NO.3 SEPTEMBER 2014

ASIAN HEAT PUMP & THERMAL STORAGE TECHNOLOGIES NETWORK

NEWSLETTER

Heat Pump & TES's current situation in each country

（China, Korea, Vietnam, Japan, India）

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Asian Heat Pump & Thermal Storage Technologies Network

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ABSTRACTS

RESEARCH AND DEVELOPMENT OF LARGE SCALE GROUND SOURCE HEAT PUMP SYSTEM (CHINA)

A large number of ground-source heat pumps (GSHP) systems have been used in residential and commercial buildings in different climate zones in China because it was considered as an environmentally-friendly and cost-effective alternative with potential to replace fossil fuels and help mitigate global warming by the central government since 2006. The total floor area that uses this technology is nearly 10 times at the end of 2012 compared with 2006. Ground heat exchanger heat pump system in China are always used for large scale residential and commercial building with the floor area more than 20,000 m2 and some surface water and sea water heat pump system could reach to city level, such as provide heating and cooling with several large GSHP energy station for an new district with the building floor area more than 5 million m2. At the same time, how to planning, design and operation such large system correctly to achieve higher COP is still needed to be answered. With latest research and development information of large scale GSHP collected from EU, USA and Japan, this paper raise a series of questions that needed to be solved in China in the future to keep promoting this technology, such as simultaneity usage coefficient of different buildings selection in one district, more accurate TRT and ground water flow consideration during the load calculation, heat extraction and rejection point selection and control strategy for hybrid system

HEAT PUMP WATER HEATER: KEY ALTERNATIVE PLAYER (KOREA)

Electric heat pump water heater technology draws in warm ambient air to more efficiently heat water for residential use. Recently, heat pump water heater sales have increased dramatically in several countries including: China, Japan, France, Germany, and Denmark. If the technology was adopted in place of less efficient technologies such as electric resistance heating, and sales achieved a 10% market share, it could save almost 1.3 billion kilowatt-hours of energy annually. Furthermore, with estimated annual household savings of $290 (ENERGY STAR, 2009), consumers would benefit from lower utility bills. Recently ISO (international Organization for Standardization) has launched to develop a new standard for a domestic hot water supply heat pump water heater. This paper is to report a market situation of, product application of and standardization of heat pump water heater which is in the spotlight as an alternative to heating and supplying hot water using the existing equipment used fossil fuel and resistance electric heater.

ABSTRACTS

RESERCH AND DEVELOPMENT OF COMBINED SOLAR THERMAL HEAT PUMP HOT WATER SYSTEM (VEITNAM)

Solar domestic hot water systems are widely used due to their capability of saving energy. In order to cope with the intermittent solar radiation on both seasonal and daily bases, they are usually combined with a conventional system that uses electrical energy or fossil fuel. Recently, heat pump systems with the improvement of the efficiency, together with the decrease in their cost are widely disseminated not only in air conditioning applications, but also in applications such as drying or hot water production. Because a heat pump system can reduce the consumed energy to third or even to sixth, the use of heat pump as an auxiliary energy source for solar domestic hot water system can achieve a significant energy saving. Unfortunately, this kind of hot water system is still not widely spread. Therefore, solar domestic hot water systems that use heat pump as back-up sources have been developed in a research project with the number sign of KC.05.03/11-15.

CURRENT STATUS OF ENERGY SAVING POLICY ON AIR CONDITIONERS AND BUILDING UP OF AIR CONDITIONER PERFORMANCE TESTING FACILITIES IN ASIAN COUNTRIES (JAPAN)

With growing global awareness of energy saving in recent years, the fast-growing Asian countries are actively introducing the MEPS, labeling systems and others for home appliance products including air conditioners in order to curtail energy consumptions that grow year by year. For ensuring effectiveness of such energy saving schemes, performance testing facilities are required to accurately measure the product performance. However, it is important for creation of such energy saving schemes to introduce not only necessary facilities but also many processes including calibration of measuring instruments and mutual calibration with external organizations. A third party air conditioner performance testing laboratory, JATL has been ensuring a steady implementation of its efforts based on ISO/IEC17025 and has maintained high accuracy and reliability. Moreover, JATL periodically implements mutual calibration with testing facilities of domestic air conditioner manufacturers as well as overseas national level testing laboratories. In the future, through JATL's technical assistance for the yet-to-be-built testing laboratories in Asian countries, we believe that contribution to improve reliability of performance testing in energy saving systems in each nation will prove to be mutually beneficial.

ABSTRACTS

ROLE OF HEAT PUMP IN ENVIRONMENTAL PROTECTION (INDIA)

The Northeast states of India are the eastern-most region of India connected to East India via a narrow corridor squeezed between Nepal and Bangladesh. The key development issues and challenges are basically backward rural areas, poor connectivity within the states and with rest of India, lack of industrialization, accelerated growth rate of urban centres and environmental protection. These states are power deficit in spite of huge potential for hydro power generation but majority of rural and semi urban areas because of its difficult terrain are not connected to grid and these areas would remain off grid in future as well.

RESEARCH AND DEVELOPMENT OF LARGE SCALE GROUND SOURCE HEAT PUMP SYSTEM

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Abstract: A large number of ground-source heat pumps (GSHP) systems have been used in residential and commercial buildings in different climate zones in China because it was considered as an environmentally-friendly and cost-effective alternative with potential to replace fossil fuels and help mitigate global warming by the central government since 2006. The total floor area that uses this technology is nearly 10 times at the end of 2012 compared with 2006. Ground heat exchanger heat pump system in China are always used for large scale residential and commercial building with the floor area more than 20,000 m2 and some surface water and sea water heat pump system could reach to city level, such as provide heating and cooling with several large GSHP energy station for an new district with the building floor area more than 5 million m2. At the same time, how to planning, design and operation such large system correctly to achieve higher COP is still needed to be answered. With latest research and development information of large scale GSHP collected from EU, USA and Japan, this paper raise a series of questions that needed to be solved in China in the future to keep promoting this technology, such as simultaneity usage coefficient of different buildings selection in one district, more accurate TRT and ground water flow consideration during the load calculation, heat extraction and rejection point selection and control strategy for hybrid system..

Key Words: large scale, GSHP

1 INTRODUCTION

Since 2000, GSHP started to be used in few small pilot projects, the total floor area that uses this technology reach to 240 million m2 at the end of 2012, which is nearly 10 times compared with 2006. Technical Code for Ground Source Heat Pump System GB50366-2005 made a clear definition of GSHP for China, which let the government much easier to provide policies and subsidies for this technology. But, due to the China’s fast development in urbanization and its own building form, GSHP always use for large building more than 20,000m2 and even for district with total building floor area reach to 5 million m2. As the system goes larger, the COP of the system couldn’t reach the design requirement and some problems raise up. By latest research and development information collection of large scale and city level GSHP of EU, USA and Japan, the future research area that should be paid attention to in China are discussed..

2 RESEARCHES AND DEMOSTRATION OF LARGE SCALE GSHP

Ground-source heat pumps (GSHP) systems have been used in residential、commercial and industry buildings throughout the world because of the highly energy saving and greenhouse gas emissions reduction potential. The GSHP technology can be used both in cold and hot weather areas and the energy saving potential is significant. During the past few decades, due to the renewable energy policies and financial subsidy, GSHP systems have been applied in larger and larger scale around the world, some systems even reached community and city level. (Ioan, 2014).

2.1 EU large scale GSHP utilization

On 2008, the European Parliament adopted the Renewable Energy Directive， which establishes a common framework for the promotion of energy from renewable sources. This directive opens up a new opportunity for widely use of heat pumps for heating and cooling of new and existing buildings. Also, EU set up three key objectives for 2020, known as the "20-20-20" targets, which including Raising the share of EU energy consumption produced from renewable resources to 20%.

With the promotion from the EU and member countries, GSHP had been promoted by different programs, such as The GEO.POWER project etc. The GEO.POWER project ("Geothermal energy to address energy performance strategies in residential and industrial buildings") (B.M.S. Giambastiani.,2014) was co-financed by the European Regional Development Fund in the frame of the INTERREG IVC Programme. The general project objective was to exchange the partners' own experiences on heating and cooling supply mainly through GSHP and from low enthalpy geothermal energy. After a SWOT technical and cost–benefit assessment, Participants evaluated the reproducibility and transferability of the best practices currently exists in Europe. It could find out that the most transferable example of technology is the TELENOR building in Hungary. The TELENOR building is a new industrial building with 180 Borehole Heat Exchangers (BHE) drilled 100m deep for cold and hot water, it also has 168 m2 solar collectors to meet 60–70% of the hot water demand. The CO2 emission saving could reach to 800–850t/year and the energy saving is 2.1 million kWh; the payback time is 8–10 years.

The core results achieved by the GEO.POWER project focused on the elaboration of action plans to encourage the GSHP market development and through the use of the EU Structural Funds in the current and in the future Programming Period 2014–2020. All documents contain a set of potential flanking measures to be implemented in the concerned areas to address strategies for GSHP large scale introduction and subsidy schemes to support geothermal energy investments.

Most large cities use tunnels to provide transportation and utility networks and some of the tunnels need to be cooled to meet operational requirements. Nicholson D. P. discusses the use of system-wide thermal tunnels with closed loops embedded in the tunnel segments to extract heat from the tunnel and then used with GSHP systems to heat adjacent buildings via a district heating system. After the detailed analysis of the system, Nicholson D. P. point out that this kind of large scale GSHP system requires a city scale investment in long term heat supply because the thermal tunnel system requires an early investment when the tunnels are being built to provide pipe work for heating adjacent buildings (Nicholson D. P.2013). The author carried out a preliminary study for the buildings in a corridor extending 100m beyond the tunnels for CROSSRAIL project, which including 34 hotels, large residential, hospitals, 4 schools, colleges, libraries, museums and 327 offices, leisure centers, retailers, with the conclusion that based on header pipe access points connecting to 500m of twin tunnels, the heat output would be about 200 to 600kW for 10 to 30 W/m2 of tunnel surface heat extraction.

A. Sciacovelli (A. Sciacovelli,2013) investigated the impact of a ground source heat pump installation for a public building in Italy through a thermo-fluid dynamic model of the subsurface which considers fluid flow in the saturated unit and heat transfer in both the saturated and unsaturated units. The building is 160m high and its volume is about 240,000m3. The groundwater flows in the south-east direction toward PO River, which is about 2 km far from the building. The groundwater system is composed of four wells, two for the water extraction and two for the re-injection. The distance between re-injection and extraction wells is 150m, while the transversal distance between the wells is 80 m. The cooling season lasts for about 6000 h with a peak request of 7MW and the heating period is of about 2800 h with a peak heating load of 2.5MW for the building. The author made analysis of two possible scenarios, one is constant heat pump mass flow rate case and the other is variable heat pump mass flow rate case. The result shows that at 1.8 km downstream the wells the difference between the unperturbed temperature and thermal plume temperature is about 3K when the heat pump operates with a variable mass flow rate and the wells thermal plume temperature is 5K higher than the unperturbed one when the heat pump operates with a constant mass flow rate.

2.2 USA large scale GSHP utilization

Justin Mahlmann considered that the only way to achieve California's stringent policies and emission goals that set a minimum for emissions reductions is strategic planning of the energy system on the community scale. Technologies such as geothermal heat pump systems (GHPS) can be implemented to heat and cool an entire community, reducing energy consumption, emissions and water consumption, while also serving as a backbone for carbon neutrality and zero net energy. Justin Mahlmann introduced Ball State University GSHP system, which have a capacity of approximately 5000 tons, and will serve the heating and cooling purposes for 47 buildings over 731 acres. The underground heat exchanger consists of 3600 boreholes with depths ranging from 400-500 ft and diameters of 5-6 inches. Capital expenditures for the project cost upwards of $70 – 75 million, which is only $15 million more than that for a conventional HVAC, resulting in a payback period of 7.5 years. The system will reduce the campus's CO2 an estimated 85,000 tons annually (Justin Mahlmann,2012).
Alaska Sea Life Center demonstrates a seawater heat pump system with the funding from Denali Commission Emerging Energy Technology Grant (EETG) program. Two 90-ton heat pumps were installed to provide heating and hot water. Since February 2013 the project was successfully commission, over the course of three months of monitoring since that time (1,900 hours of system operation), the average COP was 2.90, displacing a total equivalent of 20,000 gallons of heating oil while consuming 300,000 kWh of electricity. Years to payback the investment is 8.5(ACEP,2013).

2.3 Japan large scale GSHP utilization

Hikari Fujii developed a mass and heat transport model to simulate the long-term performance behavior of large-scale GSHP systems with the consideration of well-to-well interference in the presence of groundwater flow for a public building. The GSHP system was installed in the basement of a gymnasium of a public school in the central part of the Akita Plain with 75 cast-in-place, one-meter diameter and 50m deep piles in the foundation of the building. All of the piles were equipped with two 2.5 cm i.d, 50m long U-tubes to be used as GHEs.With the set up and analysis of the field wide numerical model of Akita Plain on the basis of groundwater levels and temperatures measured in the field. Groundwater velocity at the GCHP system location was estimated to be 1.4×10-4m/day. Four simulation run cases all with 120 days of heat extraction and different heat storage periods (none, 30 days, 60days, 120days) were carried out, the author find that more heat storage operations should be implemented in the downstream GHEs than in the upstream GHEs to maintain heat extraction

rates and wider GHE spacing is preferable in cases without heat storage operations (Hikari,2005).
Li Huai used both field data and a numerical simulation to examine the long term performance and environmental effects of a large GSHP (ground source heat pump) system installed in the city of Akabira in the north of Hokkaido, Japan. The heat exchange system of the GSHP consists of 78 boreholes, each with a depth of 85 m, that could provide a maximum capacity of 640 and 648 kW for heating and cooling for 12 greenhouses, each greenhouse comprises a total area of 450 m2.The system was monitored and analyzed from Oct 2010 through May 2011. The system had a COP of 3.0 and the average heat extraction rate of the system was approximately 27.7 W/m. Six wells were drilled in the borehole field to monitor the soil temperature and groundwater level, the author found the ground temperature at a depth of 40 m decreased from approximately 7.8℃ to 0 ℃after 8 months of operation and the operation of system with unbalanced heating and cooling loads (less than two times) is available with an average groundwater flow velocity around 10-15 m/y (Huai,2013).

Table 1 Typical large scale and city level GSHP projects

Country	Location	Building Type	Installed year	Collector Type	Collector Index	Load/Heat Pump(kW)	COP	Payback Period (years)	CO_2 reduction
Hungary	Torokbalint	industrial building	-	Vertical Borehole	180*100m		-	8 to 10	800–850 t/year
Italy	Turin	240,000m^3	-	Underground Water	2 extraction wells, 2 injection wells	peak heating load=2.5MW	-	-	-
USA	Indiana	47 buildings	2012	Vertical Borehole	3600*120m	5000 tons		7.5	85,000t/year
USA	Alaska	-	2013	Seawater	-	2 90-ton heat pumps	2.9	8.5	-
Japan	Akita	public building	2003	Vertical Borehole	75*50m	-	-	-	-
Japan	Akabira	12 greenhouses	2010	Vertical Borehole	78*85m	640kW for heating;	3		291t/year

3 CURRENT STATUS OF GSHP IN CHINA

The last decade of the 20th century was the infant phase of GSHP application in China. During that period, policymakers and the real estate developers started to realize the advantages of GSHP through some pilot projects.

