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ASIAN HEAT PUMP & THERMAL STORAGE TECHNOLOGIES NETWORK

NEWSLETTER

Heat Pump & TES's current situation in each country

（China, Japan, Korea）

CONTENT

Asian Heat Pump & Thermal Storage Technologies Network

http://www.hptcj.or.jp/e/ahpnw/tabid/571/language/en-US/Default.aspx

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HEAT PUMP MARKET AND TECHONOLOGIES IN REPUBLIC OF KOREA

This paper is to report Korean market situation of and change in technology development of heat pump which is in the spotlight as an alternative to heating and air conditioning using the existing equipment used fossil fuel, and to prospect the heat pump market and technology of Korea to mitigate CO2 emission for the future.

SAVING ENERGY BY UTILIZATION OF THERMAL ENERGY STORAGE (TES) AIR CONDITIONING SYSTEM

The nuclear power station accident caused by the great earthquake and tsunami in March 2011 had put Japan into a tight electricity demand and supply situation. Even in such situation, the buildings equipped with TES were fully able to provide cooling, while contributing to “electricity saving (reduction of peak power)” as well as realizing energy saving. In addition, the advantages of a TES as an effective responsive measure for disaster prevention, that water in its TES tank can be used for daily life or fire fighting purpose, begin to be recognized anew. Now is a good time to publicize the benefits of a “TES air conditioning system which is designed to assist the heat pump” as an energy efficient equipment, in terms of higher efficiency of equipment and systems, energy saving, CO2 emissions reduction, peak load leveling and disaster response.

OVERVIEW ON COOL STORAGE INDUSTRY DEVELOPMENT IN CHINA

Advanced in “peak load shifting”, grid load balancing, and operation cost saving by taking advantage of the price difference between peaks and through, cool storage air-conditioning system has got wide application in recent years. This article addresses the contribution of cool storage air conditioning system to both nation and consumer under the current Chinese energy and electrical situation, introduces time of use (TOU) policy and cool storage incentives policy of central and local government as well as the industrial standard code. The application character of cool storage air conditioning technology in China mainly on water storage and ice storage are presented. Latest achievements and hot point in technology research are introduced. The existing problems in application and methodology of system evaluation are summarized. Suggestion for future development in support system and application are proposed.

HEAT PUMP MARKET AND TECHNOLOGIES IN REPUBLIC OF KOREA

Jun-Young CHOI, Republic of KOREA

Abstract

This paper is to report Korean market situation of and change in technology development of heat pump which is in the spotlight as an alternative to heating and air conditioning using the existing equipment used fossil fuel, and to prospect the heat pump market and technology of Korea to mitigate CO2 emission for the future.

Introduction

Recently, International Energy Agency (IEA) is promoting a research to estimate national performance indicators for heat pumps to quantify CO2 reduction, and based on it there is a move to formulate the amount of energy savings. Also International Organization for Standardization (ISO) is conveying the utility of and fostering the penetration of heat pumps to governments and consumers by establishing Annual Performance Factor (APF) to define the amount of annual energy consumption.

Residential, commercial and public buildings account for approximately 24% of total energy consumption in Korea, therefore energy efficient buildings are indispensable to realize a green developed country as it is strongly required to reduce energy. Air conditioners which account for the largest energy consumption in buildings have used 28% thermal energy and 13% electricity of total energy consumption in Korea. Because the thermal energy is mostly consumed in the housing and building sector (housing sector 90%, business sector 8%, public sector 2%), when the housing and building sector use energy efficiently by making the thermal energy consumption high efficient, absolute savings of national energy and reduction of CO2 emission are possible.

The heat pump used for high efficient cooling and heating in buildings are recognized as an alternative to existing primary heat resource device and needs of technology development and market of the heat pump are growing as the major means in response to Framework Convention on Climate Change. With these circumstances this paper is to summarize current Korean market situation of and change in technology development of a heat pump which is in the spotlight as an alternative to heating and air conditioning using the existing equipment used fossil fuel, and to prospect the heat pump market for Korea to mitigate CO2 emission for the future.

