and expansion (Fig2).

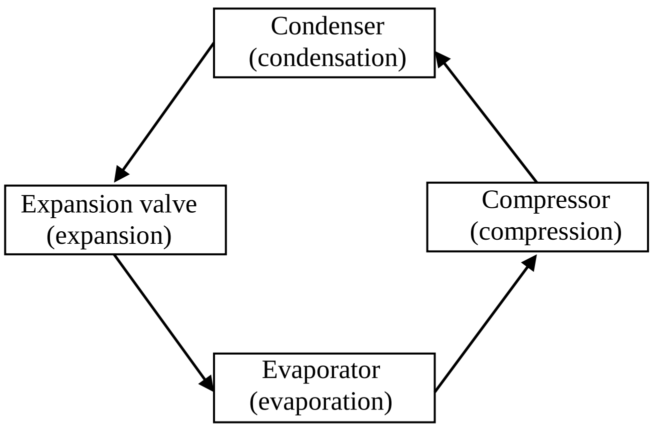

Fig2. Schema of heat pump system

Using the Fig2. the cycle is described in the following list:

1. The refrigerant enters the evaporator and is vaporized by the heat it receives from the heat source.
2. The pressure of the refrigerant vapor is raised in the compressor.
3. Pressurized and high temperature refrigerant vapor enters the condenser where it releases heat into the heat sink.

4. The refrigerant's pressure drops as it goes through the expansion device and becomes a vapor liquid mixture or a liquid.

The operation of a heat pump is characterized by the coefficient of performance (COP) defined as the ratio between useful thermal energy E_t and electrical energy consumption E_{el}.

$$COP = \frac{E_t}{E_{el}}$$

The COP of vapour-compression heat pump ranges between from 1 to 4, depending on the temperature difference between the heat source and heat sink [5].

The factors that can affect the life-cycle efficiency of a HP are the local method of electricity generation, the local climate, the type of heat pump (ground or air source), the refrigerant used, the size of the heat pump, the thermostat controls and the quality of work during installation.

Considering that the HP has over-unit efficiency, to evaluate the consumed primary energy uses a synthetic indicator [6]:

$$\eta_S = \eta_g \times COP$$

in which:

$$\eta_g = \eta_P \eta_T \eta_{EM}$$

where η_g is the global efficiency and η_P, η_T and η_{EM} are the electricity production, the transportation and the electromotor efficiency, respectively. For justifying the use of a heat pump, the synthetic indicator has to satisfy the condition η_S >1.

On the other hand the COP of a heat pump is restricted by the second law of thermodynamics:

In heating mode

$$COP \leq \frac{T_c}{T_c - T_s}$$

In cooling mode

$$COP \leq \frac{T_s}{T_s - T_c}$$

where T_c and T_s are the absolute temperatures of the hot environment (condensation temperature) and the cold source (evaporation temperature), respectively, in K.

In order to asses real work efficiency of heat pump system several experimentations are being done by authors on a one floor routine house heating system over a heating period in Tashkent region. In experimentation ground heat pump system is used and as an evaporator was chosen horizontal ground heat exchanger. Input dates are given in the table 1.

Table 1

Input data		
Definition	Value	Unit
Heating area	180	m^2
Heating load	11,03	kW
COP of heat pump system	3,5	
Investment (purchasing and installing)	38 700 000	sum

Using numerical methods [7] of calculation following dates were founded and are showed in the table below.

Table 2

Output data		
Definition	Value	Unit
Depth of the ground	5	m
Specific heat extraction from ground	20	W/m^2
Compressor power	3,14	kW
Evaporator power	8	kW
Surface of ground heat exchanger	400	m^2
Primary energy coefficient, η_S	1,8	
Direct gas burning for heating period	3590	m^3
Saved natural gas for heating period	1596	m^3
Payback period	8,5	years
Reduction of green house gases for heating period	3135	kg

As conclusion, implementing heat pump systems in house heating systems makes it possible to save finite natural recourses like natural gas by 1596 m^3 and reduction of releasing carbon dioxide to atmosphere by 3135 for heating period. Although, the initial investment payback period equal to 8,5 years, this amount is well acceptable for systems like heating system. Because this period is regarded as a normal because of life cycle period of heating system is almost three times more than payback period.