3.1 Technical Code

One technical code set the concrete foundation for the fast development of GSHP after 2005 because it gave the financial incentive mechanism from the central and local government a technical reference. The technical code is "Technical Code for Ground Source Heat Pump System (GB50366-2005)", which was promulgated and took effect on January 1, 2006. The code plays a significant role for the development of geothermal heat pump industry as it is first time made the clear definition of Ground-Source Heat Pump System of China, which including three major types, that are Ground Heat Exchanger Heat Pump System (same as ASHRAE ground-coupled heat pump (GCHP) systems), Groundwater Heat Pump System, Surface Water Heat Pump System (sea water, lake water, river water and sewage water). The code is composed of eight parts, including general principles, technical terms, engineering exploitation, buried pipeline heat exchange systems, groundwater heat exchange systems, surface water heat exchange systems, indoor systems, equipment operation and trial running, etc (CABR, 2005).

3.2 Government Policies and Subsidies

On September 2006, ''Opinions on promoting application of renewable energy in buildings'' and ''A tentative management method of special funds for renewable energy development'' were promulgated by the Ministry of Construction (now called Ministry of Housing and Urban-Rural Development, MOHURD) cooperating with the Ministry of Finance. In these two documents, 4 of the 8 technologies which are subsidies by the state are GSHP system:
Ground source heat pump system and shallow groundwater source heat pump system.

- Water source heat pump system.
- Seawater source heat pump system.
- Sewage source heat pump system.

After that, a series of policies came out to promote GSHP on the city level and town level, at the end of 2010, 47 cities and 98 towns got the funding from the central government to promote GSHP, each city got 50 to 80 million RMB and each town got 15 to 20 million RMB to promote this technology. Based on the information from The State Council Information Office of P.R.China, at the end of 2006, the total floor area of GSHP application is just 26.5 million m2, by the end of 2007, the number reach to 80 million m2, till the end of 2012, the total project number use GSHP is 23,000 with the floor area reach to 227 million m2 and the number of GSHP system integration companies reach to 4,000. The increasing rate of GSHP in China from 2000 to 2012 could be found in Figure 1 (Xu, 2013).

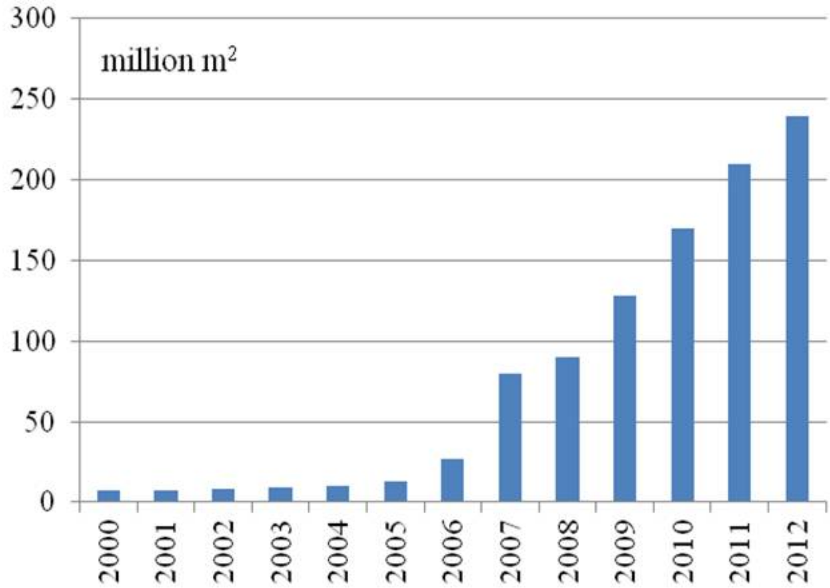

Figure 1 Increasing of GSHP in China

3.3 Project Type Distribution

Based on the analysis of 291 projects that funded by the Ministry of Construction and the Ministry of Finance, which the total floor area is about 32.72 million m2, we could find out that:

259 projects use GHSP at the only heating and cooling source while 32 projects use hybrid system. In the GSHP only projects, 110 projects use Ground Heat Exchanger Heat Pump System with the total floor area of 11.19 million m2 which accounts for 33.70% of all the projects, 78 projects use Groundwater Heat Pump System with the total floor area of 8.84 million m2 which accounts for 26.63% of all the projects, 32 projects use Surface Water Heat Pump System (heat source are river and lake water) with the total floor area of 3.63 million m2 which accounts for 10.92% of all the projects, 16 projects use Surface Water Heat Pump System (heat source is sea water) with the total floor area of 1.82 million m2 which accounts for 5.46% of all the projects, 23 projects use Surface Water Heat Pump System (heat source are civil sewage water, cooling water in Refinery, coal mine tunnel water and circulating cooling water from thermal power plant)with the total floor area of 4.52 million m2 which accounts for 13.61% of all the projects (Xu, 2013).

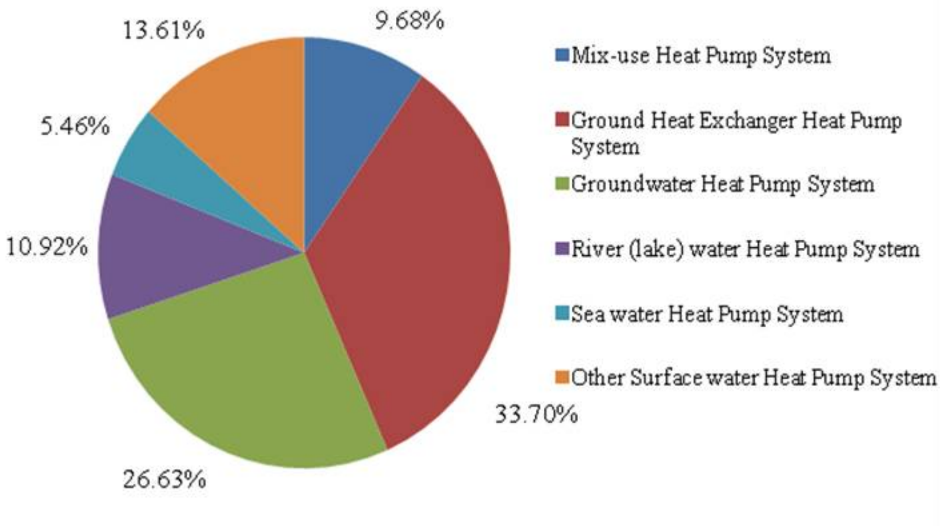

Figure 2 Percentage of different type GSHP system in China

4 LARGE SCALE GSHP APPLICATION IN CHINA

Due to China's different climatic zones, each type of GSHP have their own characteristics and suitable location, The Ground Heat Exchanger Heat Pump System are suggested to be mainly used in cold, cold winter & hot summer and temperate zones. In the southeast and coastal areas, where there is abundant groundwater and surface water resource, the Ground and Surface Water Heat Pump System are suggested to be used while in the cold and cold winter and hot summer zone. If the heat extraction and heat rejection cannot be balanced, the hybrid systems are suggested. Because the average single building in China is always bigger than the western style and with a much more quantity, the GSHP system is usually larger. Also, China now is going through a fast increasing period of urbanization, there are lots of new cities, new towns, new districts and new communities, from the beginning of the planning, GSHP was considered as the main heating and cooling source, that makes this technology goes to city-level in China recently. Following are some pilot projects in large-scale and city level.

4.1 Ground Heat Exchanger Heat Pump System Project

Beijing Zhongguancun International Mall is located in Beijing Zhongguancun Technology District, the total floor area is 1.56 million m2. Based on the system simulation, the total cooling load is 17MW, and the total heating load is 7.39MW.

Figure 3 Beijing Zhongguancun International Mall

Table 2 Heating and Cooling load of the Mall

Building floor area (m2)	Cooling Load Index (W/m^2)	Cooling Load (MW)	Heating Load Index (W/m^2)	Heating Load (kW)
156000	108.9	17	47.4	7.39

Based on the TRT, the geological condition is as follow:

Table 3 Geological condition of the Project

Depth（m）	thermal conductivity W/(m.K)
0~19m	1.4
19~32m	2.0
32~35m	1.6
35~38m	2.2
38~44m	1.4
40~52m	1.7
52~57m	1.6
57~70m	2.2
70~75m	1.6
75~100m	1.4

According to the on-site condition and the TRT result, 1,060 vertical boreholes with 123 m depth and distance as 4.5 are drilled under the parking lot. Double-U ground heat exchanger with diameter as DN32 is used.

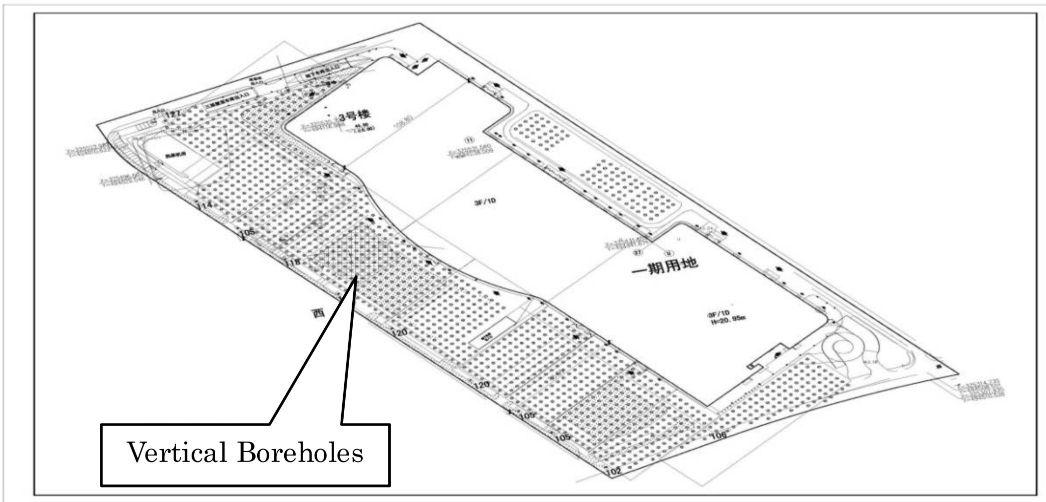

Figure 4 Vertical boreholes map of the projects

3 LSBLGR-M2800 heat pumps are selected, the heating capacity of single heat pump is 2.32MW, and the cooling capacity is 2.28MW. The system heating COP could reach 3.0 according to the system testing result during 120 days in the 2008 winter.

4.2 Groundwater Heat Pump System Project

Qindao Yinshengtai International Center and Business Center are two buildings in one district near each other. The total floor area of International Center is 58,000m2 and the total floor area of Business Center is 26,400 m2. The water extracted from underground from one well is 80t/h and the rejection data is 67t/h.
According to the calculation, 464tons of water per hour with the inlet/outlet temperature as 16℃/31℃in summer and 348t/h tons of water per hour with the inlet/outlet temperature as 15℃/7℃in winter is needed. 14 wells with the minimum distance as 40m are drilled; other 3 spare wells are also constructed. Cost of the GSHP system is 350 RMB/m^2.

4.3 Surface Water Heat Pump System Project

(1) Wuxi T-Park Energy Center
WUXI T-Park is a new district on the south of the urban area, the total construction floor area will be 8 million m2, and the first phase is just finished with the total floor area of 4 million m2. Across the district, there is a river with stable flow rate, the temperature is 6.8-12.4℃in winter and 23.6-32.4℃ in summer, also there is a sewage plant, the temperature of the sewage is 9-14℃in winter and 25-28℃ in summer. Two energy stations B and G that use the energy from the river water and sewage water are built to supply energy for the entire district.
4 water source heat pump with cooling (heating) capacity as 7.8MW（9.2MW）and 4 water source heat pump with cooling (heating) capacity as 5.9MW（10.6MW）are installed in the energy center B. 1 water source heat pump with cooling (heating) capacity as 6MW(6.5MW) and 1 water source heat pump with cooling (heating) capacity as 6MW（6.4MW）are installed in the energy center G. 860,000Mwh electricity and 900,000tons of CO_2 will be saved each year after the whole district completed.

(2) Thaizhou Medical City Energy Center
Thaizhou is a city near Yangtse River, the water average temperature and the flow rate is suitable to use in a heat pump system to provide energy for the whole district. So the new core city areas with the total floor area of 5 million m2 use the river water heat pump system for energy service. The total cost of the energy station in the first phase is 1.84 billion RMB with the cooling load of 55MW and heating load of 38.5MW. 3 water source heat pumps with cooling (heating) capacity as 7.9MW（8.4MW）and 3 water source heat pumps with cooling (heating) capacity as 6.0MW（9.5MW）were selected for the system.

Table 4 average water temperature and flow rate

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Auf	Sep	Oct	Nov	Dec
Ave Temp（℃）	9.2	10.6	13.1	17.9	22.3	25.5	28.1	29.1	26.2	22.4	17.4	12.6
Flow Rate（m^3/s）	6.5	8.3	9.4	15.0	22.2	24.1	18.4	19.4	18.9	22.4	13.7	6.7

4.4 Hybrid Heat Pump System Project

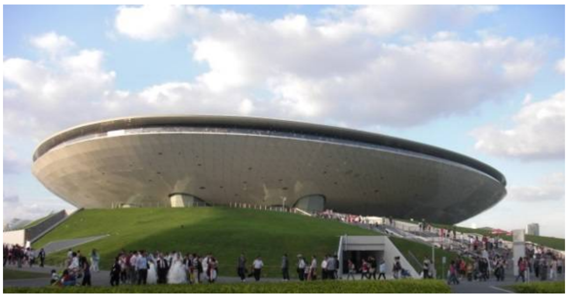

Figure 5 Shanghai World Expo Culture Center

Shanghai World Expo Culture Center is a mix-use building, above the ground is a theatre with 18,000 seats and the six floor building circulated the theatre, 2 floors are under the ground. Peak cooling load in summer is 14.95MW and peaking heating load is 9.2MW in winter. The center is very close to the Shanghai Huangpu River, the hydrological data shows that the water temperature is 26~32℃ in the upper level and 15~22℃ in the lower level in summer, in winter, the water temperature is 3~8℃ in the upper level and 10~15℃ in the lower level. As in the summer the river water temperature is relatively high and in winter cold, besides the heat pump system, ice storage system and boiler are also installed for summer and winter. According to the test, the river water heat pump system could cover 40% cooling load with COP 5.1 in summer and 55% heating load with COP 4.1 in winter.

5 FUTURE RESEARCH DIRECTION OF LARGE SCALE GSHP IN CHINA

From the general data of GSHP developments in China we could find that GSHP in China are always in a large scale and even reach to city level. According to the Ministry of Science and Technology of China, the total area adopting the GSHP systems will be up to 350 million square meters by the end of 2015. From the operation COP of the pilot projects, there are still big potential for the large scale and city-level GSHP system to enhance the energy efficiency in the future. Compare with the research of large GSHP system internationally, there are still several problems that needs to be resolved in China

5.1 Simultaneity usage coefficient

When use GSHP system to provide heating and cooling for a city level system, which including lots of residential buildings and commercial buildings, some of them are mix-use, the simultaneity usage coefficient between different function area in the same between and between different buildings should be considered, especially the coefficient between different buildings. Because for large central heating system with boilers in the northern part of China, this coefficient should be 1 to secure the heating supply. For the mix-use building, according to the China National Standard <Design code for heating ventilation and air conditioning of civil buildings> GB50736-2012, the coefficient could be 0.7-0.9. But In the GSHP system, heating and cooling are both supply within the GSHP system, usually, the GSHP provide cooling only for commercial buildings in summer but for heating for all the buildings, including residential buildings in winter, how to calculate the simultaneity usage coefficient of the large scale GSHP system is a key question.

5.2 TRT and ground water flow

For the Ground Heat Exchanger Heat Pump System, accuracy of the TRT result to calculate the thermal conductivity will contribute significantly to the total costs of system planning. The TRT equipment is commonly built in a few portable boxes or mounted on a car trailer for easy transportation to test sites. The mobile TRT method is becoming more and more important in the rapid spreading of Ground Heat Exchanger Heat Pump System. In the future, how to make the mobile TRT box smaller while more accurate will be put more effort. Groundwater flow is normally present and could enhance the heat exchanger rate and balance the heat extraction and injection to increase the COP of GSHP systems. But nowadays, the underground flow rate is not taking consideration during the design of Ground Heat Exchanger Heat Pump System; the engineer took it as a safety factor for the system. From the international experience, if the underground water flow is carefully calculated, the underground heat exchanger system could be 10-20% smaller to save cost; so the impact of groundwater flow on the performance of ground heat exchangers will be a future research area in China.