Market

The worldwide market for heat pumps is heating up recently. As the heat pump rises as an alternative energy appliance to the fossil fuel, it grows fast with Europe as the center. The heat pump market which was as large as shipbuilding market with a 61.5 billion dollar valuation in 2008 is expected to increase rapidly up to 170 billion dollars in 2012. Particularly, residential heating market using the heat pump has sharply increased by more than 53% annually in global.

According to the change in the market, European Union (EU) passed legislation to include the aero thermal, geothermal or hydrothermal energy captured by heat pump in renewable energy and major European countries such as France, Belgium and Netherland encourage penetration of heat pumps through various subsidy benefits. Japan boasts the world's best technical skills in the heat pump field and with COP of 6 or more heat pump water heater to use natural refrigerant CO_2 is already commercialized. Also, Japan takes the lead by showing a different product family such as residential heat pump water heater called ECO CUTE and heat pump hot water floor heating etc. It is because of Japanese government's active supports and businesses' efforts for technology development.

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.

As of 2008, the number of sales of air-conditioner in Korea, the fourth producer in worldwide air conditioning market, was 1.26 million units (residential air-to-air cooling only unit), whereas the share of heat pumps was around 5%, which is low level. (See [Figure 1]) Even it is concentrated on the commercial VRF market. (See [Figure 2]) The main reason is that as most of the population lives in high-rise apartments and condominiums in downtown, they prefer to room air conditioner for cooling considering installation space. Currently, technological level does not satisfy demands of consumers, therefore they refuse to use heat pumps psychologically, which is showing different phenomenon from Japan and China. In addition, owing to Korean traditional Ondol culture, a floor heating system which circulates hot water from a boiler, a fossil fuel appliance, is chosen for living space.

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 62 million US$ market in 2008. But, air-to-air heat pump is dominant in Korean market, even there are a limited demand for air-to-water, water-to-water, and water-to-brine heat pump for commercial and industrial sector. This market is not easy to analyze because of lack of data. With renewable incentive benefit geothermal heat pump has grown up steadily every year. (See [Figure 3]) For geothermal heat pump market water-to-water type is dominant because school, public and commercial buildings adopt geothermal system.

In case of Korea, electricity bill has increased by 25% for 20 years, on the other hand, the price of LNG and kerosene has soared sharply. Currently, heat pump have enough competitiveness in the commercial and industrial sector to which progressive stage system does not apply considering electricity and gas bill. Residential heat pumps are expected to be competitive when stable power supply is possible as electricity dependency gets higher by nuclear energy for the future.

Moreover, it is anticipated that the market share of heat pumps will increase dramatically as energy source and the scope such as advancement of development technology for heat pumps, the rise of eco-friendly issues, the increase in fuel price and renewable energy are getting diversified. The heat pump in domestic market is expected to grow continuously in the sector of skyscrapers and commercial buildings (restaurants etc.) and to form a market in residential sector as an alternative to a boiler.