References

1. Sharipov O. The main directions of developing renewable energy sources in Uzbekistan. Tashkent, 2016. -13 p.
2. Dincer I. Renewable energy and sustainable development. A crucial review. Renew. Sustain. Energy Rev, 2016. P. 157–175.
3. Carson J.E. Analysis of soil and air temperatures, 2015. P. 2217–2232.
4. Eui-Jong Kim. Numerical modeling of geothermal heat exchangers, 2017. -16 p.
5. Lea Teiniranta. Heating and Cooling with a Heat Pump. Master's Thesis, 2015. P.13.
6. Ioan Sarbu. Using Ground-Source Heat Pump Systems for Heating and cooling buildings, 2016. P.7.
7. https://www.researchgate.net/publication/30500353_Annual_ground_temperature_measurements_at_various_depths

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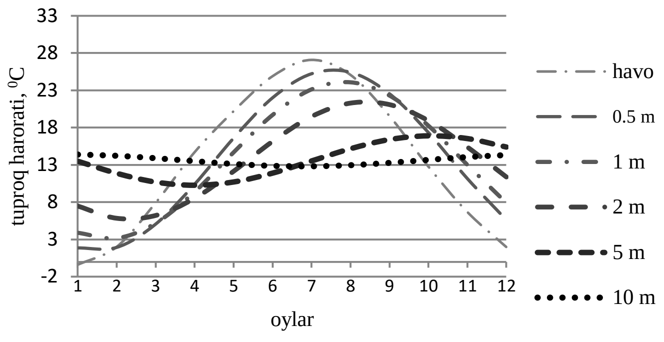
Hozrigi kunda, muqobil energiya texnalogiyalari qurilish sohasiga ham jalb etib borilmoqda. Aniqroq qilib aytganda, geotermal issiqlik manbaasi kabi tabiiy enegiya manbaalaridan foydalanuvchi tizimlar, o'zlaridagi ulkan potensil sababli yuksak e'tiborga sazovor bo'lmoqda. Tuproq issiqlik nasoslari (TIN) tizimi, binoning issiq suv ta'minoti, isitish va sovutish tizimlarini issiqlik bilan taminlashda tuproq issiqlikidan foydalanadi. Tuproq issiqlik nasoslari, odatiy havo konditsionerlariga nisbatan yuqori samaradorlikka ega. Bunga sabab yer sathidan pastda joylashgan tuproq, isitish uchun yuqori, sovutish uchun past haroratga ega va atrof muhit haroratidagi o'zgarishilarga nisbatan kamroq tasirchan [2].

Yer yuzasiga uzluksiz yetib kelayotgan quyosh energiyasi va atmosferadagi boshqa omillar, yer sathiga yaqin bo'lgan chuqurlikdagi tuproq haroratiga ta'sir ko'rsatadi. Azaldan, turli chuqurlikdagi tuproqning harorati o'rganilib kelingan [3]. Ammo yuqori texnologik o'lchov asboblari va ma'lumotlarni qayta ishlovchi texnika hayotga tadbiq qilinmaguncha, bu sohada hech qanday ailjiah bo'lmagan. Hozirda esa, yer yuzasidagi tuproqning va unga yaqin bo'lgan chuqurlikdagi tuproq haroratining o'rtacha qiymatidagi o'zgarishlar oddiygina garmonik ko'rinishga egaligi ma'lum.

Biroq, yer sathiga nisbatan chuquroq qisimlarda tuproq haroratidagi o'zgarishlari qisqarib borib, mintaqaning o'rtacha yillik haroratga yaqinlashib boradi. Amaliyotda shu kuzatiladiki, yer sathi va 10 m chuqurlik oraliqdagi tuproq harorati, shu joydagi tiproq hossalariga: zichligi, namligi, qovushqoqligi, tarkibi (isiqlik o'tkazuvchaligiga ta'sir etuvchi barcha omillar) ko'ra o'zgarib boradi.