6. CONCLUSION

More and more large scale GSHP system and GSHP energy station are used in China for buildings and districts, GSHP have a bright future in China as an environmentally-friendly and cost-effective technology to help mitigate global warming. As the system grow larger and hybrid, some technical problems that will not affect the COP of small GSHP system obviously became a hot topic to save cost for the large scale and city level project, such as more accurate TRT and ground water flow consideration during the system calculation, heat extraction and rejection point selection and control strategy for hybrid system and so on. Compare with the latest research and development information collection of large scale and city level GSHP of EU, USA and Japan, the future research area of GSHP in China are discussed.

7 ACKONWLEDGEMENTS

The work of this paper is financially supported by the 12th FYP-National Key Technology R&D Program-Renewable Energy Utilization to Achieve Higher Level Building Energy Efficiency Target-2014BAJ01B03.

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HEAT PUMP WATER HEATER:

Key Alternative Player

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Abstract: Electric heat pump water heater technology draws in warm ambient air to more efficiently heat water for residential use. Recently, heat pump water heater sales have increased dramatically in several countries including: China, Japan, France, Germany, and Denmark. If the technology was adopted in place of less efficient technologies such as electric resistance heating, and sales achieved a 10% market share, it could save almost 1.3 billion kilowatt-hours of energy annually. Furthermore, with estimated annual household savings of $290 (ENERGY STAR, 2009), consumers would benefit from lower utility bills. Recently ISO (international Organization for Standardization) has launched to develop a new standard for a domestic hot water supply heat pump water heater. This paper is to report a market situation of, product application of and standardization of heat pump water heater which is in the spotlight as an alternative to heating and supplying hot water using the existing equipment used fossil fuel and resistance electric heater.

Introduction

Importance of international climate change measure and environmental issues is increasing in the 21st century, and because of adoption of the Kyoto Protocol, emissions trading between countries and practice Stay Clean Development etc, with respect to the environment since the new order in the energy market will be emerging, so the national response strategies to be established. To date, however, most of the reduction projects are about the chemical process heat recovery or business transition primary materials and savings verification process for high-efficiency equipment are considered based on the input and output evaluation only. In addition, the distorted cost structure between electricity and fossil fuels was to make a difficulty to quantify evaluation. In case of high efficiency air conditioner with a complicated structure needs standard to quantify the energy savings and especially standard of heat pump does not define output such as indoor load, unlike input energy.

Heat pump water heater is one of application of heat pump systems to replace existing fossil fuel boiler in domestic, commercial, and industrial area. The technology is a far more energy efficient way to use electricity to heat water than traditional electric resistance technology. Heat pump water heaters collect energy from the ambient air, water or the ground, and transfer it to water in an insulated storage vessel. The electricity is used in the motor that drives the refrigeration compressor although some units also have backup resistance elements for periods of high hot water demand or when the external conditions make normal heat pump operation difficult. Heat pump water heater(HPWH) providing space heating and hot water is a product that can replace existing products using fossil fuel and an eco-friendly green products that can reduce CO2 emissions. The most obvious benefit that homeowners can get from an air to water heat pump is that obvious fact that they no longer have to install another system to heat water. Basically what happens is that air source heat pump will be recycling the heat trapped in refrigerant to produce hot water. What this means is we get hot water free because the system uses a byproduct of its heating and cooling functions to come up with hot water. Another reason to celebrate an air to water heat pump is that its singular installation will drive down utility and operating costs compared to a standard heat pump plus a hot water heater.

Due to these advantages a lot of investment and research is in progress. Also that is growing fast in Europe, Japan and other developed countries. Depending on the structure of the market, and standards about heat pump water heater for energy-efficient performance standardization is set by the local and national.

In Korea, heat pump water heater market began to be formed and exports are already being made in some big companies such as LG, Samsung and Autech Carrier.

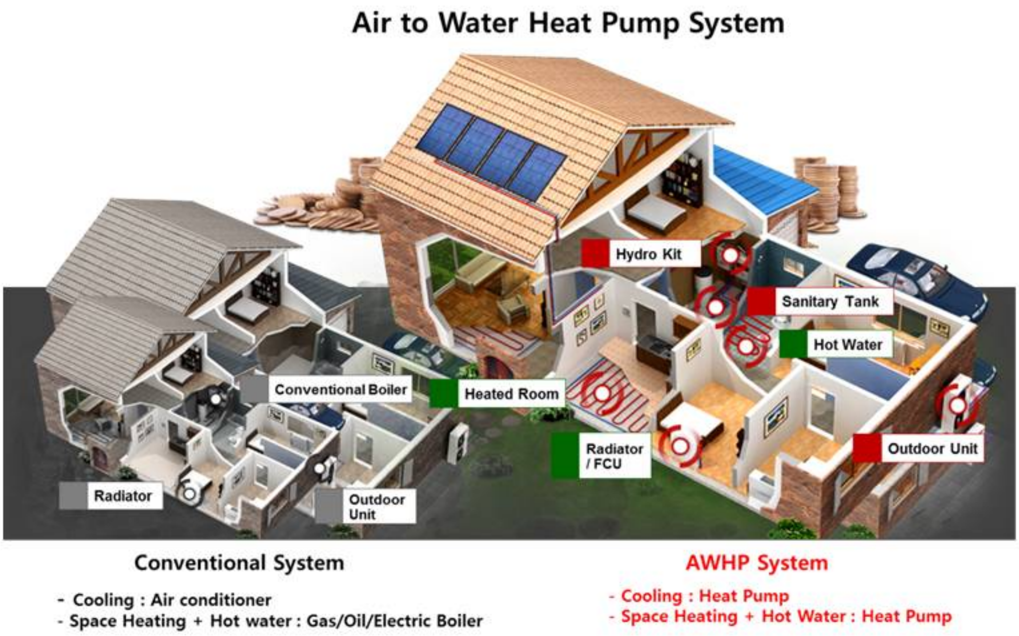

Figure 1. Installation of domestic air source heat pump water heater

How they work[1]

Heat pump water heaters use electricity to move heat from one place to another instead of generating heat directly. Therefore, they can be two to three times more energy efficient than conventional electric resistance water heaters. To move the heat, heat pumps work like a refrigerator in reverse.

While a refrigerator pulls heat from inside a box and dumps it into the surrounding room, a stand-alone air-source heat pump water heater pulls heat from the surrounding air and dumps it - at a higher temperature - into a tank to heat water. You can purchase a stand-alone heat pump water heating system as an integrated unit with a built-in water storage tank and back-up resistance heating elements. You can also retrofit a heat pump to work with an existing conventional storage water heater.

[1] US DOE, http://energy.gov/energysaver/articles/heat-pump-water-heaters

Heat pump water heaters require installation in locations that remain in the 4.4º–32.2ºC range year-round and provide at least 28.3 cubic meters of air space around the water heater. Cool exhaust air can be exhausted to the room or outdoors. Install them in a space with excess heat, such as a furnace room. Heat pump water heaters will not operate efficiently in a cold space. They tend to cool the spaces they are in. You can also install an air-source heat pump system that combines heating, cooling, and water heating. These combination systems pull their heat indoors from the outdoor air in the winter and from the indoor air in the summer. Because they remove heat from the air, any type of air-source heat pump system works more efficiently in a warm climate.

Homeowners primarily install geothermal heat pumps - which draw heat from the ground during the winter and from the indoor air during the summer -- for heating and cooling their homes. For water heating, you can add a desuperheater to a geothermal heat pump system. A desuperheater is a small, auxiliary heat exchanger that uses superheated gases from the heat pump's compressor to heat water. This hot water then circulates through a pipe to the home's storage water heater tank.

Desuperheaters are also available for tankless or demand-type water heaters. In the summer, the desuperheater uses the excess heat that would otherwise be expelled to the ground. Therefore, when the geothermal heat pump runs frequently during the summer, it can heat all of your water.

During the fall, winter, and spring - when the desuperheater isn't producing as much excess heat - you'll need to rely more on your storage or demand water heater to heat the water. Some manufacturers also offer triple-function geothermal heat pump systems, which provide heating, cooling, and hot water. They use a separate heat exchanger to meet all of a household's hot water needs.

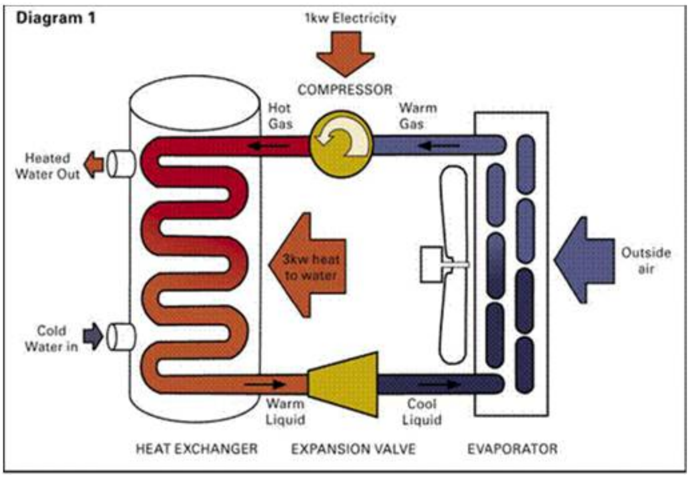

Figure 2. Basic cycle of refrigeration cycle for heat pump water heater

Market

The worldwide market for heat pump water heater is heating up recently. Sales of air to water heat pumps were the fastest growing segment at a CAGR of 21.5% over 2007-2010, reaching

1.3 million units in 2010 from an estimated 730 thousand units in 2007. Further, volume sales of air to water heat pumps are likely to surpass the other heat pump categories by registering a 2014-2020 compounded annual growth rate of 13.6% in some regions.[2]

The significant change of the market is the continued boom of sanitary hot water or cylinder-integrated air-to-water(ATW) heat pumps, whose sales continue to boom in France, registering the highest growth of around 34% compared to 2011, with an estimated sales of over 36,000 units in 2012. In Italy thanks to incentives and costs, the market registered its biggest growth in Europe of about 113%, to reach around 9,000 units in 2012. Outside Europe, sales of cylinder-integrated units have expanded in the United States to reach over 12,500 units in 2012. As more manufacturers are increasingly distributing these units, the market is likely to continue growing at the same pace over the next 5 to 10 years.

Especially air-to-water (ATW) heat pumps are mostly used for generating hot water in China. China's ATW heat pump water heater market rose to RMB 4.8 billion (US$ 780 million) in 2012, growing by 10.5% over that of previous year. Recent years, ATW heat pump-based heating is increasing. In 2012, more than 15 heat pump companies launched their ATW heat pumps for space heating.

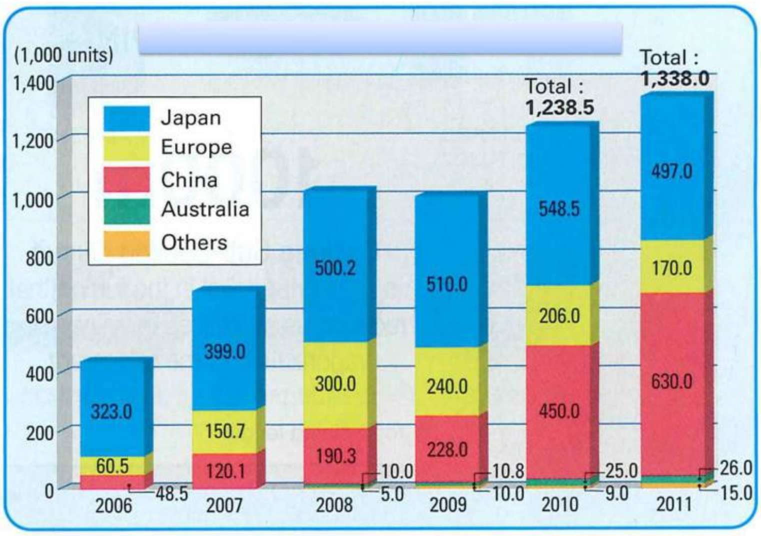

Figure 3. Worldwide market of air-to-water heat pump water heater
Source : JRAIA, and JARN magazine

As a newcomer, South Korea also makes various efforts to expand the heat pump market. Although the heat pump market continues to expand recently, domestic market is still staying in the poor level. In domestic heating space market, residential gas or oil boilers have accounted for 60% traditionally, however the market of heaters using heat pump water heater is growing recently and it makes up a 140 million US$ market in 2012. Recently KEPCO[3] has launched a new program to promote heat pump water heater with a thermal storage for mid-night electric tariff program in order to replace the existing resistance electric heater, which can be expected to trigger a new market.

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2 London, 2014, PR Newswire, Heat Pumps (Heating, Cooling and Hot Water) - A Global Market Overview

3 KEPCO : The Korea Electric Power Corporation

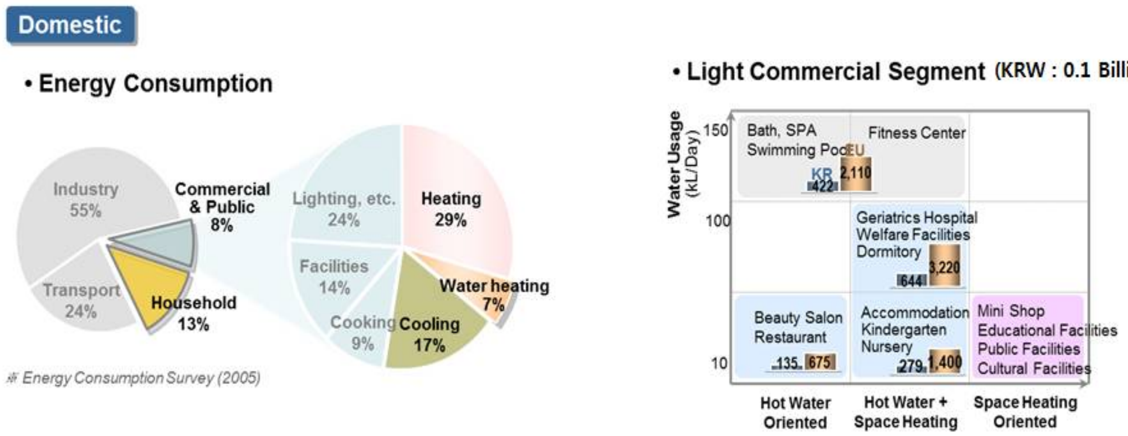

Figure 4. Korean market of air-to-water heat pump water heater

Source : KRAIA

Products and Applications

In general, heat pumps can be classified into air-to-air, air-to-water, water-to-air, and water-to-water system depending on heating medium type of heat source supply side and using side. Of these, heat pump water heaters are classified as air-to-water and water-to-water system as it can produce cold water and hot water at the same time. Heat pump water heaters can perform the role of cooler in summer, heater in winter, can cool and heat at the same time in condition where cooling and heating are required at the same time depending on the configuration on the system, and also provides hot water at 4 seasons.

The leading manufactures in domestic heat pump water heater, secure related products and application technologies, and are at the stage of checking system applications of various products, but related core technology and system integration technology developments are required urgently for high-efficiency and optimal control of the system. Secure on system optimization technology using variable capacity technology, system minimization technology using advanced heat flow application technology, etc are possible. Also, intelligent controller development for optimal operation of multi, hybrid products, development on intelligent integrated management system technology and system distribution control using wireless technology, are possible.