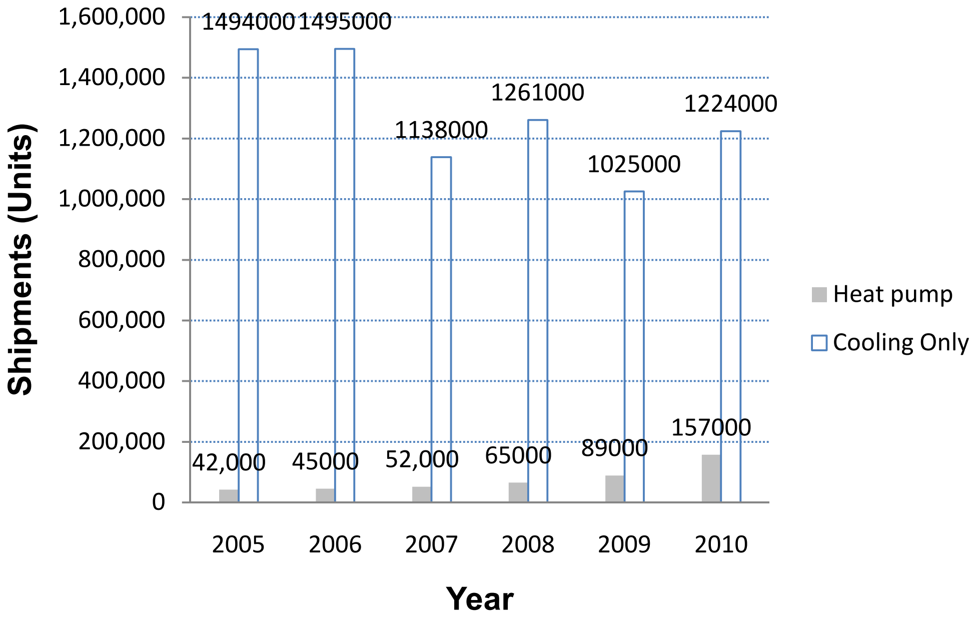

Figure 1.Shipments of residential air-to-air heat pump and cooling only air-conditioner under 23kW cooling capacity

*Source from KEMCO(Korea Energy Management Corporation) annual report 2011

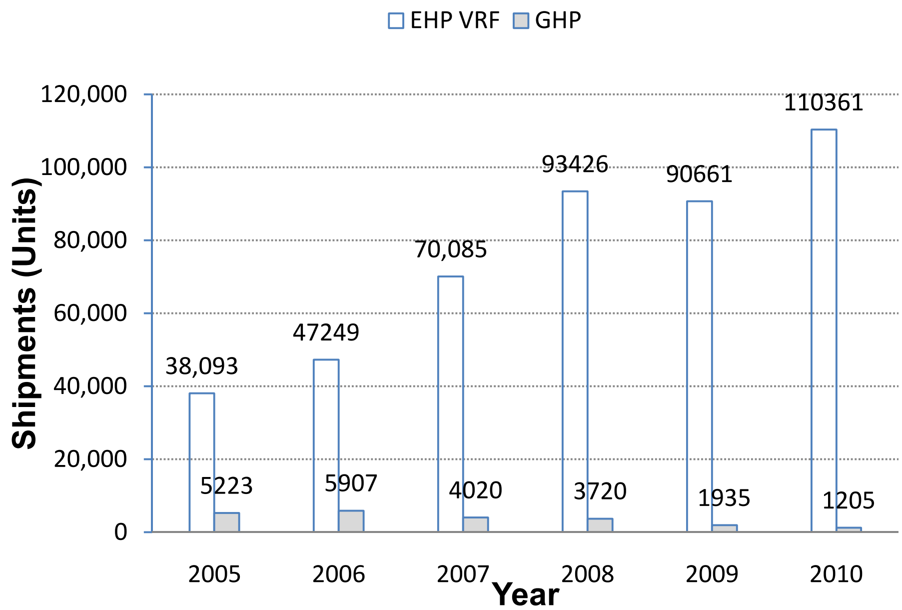

Figure 2.Shipments of EHP VRF and GHP

Remark : EHP VRF is variable refrigerant flow system by electric heat pumpGHP is gas driven heat pump
*Source from KRAIA(Korea Refrigeration and Air conditioning Industry Association) statistic data 2011