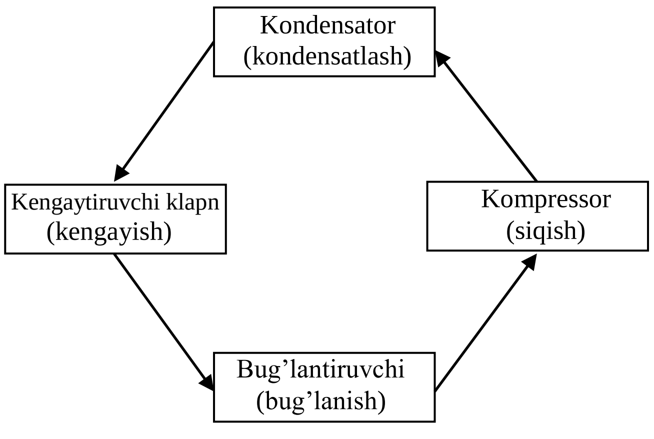
Raqamli modellash [4] metodidan foydalanib, Toshkent viloyati iqlim sharoiti va tuproqning hususiyatlarini hisobga olgan holda, turli chuqurlikdagi tuproq haroratining yil mobaynida o'zgarishlari hisoblandi va natijalar 1 rasmda keltirilgan. Ushbu 1 rasmda, yer sathiga nisbatan besh hil chuqurlikdagi tuproqning va shu mintaqa uchun atrof muhitning o'rtacha oylik haroratlari keltilgan. Rasmdan yaqqol ko’rinib turibtiki, yer sathidan qanchalik chuquroq kirib borilsa, shunchalik toproq harorati mo’ttadil bo’lib boradi va taxminan 10 m chuqurlikda tuproq harorati yil mobaynida o’zgarishsiz doimiy qoladi.



Rasm1. Turli chuqurlikdagi tuproq harorati

Issiqlik nasosi (IN) bu termal qurilma bo’lib, uning ishlash prinsipi Karno sikliga qarama qarshi sikilga asoslangan (yurituvchi energiya iste’mol qilib issiqlik energiyasi ishlab chiqaradi). Istalgan issiqlik nasosi, past haroratdagi manbaadan issiqlikni yuqori haroratli manbaaga uzatadi va bunda yurituvchi energiyani iste’mol qiladi. Bunda yuqori haroratli issiqlik iste’molchisi ayni damda sovutish tizimiga ham zaruriyati bo’lishi kerakligi tavsiya etiladi. Bunga issiqlik nasosi ishlash rejimini qarama-qarshisiga (isitish-sovutish) o’zgartirish bilan erishiladi. Sovutish rejimida, issiqlik nasosi aynan havo konditsioneri kabi ishlaydi.

Barcha issiqlik nasosi tizimlari to’rt asosiy qisimdan tashkil topgan, bular: komperssor, kondensator, kengaytiruvchi klapn va bug’lantiruvchi qurilma. Past haroratli issiqlikni yuqori haroratli issiqlik iste’molchisiga uzatish bug’lantirish, siqish, kondensatlash va kengaytirish jarayonlaridan iborat (rasm 2).



Rasm 2. Issiqlik nasos tiziming sxemasi

Issiqlik nasosi tizimi ishlash prinspi quyida tasvirlangan.

1. Issiqlik tashuvchi modda bug’lantiruvchi qurilmaga kiradi va past haroratli issiqlik manbaasidan issiqlikni olib bug’lanadi.

2. Bug’ ko’rinishdagi issiqlik tashuvchi modda kompressorga kirgach, siqiladi va bosimi oratishi bilan harorati ham ortadi.

3. Siqilgan va yuqori haroratli bug’ ko’rinishdagi issiqlik atshuvchi modda kondensatorga kiradi va u yerda o’z issiqligini yo’qotib, qisman kondensatga aylanadi.

4. Kengaytiruvchi klapndan o’tgan issiqlik tashuvchi modda bosimi keskin tushib, suyuq holatga o’tadi va bug’lantiruvchi qurilmaga kelib tushadi.

Issiqlik nasosi tizimining samaradorligi uning Samaradorlik koeffitsienti (SK) bilan o’lchanadi. Samaradorlik koeffitsienti - issiqlik nasosi ishlab chiqargan issiqlik energiyasining E_{Is} shu issiqlikni ishlab chiqarish uchun iste’mol qilgan elektr energiyasi E_{El} miqdorining nisbatiga teng.

$$SK = \frac{E_{Is}}{E_{El}}$$

Bug’ kompressorli issiqlik nasosining samaradorlik koeffitsienti 1 dan 4 gacha bo’lib [5], iste’molchi va issiqlik manbaasi haroratlari orasidagi farqqa bog’liq.

Issiqlik nasoslarini tadbiq qilishda erishish mukin bo’lgan samaradorlik mahalliy elektr energiyasini ishlab chiqarish metodi, mahalliy iqlim, issiqlik nasosining turi, uning hajmi, issiqlik tashuvchi moddaning turi, haroratni boshqaruvchi qurilma va umumiy tizimga hizmat ko’rsatish sifatiga bog’liq.