Currently the typical products are shown in **Figure 5.**, where unitary HPWH may be designed to be installed outside, inside or with ducted air, and heat exchanger may be wrap-around or immersion coil and heat exchanger of split HPWH could be in tank or in evaporator unit.

Table 1. shows the characteristics of popular heat pump water heater, where we can find each country and region has different application, temperature, and capacity for his market demands. New product also provides space heating, sanitary hot water supply, and space cooling simultaneously or separately (**Figure 6**).

In Korea market a high water temperature should be required because of a cold condition in winter season, which allows to adopt cascade condenser to increase water temperature with two refrigeration cycles that use two different refrigerants are linked by a heat exchanger as **Figure 7**.

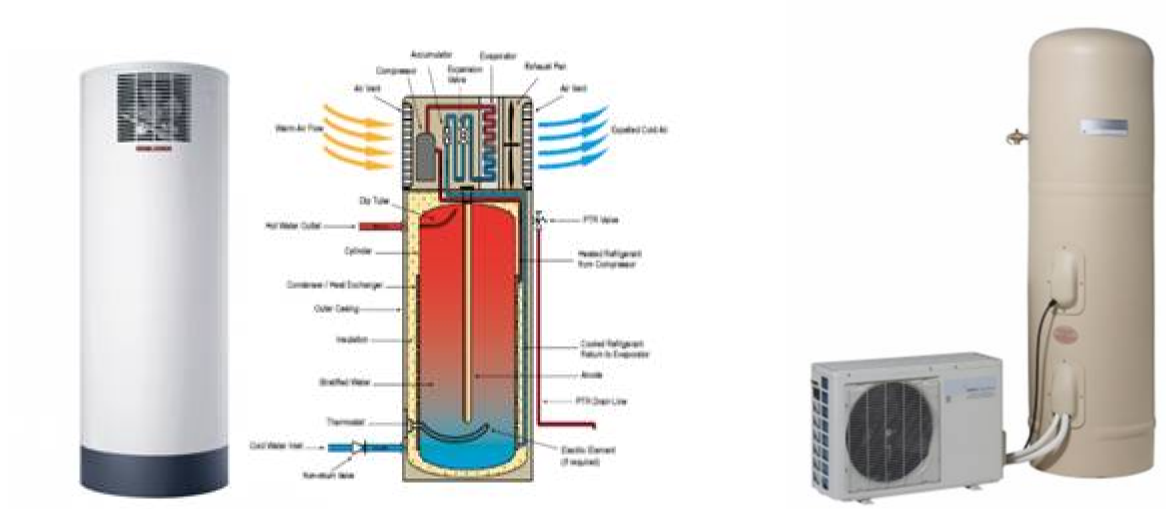

Figure 5. Typical products (left, Unitary HPWH and right Split HPWH)

Table 1. Characteristics of popular heat pump water heater

	Residential			Commercial
	Korea	Japan	EU	
Application	Space heating (50%), Sanitary hot water (50%)	Sanitary Hot water	Space heating (80%), Sanitary hot water (20%)	Sanitary Hot water
Capacity	6 ~ 25 kW	4~6 kW (300~460L)	6 ~ 16 kW (3~6 kW resistance heater)	15~80 kW
Temperature	~50°C (floor heating), ~65°C (hot water or Radiator)	65°C ↑	~40°C (floor heating), ~65°C (hot water or Radiator)	70~80°C
High temperature	Cascade, R410A, R134A	CO_2 (90°C ↑)	Backup heater or R407C	CO_2 (90°C ↑)

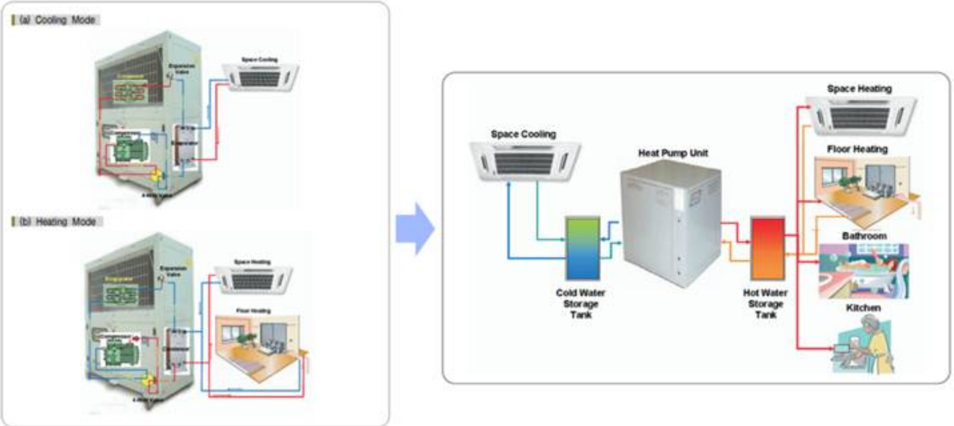

Figure 6. Schematic diagram of new product

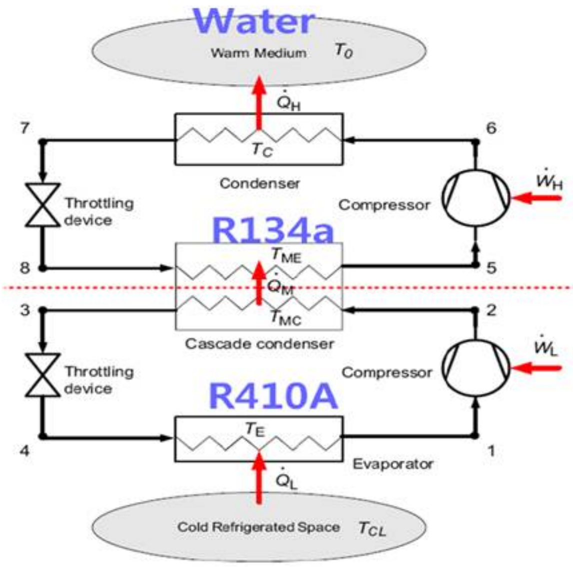

Figure 7. Cascade cycle refrigeration

Standardization

The key energy efficiency advantage of heat pump water heaters (HPWHs) is their ability to transfer more energy to the hot water than the amount of electricity they consume, because some of the energy is extracted from the ambient heat source (usually air, water or the ground).

The energy imparted to the water divided by the electrical energy consumed is generally called the Coefficient of Performance (COP) or the Energy Factor (EF). For water heaters both COP and EF are dimension-less quantities, because the numerator and the denominator are calculated in energy units.

Conventional electric resistance water heaters cannot by definition have a COP over 1.0, because all of the heat imparted to the hot water comes from an electric resistance element. A well-designed HPWH should have a COP significantly higher than 1.0. However, HPWHs are relatively complex systems, so testing and predicting their performance is not straightforward.

The overall energy efficiency can vary with the following:

- the local climate where it is installed;
- the temperature of the cold water supplied to the HPWH and of the hot water produced;
- the performance of the heat pump/heat transfer system (compressor, evaporator, condenser and other components);
- the heat loss of the storage tank;
- the quantity of hot water drawn off each day;
- the quantity and duration of each draw and the time intervals between draws;
- the thermostat settings and the control strategy; and
- the energisation profile, e.g. whether the heat pump can run at any time or whether it cannot run at certain times due to a restricted (off-peak) tariff.

The same HPWH can give very different COP values according to how it is tested and how the results are calculated from the measurements. Some test standards only measure the COP during the period when the unit first heats the water from cold, some take into account the COP during a series of physical draw-off and reheating cycles, and some take into account the energy used to maintain the hot water at storage temperature during periods when no hot water is being drawn off.

Currently some economies and regions have already developed standard for heat pump water heater, and are using to evaluate the performance of heat pump water heater. But, there are a lot of different factors to evaluate energy efficiency. If there were no existing standards for HPWHs, then the development of an international standard would itself constitute a sufficient focus and stimulus for harmonisation.

The ideal way to avoid this would be to adopt a single common method of test. In June 2013, TC86/SC6 of the International Standards Organisation (ISO) agreed in principle to develop a new test standard for heat pump water heaters. The new project is being at ballot stage for approving until 16 August 2014. If this ballot is approved, new working under TC86 SC6 will be launched to develop a new standard.

Table 2. Overview of standards, MEPS and labelling for heat pump water heaters

Country/Economy Test Standard (a)	**Physical testing**	**Derivation of COP/SCOP**	**Requirements in standard itself (g)**	**Requirements outside standard (h)**
Australia & New Zealand (b) AS/NZS 5125.1-2010	No draw-off (e)	Seasonal Performance modelled (but not reported as SCOP)	Proposed - labelling standard under development	Voluntary – eligibility under Renewable Electricity Act
	Draw-off test under development	COP calculated	Proposed - MEPS under development	
Canada (c) CSA-C745-03	Draw-off	EF calculated	Proposed – will impact HPWHs from April 2015	Voluntary – Energy Star endorsement energy label
China GB/T23137/21362	No draw-off	COP calculated	Yes	No known program for HPWHs
Europe (b) EN 16147:2011	Draw-off	COP calculated	No	Voluntary – Top Ten endorsement

				Proposed – mandatory energy labelling and MEPS
Japan JIS C 9220:2011	Draw-off	COP calculated	No	TopRunner standards
Korea (d) KS B 6410	No draw-off	SCOP calculated	No	No known program for HPWHs
USA (c) US Code of Federal Regulations Title 10, Part 430, Appendix E to Subpart B (CFR 430)	Draw-off	EF calculated	Proposed – will impact HPWHs from April 2015	Mandatory – EnergyGuide label Voluntary – Energy Star endorsement energy label
ISO	Under development	To be determined	To be determined	To be determined

(a) See detailed descriptions in Appendix A. (b) Standard officially applies to two or more economies. (c) Separate standards but essentially the same test (d) In draft – not yet published. (e) No draw-off during testing. Load patterns are simulated in seasonal performance modelling. A revision of the test standard is under way. It is planned to include draw-off tests for the purpose of determining minimum energy performance (MEPS) levels. (g) Where energy labelling and/or MEPS are included in the standard itself, so that products failing to meet those requirements are considered non-compliant with the standard. (h) Where laws or regulations state that a product must be tested using a given standard, but any MEPS and/or labelling requirements are in the regulations, and so can be altered without changing the test standard.

Conclusion

While heat pump water heaters have been available for several decades, they are becoming more popular as buyers increasingly factor energy efficiency into purchasing decisions, due to rising electricity prices and awareness of the need to reduce greenhouse gas emissions from energy use. The most obvious benefit that homeowners can get from an air to water heat pump water heater is that obvious fact that they no longer have to install another system to heat water. They must also give a satisfactory supply of hot water without the user having to wait an unacceptable time for reheats between draw-offs, and they need to be durable and quiet. Some designs trade off energy efficiency for functionality, e.g. by relying excessively on resistance element boosting.

The energy-efficiency advantage of HPWHs over other forms of water heating is their main selling point, so manufacturers have an incentive to claim the highest possible level of efficiency (usually expressed in terms of ‘Coefficient of Performance’, or “Seasonal Coefficient of Performance). Several economies have developed tests to measure the COP, and some have developed tests to measures the SCOP so that manufacturers can report values on a consistent basis and their claims can be independently verified. Some of the test standards incorporate other tests such as noise and the ability to deliver specified volumes of hot water over specified periods.

We believe the heat pump market will grow through boiler replacement demands and it is expected to have great market potential for industrial use as well as for residential use in the future. Key alternative equipment of conventional boiler is heat pump water heater.

This paper presented a market situation of, product application of and standardization of heat pump water heater which is in the spotlight as an alternative to heating and supplying hot water using the existing equipment used fossil fuel and resistance electric heater.

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RESEARCH AND DEVELOPMENT OF COMBINED SOLAR THERMAL HEAT PUMP HOT WATER SYSTEMS

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Hanoi University of Science and Technology

Introduction
Solar domestic hot water systems are widely used due to their capability of saving energy. In order to cope with the intermittent solar radiation on both seasonal and daily bases, they are usually combined with a conventional system that uses electrical energy or fossil fuel. Recently, heat pump systems with the improvement of the efficiency, together with the decrease in their cost are widely disseminated not only in air conditioning applications, but also in applications such as drying or hot water production. Because a heat pump system can reduce the consumed energy to third or even to sixth, the use of heat pump as an auxiliary energy source for solar domestic hot water system can achieve a significant energy saving. Unfortunately, this kind of hot water system is still not widely spread. Therefore, solar domestic hot water systems that use heat pump as back-up sources have been developed in a research project with the number sign of KC.05.03/11-15.

Target and scope of works
The KC.05.03/11-15 is a project funded by Ministry of Science and Technology (MOST) of Vietnam that has the title of “Research and development of combined solar thermal heat pump hot water systems for Vietnam conditions”. The term of the project is from January of 2012 to December of 2013.
Nowadays, regarding the combination between the heat pump and solar hot water system, we often refer to two types of systems: integrated and combined. Integrated type is a system in which the solar devices are integrated to the evaporators of heat pump devices. The heat energy collected by the solar devices has the role of low-temperature heat source for the heat pump devices so the devices, both heat pump and solar, must work simultaneously. In this sense, the integrated type has another name of “Solar Assisted Heat Pump – SAHP”. Because the solar energy can increase the temperature of the low-temperature heat source of the heat pump so that the heat pump is more efficient, this configuration is suitable for the cold-weather areas. In the hot-weather areas, the environment temperature (air, surface water…) is high enough which is favorable for the working of most hot water heat pumps, the combined type, with the sense that the heat pumps and the solar devices do not interact but both supply heat to the storage tank, is more simple and more efficient in comparison with the integrated type. Thus, in the KC.05.03 project, the combined type was selected to develop hot water systems that both heat pump and solar device are applied.
In modern life, hot water is consumed more and more with approximately more than 90% of it is used in buildings (hotel, apartment building…) and households. Therefore, two combined systems were selected to develop in the KC.05.03/11-15 project: one for buildings and the other for households.
In order to disseminate these prototypes of the combined systems in future, beside with producing two combined systems as mentioned above, the KC.05.03/11-15 project has

following aims:

- Study of heat pump technologies and combination methods between heat pumps and solar hot water systems to select the best technology and best method for producing the hot water heat pump units and then, combining them with solar hot water systems in Vietnam.
- Develop a method accompanied by a set of tools to design any combined solar thermal heat pump hot water system.
- Develop two prototypes of the combined solar thermal heat pump hot water system: one for buildings and the other for households.
- Develop two prototypes of controller for combined solar thermal heat pump hot water system, including control algorithm and software: one for buildings' systems and the other for households' systems.
- Measure and analyze the working data of the 2 prototypes developed in the project to show their capability in satisfying the loads (hot water demand), their energy efficiencies, as well as their capability in reducing the CO_2 emission…

Results

Two combined system prototypes have been developed in the KC.05.03/11-15 project: the 30,000-liter system which is designed to provide hot water for a 255-room and 4-star hotel, located at Nhatrang city of Vietnam; and the 250-liter system which is design to provide hot water for 5-person household, located at Hanoi, Vietnam.

The schematic diagram of both the 30,000-liter and 250-liter systems is presented in Figure 1. As shown in the figure, both solar collector(s) and hot water heat pump(s) are designed to work individually to produce hot water, which is stored in a unique storage tank. In case of enough solar radiation for the hot water demand, only solar circulation pump(s) works to transport the absorbed heat (stored in the hot water in form of enthalpy) from the solar collector(s) to the hot water storage tank. If the hot water demand is not adequately satisfied by solar collector(s), the hot water heat pump(s) will be activated. A programmable logic controller (PLC) with control software is also developed in this project to activate ON and OFF the heat pump(s) based on the auxiliary heat required to meet the hot water load.