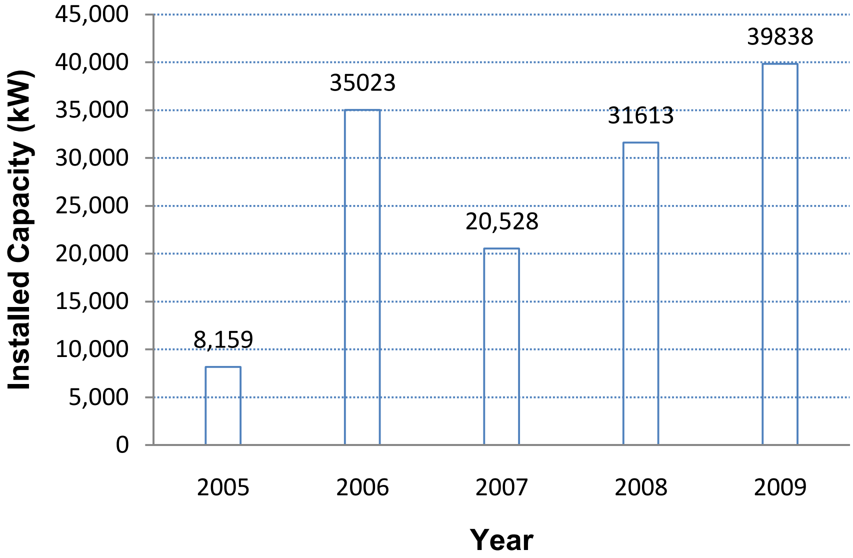

Figure 3.Installed capacity with geothermal heat pump

Remark : 1RT is 3.5kW
*Source from REC(Renewable Energy Center), 2009 report

Technology

Until now, technology development for high efficient and eco-friendly heat pumps has progressed largely and R&D for compressor technology, improvement of a product structure and a heat exchanger, microprocessor control method and solution is proceeding actively. Especially, amid the anticipation of investment on and development for high-technology for heat pump water heaters, systematic production and R&D technology infra of the Industry-University-Institute are getting larger recently.

In green energy strategic roadmap 2011 by government, heat pump sector is selected as “The domestic market expansion and achievement of international competitiveness through the development of new concept heat pumps”. The goal is to increase localization rate and technology level, which have showed 90% and 85% respectively until last year, up to 100% both of them by 2030, and on the basis of that to raise 8% global market share to 20% in 2030. Government acknowledges that the heat pump reducing CO2 emission significantly as a single technology is an energy technology to replace existing primary heat source system, and recognizes necessity for technology development as a main means to respond to convention on climate change.

For promoting the heat pump industry, roadmap divides R&D program into commercialization and original technology development. ‘Refrigerating, Air Conditioning and Freezing’ unified in a heat pump system and middle capacity air to water (ATW) heat pump system are focused on commercialization. Firstly, the project is to promote domestic market and to carve out international market by developing ‘Refrigerating, Air Conditioning and Freezing’ unified in a heat pump system with high marketing opportunities based on VRF heat pump technology. This strategy is like killing three birds with one stone in that it encourages a product family ensuring for export strategy based on domestic supply, improves energy efficiency and reduces CO2 emission in the aspect of market and technology.

A middle capacity ATW product family(See [Figure 4]), is predicted to greatly grow market and technology for the future, is fostered in the aspect of environmental protection and energy conservation according to using renewable energy. This plan is also for commercialization of ATW heat pumps that replace existing heating and cooling system used along with combination of a boiler and a chiller which use primary energy. At the same time, it says to focus on original technology development because technology development for ‘Middle-Capacity, Hot-Water Multistage-Compression Heat Pump System’ and ‘Heat Pump System Using a Latent Heat Storage’ which are available for waste heat recovery and use in industrial processes get more important in the heat pump market in the long term.
Particularly, roadmap has proposed measurement to improve regulation for boosting heat pump industry. There are inclusion of renewable energy facilities and classification of high efficient appliances, giving incentives for high efficient heat pump products, granting extra points when adopting design and exception from objective of designating a freezer safety operator in high pressure gas safety control act etc.