Issiqlik nasosi tizimi birlamchi energiyani qanchalik samarador iste’mol qilayotganini aniqlash maqsadida Birlamchi energiya koeffitsientidan (BEK) foydalanish mumin [6]:

$$\eta_{Bek} = \eta_g \times SK$$

Bu yerda:

$$\eta_g = \eta_P \eta_T \eta_{Em}$$

Bu yerda η_g global foydali ish koeffitsienti bo’lib, η_P, η_T va η_{Em} mos ravshda elekrt energiyasi ishlab chiqarish, uzatish va elektr yurituvchi matorning foydalim ish koeffitssientlari. Issiqlik nasosi tizimini tadbiq qilish uchun η_{Bek}>1 tengsizligi o’rinli bo’lishi kerak.

Issiqlik nasoslarining eng yuqori samaradorlik koeffitsientini termodinamikaning ikkinchi qonuni bilan izohlash mumkin.

Issiqlik ishlab chiqarishda

$$SK \leq \frac{T_c}{T_c - T_s}$$

Sovuqlik ishlab chiqarishda

$$SK \leq \frac{T_s}{T_s - T_c}$$

T_c va T_s mos ravishda, issiqlik tashuvchi moddaning bug’lantiruvchi va condensatordagi absalut haroratlari (Kelvin).

Haqiqiy sharoitda issiqlik nasosi tizimining samaradorligini baholash maqsadida, Toshkent viloyatida joylashgan bir qavatli namunaviy uyning issitish tizimiga issiqlik nasosi tizimini tadbiq qilish uchun avtorlar tomonidan boshlabg’ich hisoblash ishlari olib borildi. Tajriba uchun tuproq issiqlik nasosidan (TIN) va issiqlik manbaasi sifatida, gorizontal holda joylashgan tuproq issiqlik almashinuvchi qurilmasidan foydalanish nazarda tutilgan. Boshlang’ich ma’lumotlar 1 jadvalda keltirilgan.

1 jadval

Boshlang'ich ma'lumotlar		
Nomi	Qiymati	O'lchov birligi
Isitish maydoni	180	m^2
Isitish yuklamasi	11,03	kW
Issiqlik nasosining SK	3,5	
Investitsiya (issiqlika nasosini harid qilish va o'rnatish)	38 700 000	sum

Raqamli modellash [7] metodidan foydalanilgan holda so'ngi natijalar hisoblab topildi va ular 2 jadvalda keltirilgan.

2 jadval

Natijalar		
Nomi	Qiymati	O'lchov birligi
Tuproqning chuqurligi	5	m
Tuproqning solishtirma issiqlik miqdori	20	W/m^2
Kompressor quvvati	3,14	kW
Bug'lantirgish quvati	8	kW
Issiqlik almashinuvchi qurilmaning yuzasi	400	m^2
Birlamchi energiya koeffitsientidan, η_{Bek}	1,8	
Bevosita tabiiy gaz yoqish isitish davri uchun	3590	m^3
Tejalgan tabiiy gaz har isitish davri uchun	1596	m^3
Investitsiyaning to'liq qoplanish davri	8,5	yil
CO_2 chqishining qisqarishi har isitish davri uchun	3135	kg

Hulosa sifatida shuni aytish mumkinki, issiqlik nasoslarini issitish tizimiga tadbiq qilish hisobiga, faqatgina qishki isitish davri mobaynida 1596 m^3 tabiiy gazni tejab qolishga va 3135 kg karbonat angedrit gazini atmosferaga chiqishini qisqartirish imkonini yaratadi. Shunga qaramay, tajriba sifatida foydalanish uchun tanlangan issiqlik nasosi tizimning boshlang'ich investitsiyasini to'liq qoplash davri 8,5 yilni tashkil etadi, ammo bunday tizimlar uchun mazkur davr o'rta, ya'ni normal holat hisoblanadi.

Adabiyotlar

1. Sharipov O. The main directions of developing renewable energy sources in Uzbekistan. Tashkent, 2016.13.p.
2. Dincer I. Renewable energy and sustainable development. A crucial review. Renew. Sustain. Energy Rev, 2016. P. 157–175.
3. Carson J.E. Analysis of soil and air temperatures, 2015. P. 2217–2232.
4. Eui-Jong Kim. Numerical modeling of geothermal heat exchangers, 2017.16.p.
5. Lea Teiniranta. Heating and Cooling with a Heat Pump. Master's Thesis, 2015.13.p.
6. Ioan Sarbu. Using Ground-Source Heat Pump Systems for Heating, 2016.7.p.
7. https://www.researchgate.net/publication/30500353_Annual_ground_temperature_measurements_at_various_depths

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