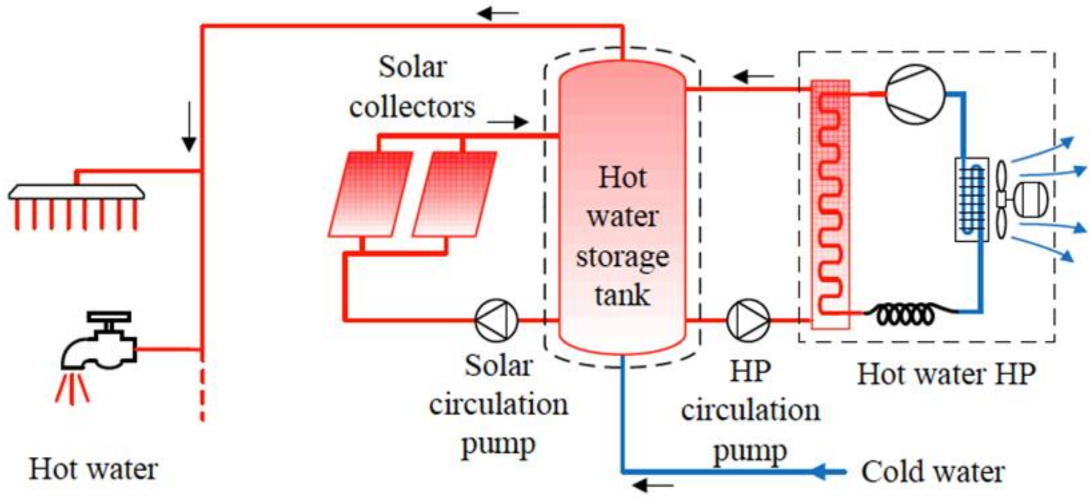

Figure 1. Schematic diagram of the combined systems

The characteristics of the two prototypes of combined systems are represented in Table 1. As can be seen here, for both prototypes, the volumes of the hot water storage tank are higher than usual whereas the total heating capacities of the hot water heat pumps are much lower than that often applied for ordinary systems. Therefore, the maximum power consumptions are much lower than usual as can be seen in the table.

Table 1. Characteristics of the prototypes of combined systems

Item	Parameter	Unit	30,000-liter system	250-liter system
1	Type of solar collectors	-	Vacuum tube, 58 mm diameter and 1750 mm length	
2	Numbers of collecting tubes and modules	-	1350 and 27	20 and 1
3	Equivalent absorption area of solar collectors (total)	m^2	179	2.65
4	Type of hot water heat pump(s)	-	Air source heat pump	
5	Number of hot water heat pump units	-	Total 5 units with 1 unit for standby	
6	Total heating capacity of heat pump(s)	kW	100	0.95
7	Maximum power consumption based on the power consumption of all installed devices	kW	35	0.4
8	Hot water load	-	For 255-room, 4-star hotel at Nhatrang, Vietnam	For 5-person household at Hanoi, Vietnam

According to the data collected from the installed prototypes, both developed combined systems can provide the amount of hot water enough for the design load at any condition all year round. For the 30,000-liter system, the initial cost is about three times higher whereas the annual power consumption, by estimation, is only tenth in comparison with the ordinary hot water systems, in which the electrical resistance water heaters are equipped. Regarding the 250-liter system, there is no comparison of initial cost because the small hot water heat pump with 950W of heating capacity, accompanied with the capability of working as the back-up source for the solar hot water systems is not available in the market today. The annual power consumption of the 250-liter system, also by estimation, is about 12% to 15% of the one of the ordinary systems.

Conclusions

The research and development of two combined solar thermal heat pump hot water systems for Vietnam weather conditions have been completed in the research project with the number sign of KC.05.03/11-15. The data collected from the prototypes of the two combined systems shows that they can meet the hot water demand of design load at any condition all year round in Vietnam. Due to the significant energy saving capability of both heat pump and solar devices, the annual power consumption of the two prototypes are much lower than those of the conventional electrical resistance heater systems, about 10% and from 12% to 15% for 30,000-liter and 250-liter systems, respectively. It should be noted here that the 30,000-liter system prototype is designed for the buildings in Vietnam that consume about 30% of electrical energy to produce hot water. Thus, significant energy saving, followed by CO_2 emission and electrical peak load reductions can be achieved if the combined solar thermal heat pump hot water systems are widely disseminated for the buildings.

Current Status of Energy Saving Policy on Air Conditioners and Building up of Air Conditioner Performance Testing Facilities in Asian Countries

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Abstract: With growing global awareness of energy saving in recent years, the fast-growing Asian countries are actively introducing the MEPS, labeling systems and others for home appliance products including air conditioners in order to curtail energy consumptions that grow year by year. For ensuring effectiveness of such energy saving schemes, performance testing facilities are required to accurately measure the product performance. However, it is important for creation of such energy saving schemes to introduce not only necessary facilities but also many processes including calibration of measuring instruments and mutual calibration with external organizations. A third party air conditioner performance testing laboratory, JATL has been ensuring a steady implementation of its efforts based on ISO/IEC17025 and has maintained high accuracy and reliability. Moreover, JATL periodically implements mutual calibration with testing facilities of domestic air conditioner manufacturers as well as overseas national level testing laboratories. In the future, through JATL's technical assistance for the yet-to-be-built testing laboratories in Asian countries, we believe that contribution to improve reliability of performance testing in energy saving systems in each nation will prove to be mutually beneficial.

Introduction

While assuming responsibility for testing through purchasing the products in the market in the air conditioner performance verification system in Japan, JATL grants certification to the manufacturers' testing facilities through mutual calibration, etc. and serves as Japan's standard laboratory for performance testing of air conditioners. Also, in recent years, JATL has been responsible for mutual calibration, Round Robin Test, technical training, etc., which are conducted jointly with the national laboratories in Asian countries, as part of a project of the Ministry of Economy, Trade and Industry (METI) to assist the creation of energy saving schemes. Through this project, the authors have visited the national laboratories in Asian countries to witness mutual calibration tests and undertake trainings on testing methods, etc. Most of the countries being assisted by us are in the process of building performance testing laboratories, in order to respond to the obligatory energy saving schemes for air conditioners such as MEPS and labeling and increased testing man-hours in conjunction with adoption of new international standards.

Current status of energy saving policy on air conditioners and performance testing in Asian countries

Table 1 summarizes the current status of energy saving policy on air conditioners in Asian countries. As shown in this Table, many countries adopt the obligatory certification systems for air conditioner performance. In addition, most of them have adopted or will adopt in the coming years seasonal energy efficiency ratio such as APF and CSPF (ISO 16358) as the criteria for judging energy efficiency. These are believed to aim at not only eliminating less energy efficient products but also increasing further the market share of inverter air conditioners (that are superior to a fixed capacity air conditioners in efficiency at a partial load), which are increasing their shares in Asian countries in recent years, through labeling with evaluating their energy saving features properly, thus curtailing total energy consumptions.

On the other hand, for effective functioning of such energy saving policy (MEPS and labeling program), highly accurate and reliable performance testing facilities are required. In particular, for calculation of seasonal energy efficiency ratio, measurement of half-load performance is necessary, in addition to the existing measurement of rated performance (capacity and energy consumptions), hence, shortage of testing facilities becomes apparent as testing man-hours increase. Table 2 shows the current status and problems in implementing air conditioner performance test in Asian countries. This represents the result of hearing survey by the authors from the managers of the national testing laboratories in Asian countries at the time of visiting there. This finds that many countries are actively introducing performance testing facilities to respond to an increased number of necessary tests due to introduction of MEPS and labeling programs. Also, at the laboratories where testing facilities are already in place, most of them were installed in recent years, therefore, shortage of testing experience becomes a problem. Measuring the performance of air conditioners is not as simple as measuring the length or weight of a certain object. It requires measuring various physical quantities after bringing enough stability in environmental conditions such as temperature and humidity and then making calculations based on such measurements. Thus, a certain extent of complexity exists. For acquisition of highly accurate results, each physical quantity needs to be measured with a high degree of accuracy, which can be achieved through periodic calibration and maintenance. Furthermore, not only the hardware such as each measuring instrument and the entire facility but also software such as staff members capable of handling them properly and their operation is a very important factor. In the following sentences, we explain these points based on the examples of JATL.

Table 1: Situation of energy saving measures for air conditioners in Asian countries

Country	Evaluation standards in MEPS and labeling programs		Response to seasonal energy efficiency ratio
	Type of air conditioners	Judgment method	
Japan	ALL	APF	APF already adopted (2006 -) *Labeling under Top runner program (not MEPS)
A	ALL	EER	Start of study on adoption of ISO 16358
B	Fixed	EER	Start of study on adoption of ISO 16358
	Inverter	Weighted EER	
C	Fixed	EER	ISO 16358 already adopted
	Inverter	CSPF(ISO16358)	
D	Fixed	EER	Start of study on adoption of ISO 16358
	Inverter	(No Regulation)	

E	Fixed	EER	Planned study on adoption of ISO 16358
	Inverter	Weighted EER	
F	Fixed	EER	Planned study on adoption of ISO 16358
	Inverter	EER & Weighted EER (combination)	
G	ALL	EER	Planned study on adoption of ISO 16358
H	ALL	APF(ISO16358)	ISO 16358 already adopted
I	Fixed	EER	APF already adopted
	Inverter	APF	
J	ALL	EER	In preparation for adoption of CSPF (In the process of soliciting public comments)

EER: Energy Efficiency Ratio = Total cooling capacity / power input
Weighted EER = 0.4 x "EER at full load" + 0.6 x "EER at half load"
CSPF: Cooling Seasonal Performance Factor
APF: Annual Performance Factor

Table 2: Outline of major air conditioner testing laboratories and facilities in Asian countries

Country	Item	Current problems, etc.
Japan	Testing facilities	-A Balanced ambient room-type calorimeter and an air enthalpy test method are already in place, but as a general rule, the calorimeter is used for certification tests. (enthalpy type is used only for heating low temperature condition.) -A new facility (balanced ambient room-type calorimeter) is planned to be installed.
	Test workload	-The number of tests is appropriate at present.
	Skill and experience	-With over 30 years' experience of joint establishment of testing technology with domestic air conditioner manufacturers, problems in terms of accuracy or technical capability are few.
	ISO/IEC17025	-ISO/IEC 17025 certified -Management work including maintenance and calibration is carried out properly and smoothly. -Experience of mutual calibration with domestic manufacturers and overseas ISO/IEC17025 certified laboratories is sufficient.
A	Testing facilities	-Balanced ambient room-type calorimeters and air enthalpy test methods are already in place, but the calorimeters are used for certification tests. -A new facility (balanced ambient room-type calorimeter) is planned to be installed.
	Test workload	-As the number of tests becomes huge due to a large number of domestic manufacturers, testing facilities become short in some cases.
	Skill and experience	-With years of experience as a testing laboratory, problems in terms of accuracy or technical capability are few.
	ISO/IEC17025	-ISO/IEC 17025 certified

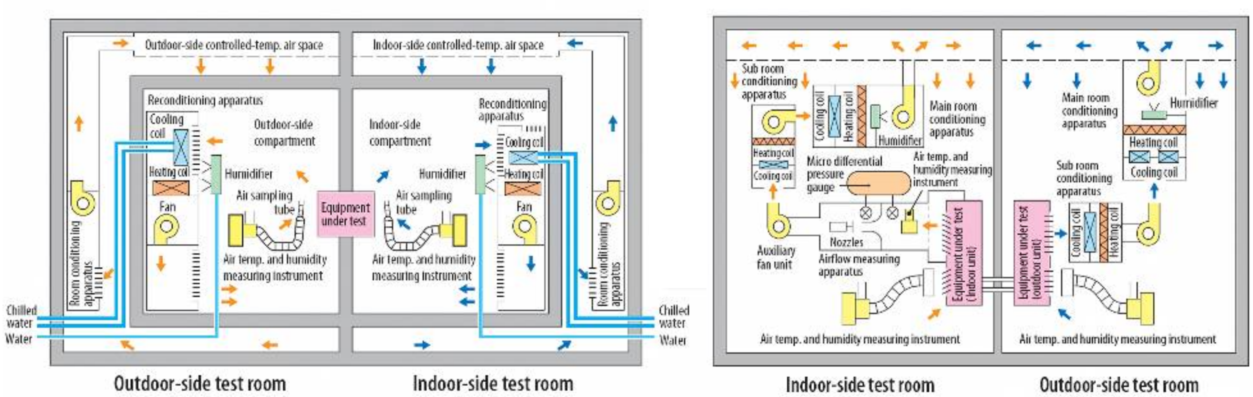
		-Management work including maintenance and calibration is carried out properly and smoothly. -A problem to be solved is less experience in mutual calibration with other testing laboratories.
B	Testing facilities	-A balanced ambient room-type calorimeter and an air enthalpy test method are already in place. (All of them were constructed in recent years.)
	Test workload	-Testing facilities become short in some cases, as tests are carried out in a highly tight schedule after the start of energy saving schemes. (There exists only one testing laboratory.)
	Skill and experience	-There is insufficient experience at present, due to a small number of years from facility introduction.
	ISO/IEC17025	-Aim at obtaining ISO/IEC 17025 certification. (Expansion of applicable scope) -Insufficient management work including maintenance and calibration is a challenge to be solved, as the facilities are new.
C	Testing facilities	-An air enthalpy test method is already in place. -A new facility is planned to be installed.
	Test workload	-Since energy saving schemes are not in operation in fact, there is no any particular test at present. But with start of such schemes, testing facilities would possibly become short due to a sharp increase in the number of tests.
	Skill and experience	-While a few years have passed since introduction of the existing facility, there is insufficient experience due to a small number of tests.
	ISO/IEC17025	-ISO/IEC 17025 certified (expansion of applicable scope) -Insufficient management work including maintenance and calibration is a challenge to be solved, as the facilities are new.
D	Testing facilities	-An air enthalpy test method is already in place. -There are several plans for new laboratory construction.
	Test workload	-The number of tests is appropriate at present, but testing facility would possibly become short due to an increase in the number of products to be regulated. (There is only one testing laboratory in operation.)
	Skill and experience	-There is insufficient experience at present, due to a small number of years from facility introduction.
	ISO/IEC17025	-Aim at obtaining ISO/IEC 17025 certification. (Expansion of applicable scope) -Insufficient management work including maintenance and calibration is a challenge to be solved, as the facility is new.
E	Testing facilities	-A calibrated room-type calorimeter is already in place. -There are several plans for construction of balanced ambient room-type calorimeters.
	Test workload	-As the number of tests becomes large, testing facilities become short in some cases. (There is only one testing facility in operation.)
	Skill and experience	-Experience is sufficient with high skill.
	ISO/IEC17025	-ISO/IEC 17025 certified -A problem is difficulty in maintenance and calibration by the

		laboratory, as technical details of the facilities are concealed by manufacturers.
F	Testing facilities	-A balanced ambient room-type calorimeter and air enthalpy test methods are already in place. Both of them can be used for certification. -There is only one balanced ambient room-type calorimeter introduced in recent years and others are air enthalpy test methods.
	Test workload	-Since there are three testing laboratories in the country, there is slightly excessive capacity available. But testing facilities would possibly become short due to an increased man-hour after introduction of new standard (CSPF).
	Skill and experience	-There is a certain level of experience in air enthalpy test method, but experience in balanced ambient room-type calorimeter is insufficient.
	ISO/IEC17025	-There are facilities which obtained ISO/IEC 17025 certification and facilities which are planned to obtain ISO/IEC 17025 certification. -While calibration and maintenance are conducted by the laboratory, such work seems insufficient in some aspects.

Outline of air conditioner performance testing facilities

1) Outline

As testing facilities, a balanced ambient room-type calorimeter or an air enthalpy test method is used in many cases. Fig. 1 indicates the schematic views of these facilities. Also, Table 3 shows the comparison of them.



Balanced ambient room-type calorimeter *Air enthalpy test method*

Figure 1: Examples of air conditioner performance testing facilities

2) Balanced ambient room-type calorimeter

A layer of air surrounds both a room for indoor units and a room for outdoor units. The layer of air is controlled to be at the same temperature as that of both rooms, so that leakage of heat to (or intrusion of heat into) the environs through wall surface is prevented. This is the largest characteristics of a balanced ambient room-type calorimeter. For your information, a calorimeter without a layer of air is called as a calibrated room-type calorimeter. In an facility with such calorimeter, the capacity of a sample machine (air conditioner) is balanced with the capacity of the facility to keep the temperature and humidity conditions of both the room for indoor units and the room for outdoor units and the capacity of the facility at that time is regarded as the capacity of a sample machine (air conditioner). For example, in a cooling mode, a heater and a humidifier of the facility is controlled to balance with the cooling and humidifying capacity of a sample machine and a total sum of electricity used by the heater, humidifier and other devices such as blower fan and electric lamp is regarded as a cooling capacity of a sample machine.

3) Air enthalpy test method
In a state that intake temperature and humidity of a sample machine are stable under the testing conditions, an air flow volume of a sample machine is obtained from such data as a differential pressure at a nozzle section of an air flow meter and the conditions of passing air flow (temperature, specific volume). Also, each specific enthalpy is obtained from temperature and humidity of air at intake and outlet of a sample machine and an atmospheric pressure and then the capacity of air conditioner is obtained through multiplying a difference in specific enthalpy between intake and outlet by mass air flow rate.

Table 3: Comparison of air conditioner performance testing facilities

✔: Excellent point

Item	Balanced ambient room-type calorimeter	Air enthalpy test method
Facility cost	-As the room has double wall, balanced ambient room-type calorimeter is generally more expensive than enthalpy method.	✔ -Enthalpy method is generally less expensive than calorimeter type.
Measurement accuracy	✔ -Balanced ambient room-type calorimeter is generally considered better than enthalpy method.	-Many factors including duct, nozzle, etc. are involved in air flow measurement. (There are many factors of uncertainty.)
Measurement time	-Test period of balanced ambient room-type calorimeter is longer than that of enthalpy method. (A certain period of time is required to be stable.)	✔ -Air flow meters are smaller and more excellent in thermal stability compared to respective rooms of calorimeter type.
Measurable capacity	-Measurement of large capacity products is difficult because of temperature distribution. (Facility cost is a problem.)	✔ -A wide range of air flow (capability) can be responded by changing nozzle diameter in air flow meters. (Employ enthalpy method is mainly used for large air conditioners.)
Load following capability	-If loads in a sample machine change, thermal balance becomes unstable, requiring a longer time to be stable.	✔ -Load following capability is good, since operating conditions of a sample machine have a limited effect on temperature control.
Testing work	✔ -Installation work is easier than that for enthalpy method and factors that have an effect on installation work are few.	-As connection work by using ducts is required, installation work is more difficult than calorimeter type.
Facility operation	-Adjustment work to keep balance on the facility side may be necessary depending on	✔ -Operation is relatively easy, since operating conditions of a sample machine have a smaller effect on

	operating conditions of a sample machine.	temperature control than calorimeter type.
Maintenance	✔ -Maintenance work is slightly easier than that for enthalpy method but there is no large difference in man-hours.	-The number of instruments is larger than that of calorimeter type and the number of man-hours is slightly larger. (It is more expensive as well.)

4) Testing facility for air conditioner performance verification system in Japan
Under the air conditioner performance verification system in Japan, all qualification tests are performed by JATL. As the testing facility for this purpose, a balanced ambient room-type calorimeter, which is superior in terms of accuracy, is basically used for small air conditioners for home use. Only for the conditions of heating in lower temperatures with large fluctuation in load due to defrosting operation, an air enthalpy test method that is superior in load following is employed. Also, air conditioners for commercial use that have too large capacities for calorimeters to measure are tested with employing only an enthalpy method (see Table 4).

Table 4: Testing facilities for air conditioner performance verification system in Japan

Product category	Test item	Facility	Measurable range
Small air conditioners (for residential use)	Standard cooling conditions (rated/ half load) Standard heating conditions (rated/ half load)	Balanced ambient room-type calorimeter	Cooling: 0.9 - 11.6kW Heating: 0.9 - 12.8kW
	Low temperature heating conditions	Air enthalpy test method	(Cooling: 0.0 - 10.0kW) Heating: 0.0 - 13.0kW
Large air conditioners (for commercial use)	All items	Air enthalpy test method	Cooling: 2.0 - 56.0kW Heating: 2.0 - 67.0kW

As described above, we employ several forms of air conditioner performance testing facilities with each having different characteristics and it is important for all facilities to conduct appropriately and continuously calibration and maintenance of each measuring instrument and the entire facility.

Calibration of performance testing facilities

1) Calibration of measuring instruments
As described above, the performance of air conditioners is obtained through calculation from a variety of factors such as temperature, humidity, pressure and electricity. Accordingly, in order to obtain correct results, calibration of the instruments for measuring various factors is necessary for ensuring appropriate measurement values. Moreover, it is important that the calibration has traceability to the national standard. Calibration of measuring instruments and traceability are described as requirements in Section 5.6 of ISO/IEC 17025. At JATL, each measuring instrument undergoes calibration by JATL's reference standard (that is not

used in regular tests) at the time of an annual comprehensive maintenance. The reference standard is calibrated by the ISO/IEC 17025 certified calibration organization and has traceability to the national standard. This external calibration is performed once a year as well. Also, at the time of this external calibration, a calibration certificate with a statement of uncertainty in measurement is issued in principle and such uncertainty is used for calculation of uncertainty of each measuring instrument. In addition, internal calibration at JATL is not implemented solely by each measuring instrument. Calibration is implemented in a range from measuring instruments installed in a laboratory to their indicated parts as a whole. Fig. 2 shows the traceability diagram of measuring instruments (excerpt) at JATL.

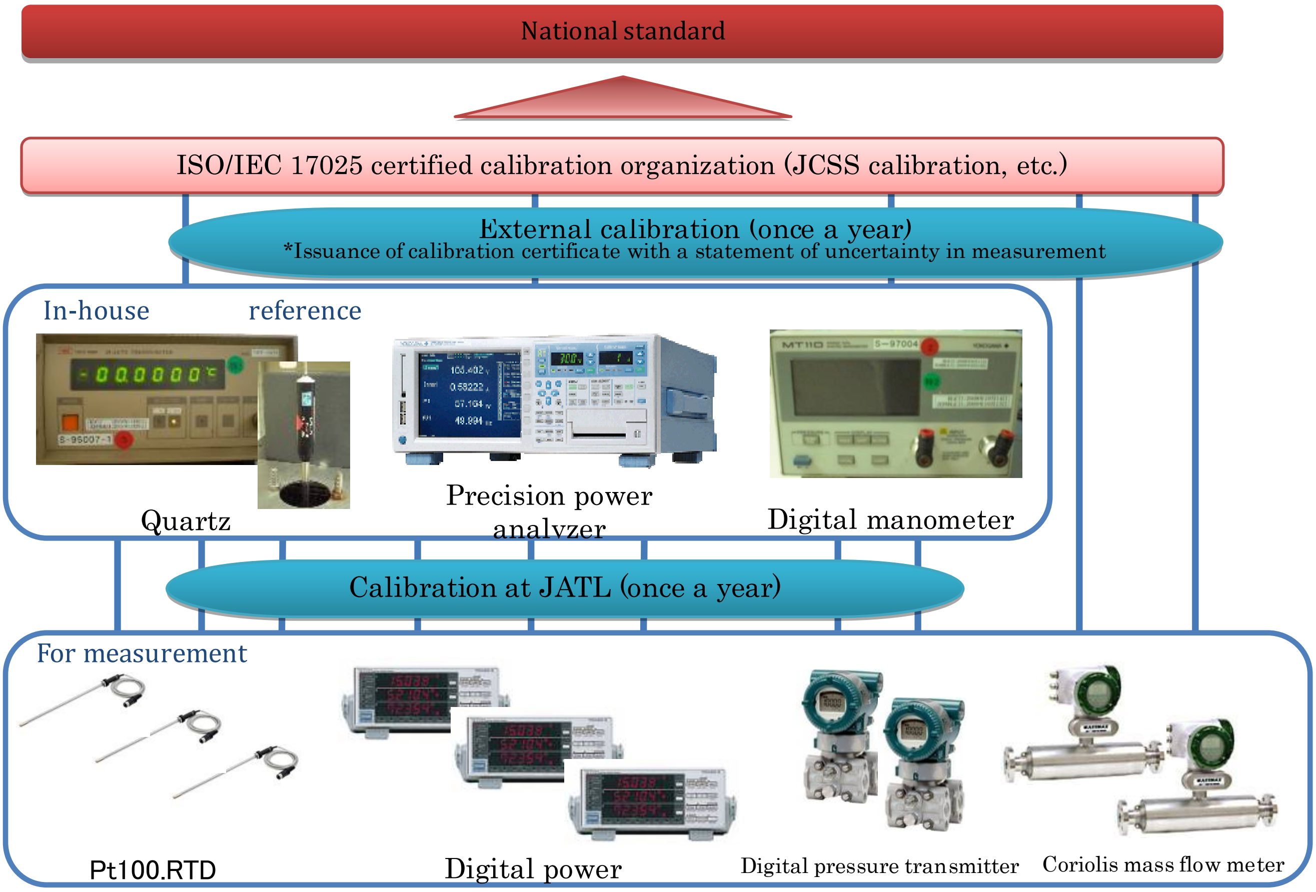


Figure 2: Traceability diagram of measuring instruments (excerpt) at JATL

2) Quality control of test results of testing facilities by comprehensive calibration

Calibration of individual measuring instrument mentioned above is insufficient for an air conditioner performance testing facilities. It is because the finally sought values of capacity or power consumptions of air conditioners may vary, due to various factors such as heat leakage from an air receiving chamber or the rooms for indoor or outdoor units, temperature distribution, etc., in addition to individual measuring instruments. Accordingly, it is necessary to confirm periodically that performance values finally sought are appropriate by implementing measurement of air conditioner performance. Quality assurance of the results is mentioned in Section 5.9 of ISO/IEC 17025.

a) Repeat tests by in-house calibrator

This is a method to measure an in-house calibrator (air conditioner) once a year and identify changes in performance values. The points in this test are shown in Table 5. At JATL, after completion of calibration of each measuring instrument and maintenance of the whole facilities implemented at an annual comprehensive maintenance, tests of both a balanced ambient room-type calorimeter and an air enthalpy test method are conducted. This also serves as mutual calibration among in-house testing facilities.

Table 5: Points of repeat test by in-house calibrator

Point	Reason
Tests should be conducted by multiple calibrators.	To determine whether it is an anomaly of calibrator itself or testing facility.
Respective calibrators should have different capacity.	To cover the measurement range of testing facility.
Respective calibrators should properly be stored and renewed in about a five-year interval.	To exclude an effect of changes in performance due to deterioration of calibrator itself.
Test results should be shown graphically.	To grasp the trend for easier anomaly detection.

b) Mutual calibration or Round Robin Test with external testing organizations

JATL implements comparison with external testing organizations through the methods shown below.

b-1) Round Robin Test in rotation with KRAAC of South Korea

KOREA Refrigeration and Assessment Center (KRAAC) of South Korea, which is operated by Korea Energy Management Corporation (KEMCO) under the Ministry of Trade, Industry and Energy, is a designated test center under the air conditioner certification system. It is an ISO/IEC 17025 certified center. JATL has signed a technical tie-up contract with KRAAC and has performed a Round Robin Test in rotation every four years to mutually validate the results.

b-2) Periodic mutual calibration with domestic air conditioner manufacturers

A voluntary air conditioner performance verification system run by the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) consists of testing conducted by JATL through purchasing the products in the market and voluntary verification testing conducted by each air conditioner manufacturer. To ensure that voluntary qualification testing conducted by each manufacturer be implemented appropriately under the system, mutual calibration with the testing facility of manufacturers is conducted (every two years in principle). Under this qualification system, JATL's testing facility is called as "(performance) standard" and each manufacturer's testing facility is called as "quasi standard." Also, each manufacturer conducts mutual calibration between its other testing facility (manufacturer's facilities) and the quasi standard registered with the verification system, which results in realizing calibration between the Japanese manufacturers' performance testing facilities and JATL's testing facility. The outline of verification system is shown in Fig. 3, while the scheme of quasi standard certification is shown in Fig. 4.

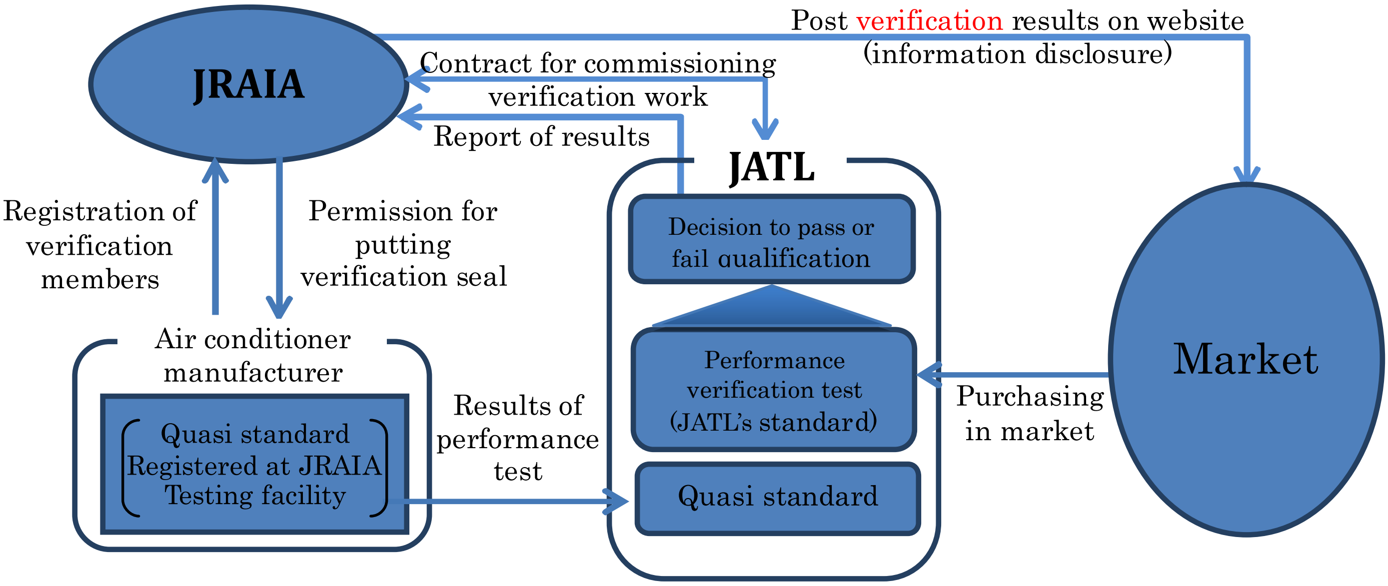


Figure. 3: Outline of air conditioner qualification system in Japan

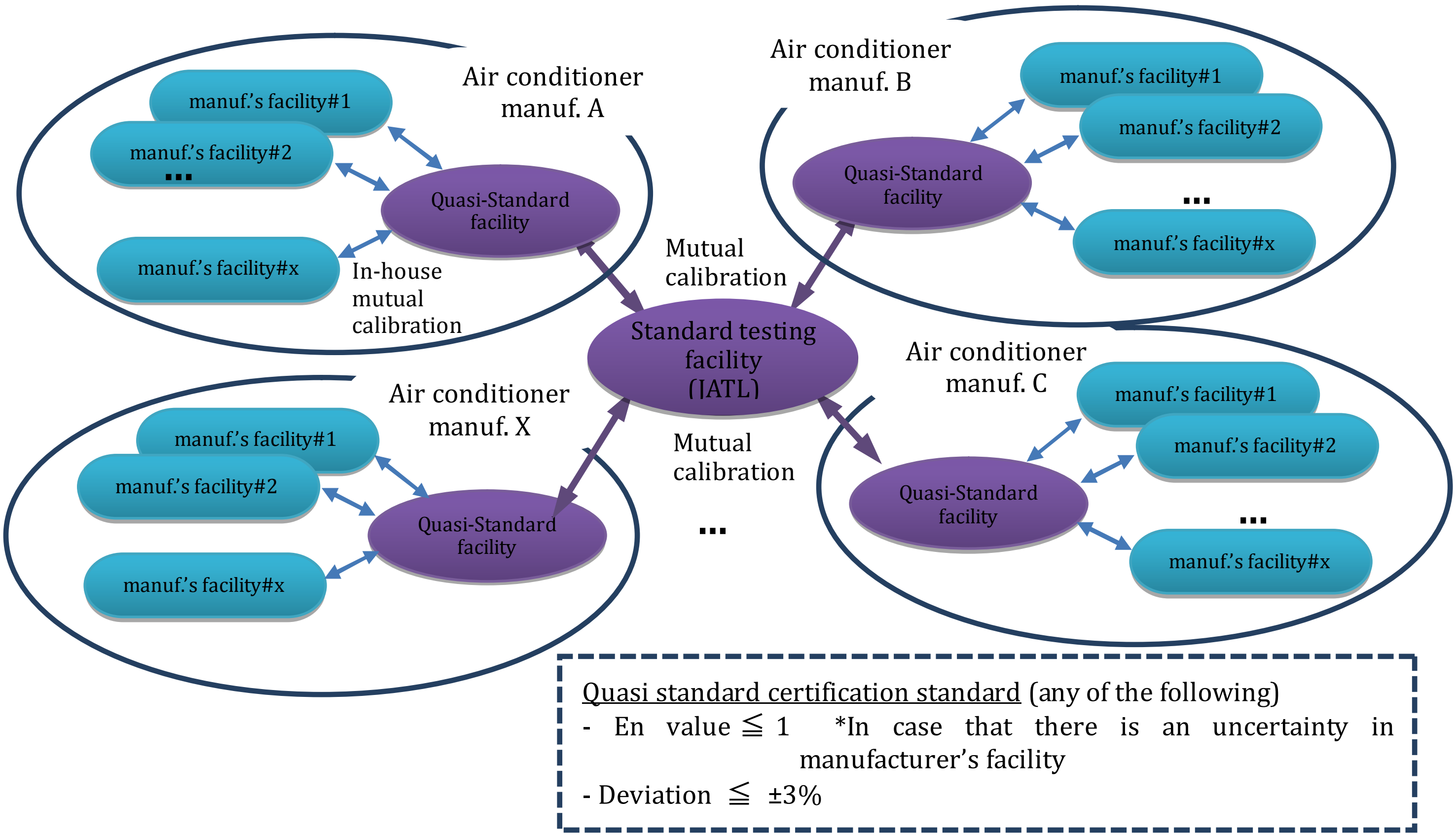


Figure 4: Scheme of quasi standard certification in verification system

b-3) Mutual calibration with overseas performance testing laboratories/Round Robin Test

In addition to mutual calibration with KRAAC of South Korea, JATL has conducted mutual calibration testing with overseas performance testing laboratories through various projects. In these projects, not only comparison of testing results but also researches on facilities, testing methods, management status, etc. have been conducted. In particular, under the projects of METI designed to assist Asian countries in their efforts to create energy saving schemes (“Project of Research on Providing Assistance to the Efforts of Creating the Base for Diffusion of Energy Saving, etc.” and “Project to Provide Assistance to the Efforts of Creating S&L Scheme in Developing Nations”), we are able to have detailed understanding of the situations on overseas performance testing laboratories through mutual calibration with them and provision of technical assistance to them. Table 6 below shows the records of tests conducted with overseas performance testing laboratories.

Table 6: Records of mutual calibration tests with overseas performance testing laboratories

Time period	Project	Country (laboratory)	Items implemented
1997, 2002 and 2010	Overseas WG of JRAIA	United States (Intertek)	Mutual calibration test
2003		South Korea (KRAAC) and Spain (CEIS)	Round Robin Test
2008 and 2009		Spain (CEIS)	Mutual calibration test
2006		Australia (UNSW)	Mutual calibration test
2003, 2007, 2010 and 2013	Comparison of testing laboratories under technical tie-up contract	South Korea (KRAAC)	Round Robin Test
2011	Project to Provide Assistance to the Efforts of Creating S&L Scheme in Developing Nations (METI)	China (CVC)	Mutual calibration test
2012		China (CVC, CHEARI)	Round Robin Test
2012	Project of Research on Providing Assistance to the Efforts of Creating the Base for Diffusion of Energy Saving, etc. (METI)	Thailand (EEI), Malaysia (SIRIM QAS), Indonesia (B4T) and Vietnam (TVCI)	Mutual calibration test and technical assistance
2013 and 2014		Thailand (EEI), Malaysia (SIRIM QAS), Indonesia (B4T) and the Philippines (OSSI-STL)	Mutual calibration test or Round Robin Test and technical assistance

Facility maintenance

1) Outline

For the purpose of keeping the conditions of test facilities, JATL implements calibration of each measuring instrument and mutual calibration of facilities as described before and conducts daily and annual inspections for the purpose of keeping the conditions of the entire facilities.

2) Importance of self-performed maintenance

These maintenance activities are performed by the testing personnel themselves at JATL to the extent technically feasible. Conducting maintenance activities by the testing personnel themselves is aimed at not only enhancing understanding of the facilities and testing technique as well as improving their skills of detecting and correcting failures at an early stage at the occasion of daily testing, but also at enhancing their abilities to make proposals properly for future testing methods and improvement of the facilities.

3) Routine inspection

Routine inspection, for example, to find out unusual sound at each section of facilities or loosened belts, is carried out to check the conditions of facilities to ensure them to function normally and the results are posted. An interval of inspection differs by item (daily/weekly/monthly). Table 7 below shows an example of inspection items and inspection cycles. Fig. 5 shows the status of posting the routine inspection sheet at JATL.

Table 7: Example of routine inspection items

Inspection item	Confirmation item	Inspection cycle
AHU blower	Unusual sound	Daily
Humidifier	Unusual water level	Daily
Thermometer	Water level of wet bulb	Daily
V belt	Looseness and damage	Monthly
Refrigerator	Unusual sound	Daily
Operating pressure of refrigerator	Pressure (high pressure and low pressure within normal range)	Weekly
Electronic force balance	Existence or nonexistence of overflow	Daily
Surrounding environment	Housekeeping	Daily

Fig. 5: Posting of routine inspection sheet (at entrance of experiment room)

4) Annual inspection

For overall inspection of the facilities, annual inspection is implemented every year for a duration of about two months. In the first month, the facilities stop their operation completely to enable inspection and maintenance. After completion of them (after restoration of the facility), the second month is used for comprehensive calibration and measurement of heat leakage. The major items implemented at the annual inspection are as follows:

- In-house calibration of each measuring instrument (Pt sensors, mercury thermometers, power meters, etc.)
- External calibration of each measuring instrument and a reference standard (quartz thermometers, fine pressure difference meters, flowmeters, etc.)
- Inspection and cleaning of humidifiers, cooling towers, etc.
- Measurement of insulation resistance of each section of the facilities
- In-house calibration tests using heater calibrator and repeat test unit (air conditioner for calibration)
- Measurement of heat leakage of a balanced ambient room-type calorimeter
- Measurement of heat leakage of an air receiving chamber of an air enthalpy test method
- Confirmation of measurement programs (version check by external organizations)

Though the annual inspection is significant both in terms of period and cost, it is important for testing laboratories (facilities) to maintain reliability and cannot be omitted.

Monitoring of effectiveness of tests

For control of testing accuracy, JATL keeps a record of results of particularly important items shown below. Also, if analysis of the results finds out any anomalies, the operation of the devices (or the facilities) in question will be stopped for investigation to determine the cause. The monitoring items and frequency are shown in Table 8 below.

Table 8: Monitoring items regarding effectiveness of tests

Monitoring item	Content	Frequency
Monitoring of effectiveness of Pt sensors	Compare temperature measurement results by a calibrated mercury thermometer with the measurement results (indicated values of measurement computers) by a Pt sensor.	At each test
Confirmation of reproducibility by heater calibrator	Install a heater calibrator, implement heating capacity test, and compare the ratio of electricity consumptions to heating capacity of the heater calibrator with the result in the past.	Once a year
Confirmation of reproducibility by in-house calibrator (air conditioner)	Implement cooling capability test by using in-house calibrator and make comparison with the result in the past.	Once a year
Confirmation of heat balance of indoor units and outdoor units	Monitor the ratio of capacity determined on indoor side to capacity determined on outdoor side (heat balance of indoor units and outdoor units).	At each test
Record of wet bulb wick replacement	Use wet bulb wick with a proper diameter for thermometer, which is appropriately be degreased for use in measurement. Inspect filth on wet bulb tray at the same time. Keep a record of wick replacement.	Each sample air conditioner

Standardization of testing work

In undertaking air conditioner performance test, calibration and maintenance of the facilities are important as noted above, and actual measurement work must be highly reproducible. The followings are the matters necessary for reproducibility.

1) Development of testing personnel

Development of the personnel responsible for testing (testing personnel) is one of the most important factors for ensuring high reproducibility in testing results. At JATL, the personnel undergo education and training under the development program as shown in Fig. 6, and only the members who have knowledge and skills necessary for conducting tests are allowed to be involved in testing duties.

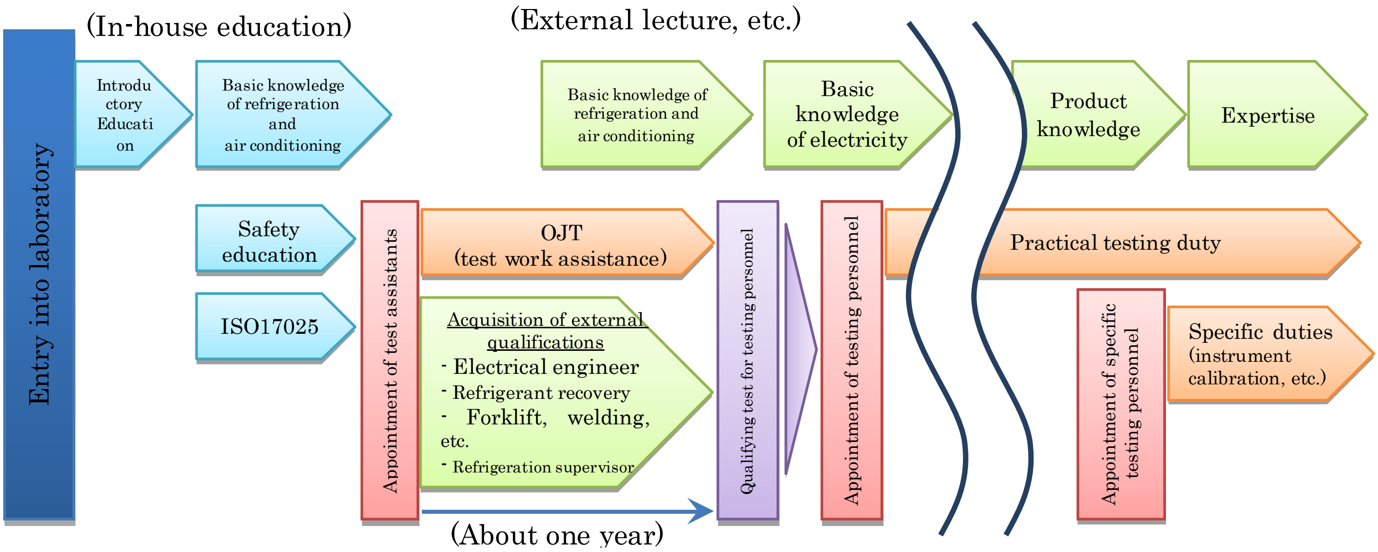
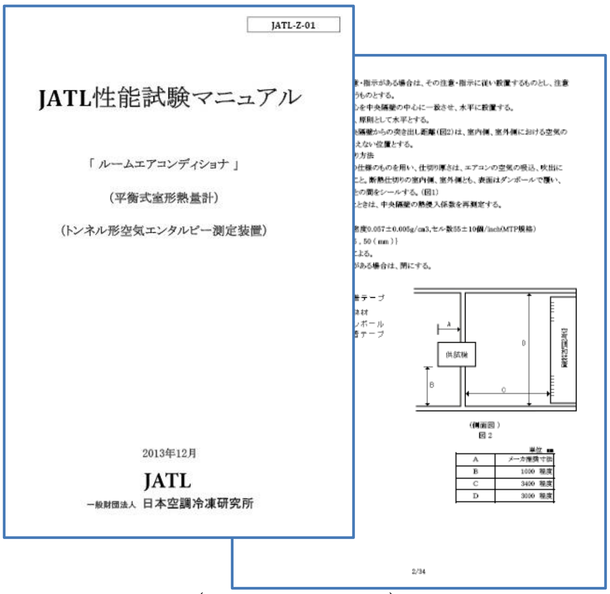


Figure 6: Testing personnel development scheme at JATL

2) Production of testing manuals

At JATL, in order to prevent variations in work of testing personnel, tests are performed based on their own manuals. The manuals have been produced in cooperation with the engineers at air conditioner manufacturers, who have been the members of JRAIA-hosted "Room Air Conditioner Inspection Technique Committee." The content of the manuals is based primarily on the testing standards (ISO 5151 or JIS B8615-1) and detailed testing methods that are not specified in these standards are set forth in line with the facilities of JATL. Also, when the testing standards for reference are revised, the manuals will be revised accordingly.

The manuals are translated into various foreign languages through a METI project to assist creation of energy-saving schemes, which are utilized in technical training provided by JATL in this project (see Fig. 7).



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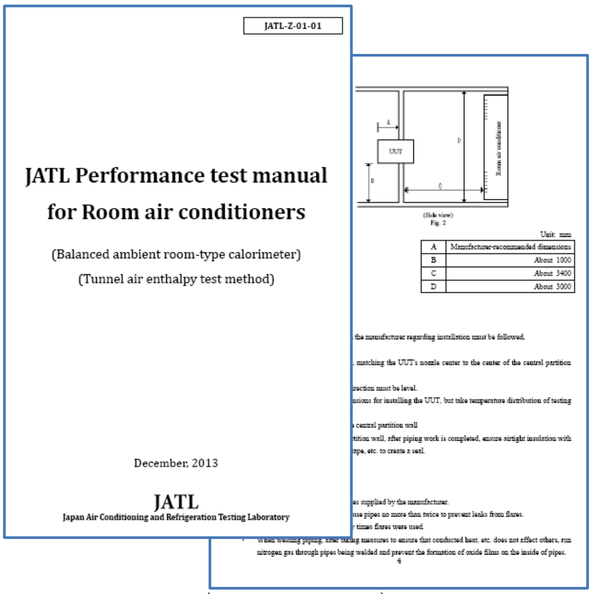

(English edition)

Figure. 7: JATL performance test manual

Uncertainty in measurement

In accordance with the requirements of ISO/IEC 17025 (Section 5.4.6), JATL estimates and calculates uncertainty in performance measurement. In addition, obtained uncertainty (relative uncertainty) is set forth in the test reports.

Regarding the method to estimate and calculate uncertainty, based on the guideline “JAB NOTE 6” published by a public interest incorporated foundation, Japan Accreditation Board and ISO technical specifications “ISO/TS 16491,” the JATL-hosted “The Society for the Study of Laboratory Uncertainties” established the method after discussion among the engineers of air conditioner manufacturers in Japan. The calculation method is shared among the respective manufacturers and the uncertainty values calculated with the standard common to the manufacturers are utilized to judge En value at the time of mutual calibration.

Also, estimation and calculation of such uncertainty deepen understanding of the error factors in the measurement of each measuring instrument and the entire facility thus contributing to the improvement of the facilities toward high precision.

Conclusion

Measurement of air conditioner performance is a complicated task, which consists of combination of various factors, and in order to obtain highly precise and reproducible results, calibration of each measuring instrument, maintenance of facilities and training of the personnel are important as described above. Moreover, in order to improve the reliability of measurement results, it is essential to prove appropriateness by continuously implementing mutual calibration with other reliable testing organizations and Round Robin Tests.

On the other hand, in recent years in Asian countries, development of performance testing facility has been in progress, in conjunction with the introduction of energy saving policies such as MEPS and labelling programs, however, it is not an easy task and takes long time to build reliable air conditioner testing facilities as described above. A central performance testing body to support the air conditioner qualification system in Japan, JATL is a reliable testing organization with steadily continuing efforts to realize high accuracy and continuously conducting mutual calibration with domestic air conditioner manufacturers. In the future, we believe that JATL's contribution in the improvement of accuracy and reliability of the performance testing organizations in each country through technical assistance, mutual calibration, etc. will bring mutual benefits to Japan as well as the entire Asian region.

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Role of Heat Pump in Environmental Protection

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Introduction

The Northeast states of India are the eastern-most region of India connected to East India via a narrow corridor squeezed between Nepal and Bangladesh. The key development issues and challenges are basically backward rural areas, poor connectivity within the states and with rest of India, lack of industrialization, accelerated growth rate of urban centres and environmental protection. These states are power deficit in spite of huge potential for hydro power generation but majority of rural and semi urban areas because of its difficult terrain are not connected to grid and these areas would remain off grid in future as well.

The few identified actions to provide appropriate solution to challenges are construction of educational, health centres, housing in the urban areas as well as in remote areas, development of tourism infrastructure and to generate employment and income for people living below poverty line and for unemployed youths.

The climate of these states could be described as cold as per climate classification by National Building Code (NBC-2005) of India. These states experience mild to severe winter for longer duration and mild summer for short duration.

In several parts which are at high altitude heating is predominantly required and where as in other parts like heating along with cooling is required. For heating, people in remote areas of North eastern region burn forest waste which is abundantly available. This burning of forest waste leads to carbon emission. The energy requirements required for heating spaces for providing thermal comfort and lighting are rapidly increasing due to high growth rate of development process. The key environmental issues in these areas are burning of twigs for heating which leads to deforestation and formation of carbon layer in atmosphere to pollute air and adds to global warming.

In order to combat this carbon emission generation due to burning of forest waste, low energy heating/cooling system or heating/cooling systems integrated with Renewable energy needs to be explored. With this objective in mind, a feasibility study for Geothermal based heat pump integrated with Solar Photovoltaic system was carried out in one of these states and a pilot project to demonstrate this model has already been started.

Proposed System for Pilot Project

The pilot project is designed for a space having day time occupancy and of the size of 51 ft *21 ft * 12 ft.

The proposed system would include Geo source Heat Pump (GSHP) for providing heating and cooling, geo-exchange system for cooling & heating water from GSHP, Solar Photovoltaic (SPV) system for providing electricity and one remote monitoring system to monitor the performance of the proposed system

Geo Source Heat Pumps (GSHP)

The detailed heat loads were calculated at first through computerized energy simulation. The peak cooling demand and heating demand of the selected space have been established as 4.6 TR and 7.5 kW. One outdoor unit (ODU) of 8 HP capacity and four indoor units (IDU) each of 1.5 TR capacities have been selected to provide required cooling and heating. The main reason for selecting Geo Source heat pumps has been lower inlet water temperature in heat pump during cooling and higher water inlet water temperature during heating which improve the efficiency and energy performance of heat pump.

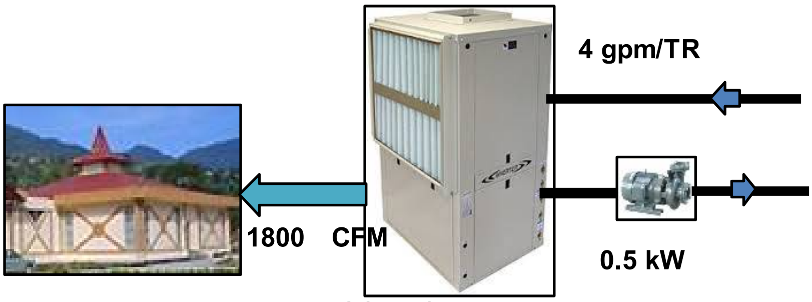

Figure 1: GSHP System

Geo-exchange system

It has been estimated that during peak conditions the heat exchange between soil and conduit carrying water from the outlet of the heat pump is approximately 21.1 kW before it cooled down or heated up to the desired temperature to the inlet of heat pump. The proposed geo-exchange consists of 5 parallel rows with connected ends, each of 90 feet having slinky HDPE pipe of 10 mm diameter and 1000 feet length laid in a trench having 90 ft*15 dimensions and at a depth of 12 feet below the ground. The total length of HDPE pipe is approximately 5000 feet.

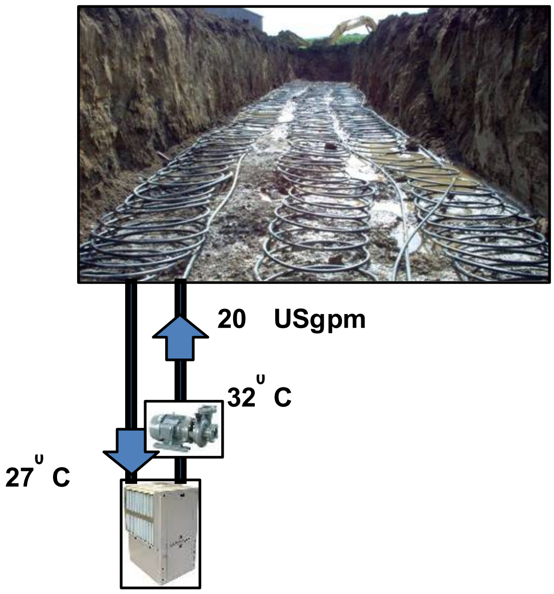

Figure 2: Geo-exchange System

Benefits of Geo-exchange based heat pumps

In cooling mode

A brief comparison between conventional water cooled heat pump and geothermal based heat pump (GSHP) is given below in table 2. It can be seen the COP of GSHP is 4.9 and is higher than COP of conventionally water cooled heat pump which is around 3.5

Table 1: Comparison between conventional and geothermal based heat pumps

Parameters	Conventional heat pump	Geothermal heat pump
Cooling medium	Water	Water
Water inlet temperature to condenser (deg C)	32	27
Water outlet temperature from condenser (deg C)	37	32
Air supply temperature from the evaporator	13	13
Room air temperature	24	24
Coefficient of Performance in cooling mode	**3.5**	**4.9**

The above mentioned parameters were fed in the energy model developed for heat load estimation and energy consumed by conventional water cooled heat pump and GSHP systems was calculated and the details are as given below

Energy consumption with conventional heat pump : 5486 kWh/yr
Energy consumption with geothermal heat pump : 3924 kWh/yr
Saving : 29%

Use of GSHP will result in a reduction of around 29% energy consumption.

In heating mode

Electrical boilers consume normally one unit of electricity per kW of heating generated through it. In comparison to it geothermal based heat pumps consume 0.7 unit of electricity to generate 1 kW of heating. The energy consumed by conventional electrical heater and geothermal heat pumps was calculated through simulation and the details are as explained below:

Energy consumption with conventional heat pump : 2004 kWh/yr
Energy consumption with geothermal heat pump : 1382 kWh/yr
Saving : 31%

The use of GSHP accounts for a reduction of around 31% in energy consumption when it operates in heating mode.

Water savings

In addition to energy savings, geothermal based cooling/heating system leads to water saving of up to 4gpm/TR which is equivalent to 20 gpm and is equal to 2880000 gallons of water in year* **Considering 10 hours a day for 250 days of the year*

Initial analysis shows that in cooling mode, geothermal based 5 TR heat pumps are 29% more efficient than conventional water based heat pump. In heating mode geothermal based heat pump is 31% more efficient that conventional electrical heater.

Integration with renewable source of energy

Compressor in heat pump requires electrical energy for its operation. This electrical energy could be offset through Renewable source of energy. One of the Renewable energy sources is Solar. Based on the size of geothermal heat pump, energy required per day by the heat pump and weather conditions of Itanagar, sizing of solar PV has been done and is shown in figure below: To offset the energy requirement of 5TR Heat pump, a 15 kWp solar PV system is required.

Parameters	Heat pump
Current requirement by Heat Pump	11 amp for 0-10 sec, 2.6-A from 12 to 1-Sec, from 16-Sec onwards, 6.3-A from
Operating hours	8 hours/day and 200 days/year
Energy generation through solar PV in Itanagar	2.8 kWh per kWp per day
Size of Solar PV to offset energy requirement of Heat pump	15 kWp
Battery Size	30 kWh/day
Area Required on Roof	1800 sqft

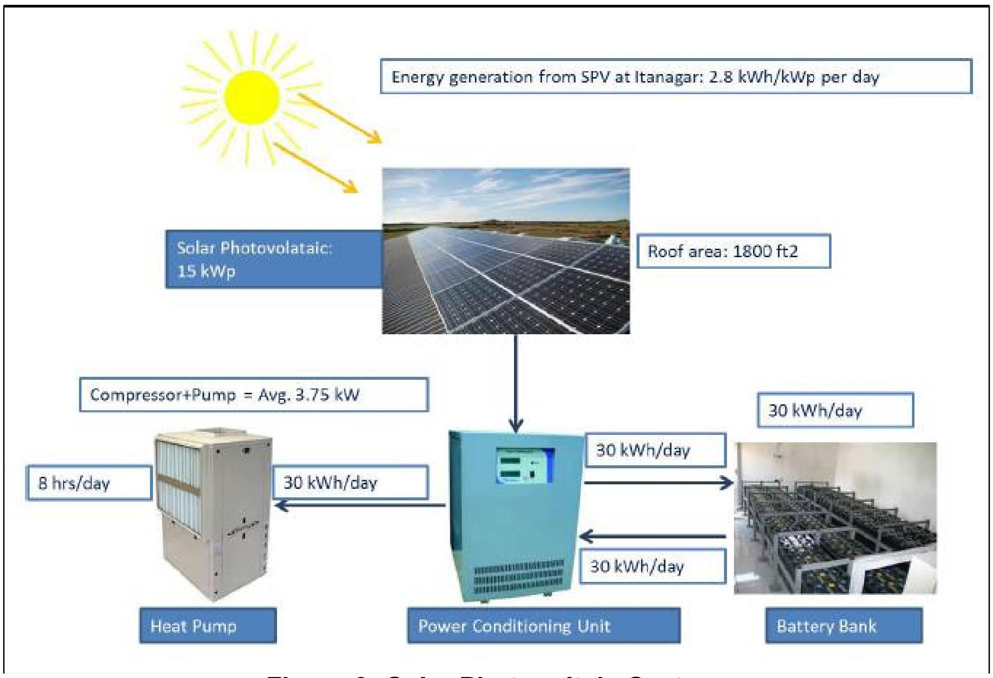

Figure 3: Solar Photovoltaic System

Designing of Remote Monitoring System

A remote monitoring system is proposed for simultaneous monitoring of different parameters that affect the performance of the system from different remote sites. Figure 10 below shows the various points which will be monitored and displayed by the remote monitoring system. These include:

- Energy generation from Solar PV
- Energy consumption of Ground Source Heat Pump
- Energy consumption of condenser water (geo-exchange) pump
- Ambient temperature and relative humidity
- Room temperature and relative humidity
- Temperature of water to and from geo exchange system

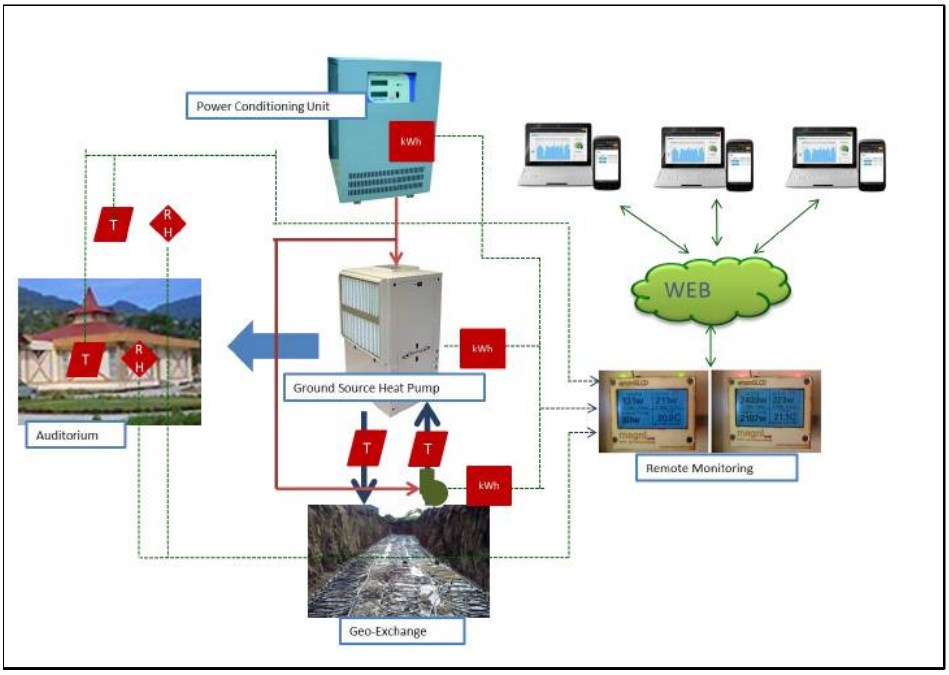

Figure 4: Remote Monitoring System

It is therefore, critical that policy interventions are put in place to improve energy efficiency in both new as well as existing buildings in these sectors. India has already identified buildings as one of the sectors in its fight against climate change. However, a long term policy initiative that encourages the development of cutting edge research and cost effective technologies can bring about step changes in the energy use in building.

Conclusion of Pilot Project

After successfully demonstrating this PV based GSHP system with geo-exchange system it would be possible to use this model in remote rural & semi-urban areas for health & institution services and areas which are connected by road but not connected to grid it would be very useful in application for tourist guest houses and offices. This would definitely be a very replicable solution for addressing many issues and challenges related to economic development, improving administration and most importantly proving clean solution for environmental challenges which almost all these states are facing badly.

Heat pump market in India

The following observation presents a strong case for heat pump market in India

- India represents huge potential for the consumer durable industry as the penetration level of space heating and cooling appliances is very low
- In spite of the erratic power supply in all Indian towns, more and more households are installing an air conditioners, and many have moved up to at least two in a household.
- Government policies & standards encourage energy efficient design or retrofit of buildings which requires energy efficient spaces heating and cooling appliances.
- India is still a power deficit country and due to increase in use of air conditioners and heaters, the gap in demand and supply will increase and in order to combat this every increasing gap energy efficiency appliances are required.

Barriers

- Indian has already launched star labeling programs for air conditioners but there is no program which supports exclusive use of air source heat pumps in India
- Initial cost of heat pump is almost double of a normal air conditioner.

Recommendations

- Campaign on heat pump needs to be initiated. The campaign needs to be financially supported either from the funding by AHPNW or from the different manufacturer's.
- Pilot studies for different applications need to be undertaken more with appropriate monitoring system to instill confidence in potential users
- Results of the Pilot study needs to be published and information should be disseminated through printed brochures, e brochures.