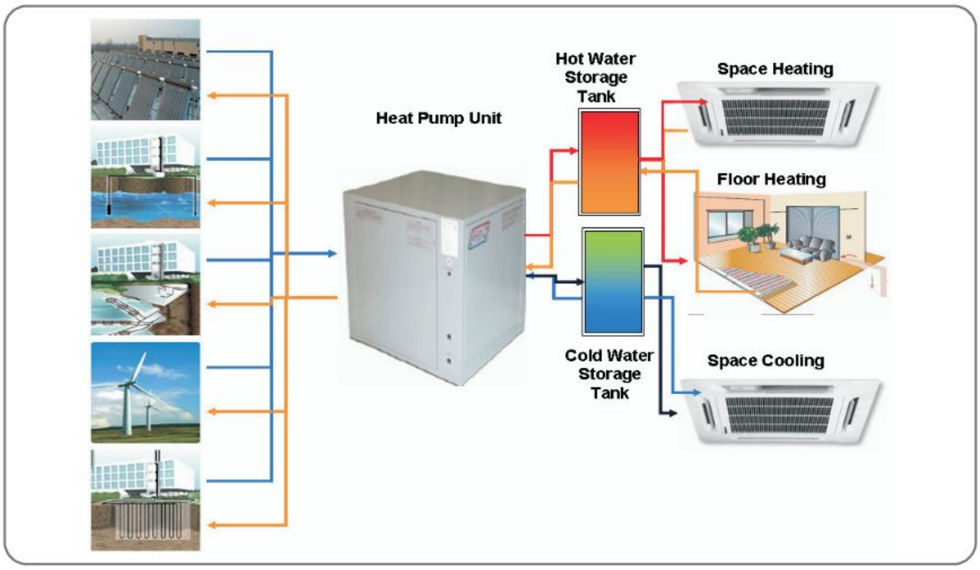

Figure 4. High efficient heat pump water heater with hybrid source

*Source from KETEP, “Green Energy Strategic Roadmap for Heat pumps”, 2009 report

Conclusion

Even though Korean heat pump market is comparatively small, recently government is struggling to deal with climate change and energy problem by expanding the heat pump market as one of products for a dynamic force for new growth in accordance with promoting green energy industry. In the future, 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. Government endeavors to support for technology development and to systemize certification of performance, standard, quality and test regarding devices and system of heat pumps by selecting the heat pump as one of 15 green energy sectors of the green energy strategic roadmap. If this effort comes to fruition, it can achieve a very large effect nationally as the major means corresponding to convention on climate change and promote to be an internationally competitive industry by fostering export-intensive industry.

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Saving energy by utilization of thermal energy storage(TES) air conditioning system

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Abstract

The nuclear power station accident caused by the great earthquake and tsunami in March 2011 had put Japan into a tight electricity demand and supply situation. Even in such situation, the buildings equipped with TES were fully able to provide cooling, while contributing to "electricity saving (reduction of peak power)" as well as realizing energy saving. In addition, the advantages of a TES as an effective responsive measure for disaster prevention, that water in its TES tank can be used for daily life or fire fighting purpose, begin to be recognized anew. Now is a good time to publicize the benefits of a "TES air conditioning system which is designed to assist the heat pump" as an energy efficient equipment, in terms of higher efficiency of equipment and systems, energy saving, CO2 emissions reduction, peak load leveling and disaster response.

Introduction

Please take a look at the photograph (Figure 1).
We can read the following: "We are saving electricity with TES air conditioning system. By providing cooling load by the cool heat stored at night this building contributes to cutting the peak power during the day."
This is a sticker proposed by myself, the author of this paper and created by HPTCJ for distribution to the buildings equipped with TES.
I would like to explain the background of this sticker and the situation of TES in Japan.

Figure 1: Saving energy by utilization of TES air conditioning system

Occurrence of Great East Japan Earthquake

The largest earthquake around Japan in recorded history occurred at 14:46:18 (Japan Standard Time) on March 11, 2011, with a hypocenter in a sea bed in the Pacific 70 km east offshore from Sendai City in the Tohoku region of Japan.
The earthquake triggered the giant tsunami with waves higher than 10 m and the maximum run up height of 40.1 m recorded in some areas, which devastated the coastal areas. In addition to the giant tsunami, the earthquake caused strong shaking and damages in greater areas, including ground liquefaction, ground sinking, and break of the dam, resulting in breakdown of various utility service systems.

As of July 10, 2013, it was officially confirmed that the earthquake caused 18,550 people dead or missing and destroyed 398,711 homes totally or partially. At the peak time immediately after the occurrence of the earthquake, it was reported that the disaster forced over 400,000 people to evacuate, cut power to more than 8 million homes, and cut off water supply to more than 1.8 million homes. (Compiled from the information of Wikipedia)

Power supply situation in Japan after occurrence of earthquake

The earthquake and the tsunami triggered a nuclear accident at Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company (TEPCO), which involved a series of radioactive substance releases, including core meltdown. The accident prompted TEPCO to implement “planned power outage,” which affected residential houses as well, for a half month in its service area. Also, in order to avoid power crisis in summer, “Civil Power Consumption Restriction Code” which mandates large-volume users contracted for at least 500 kilowatts to reduce their peak power usage by 15%, compared with the last summer, under applicable laws was implemented for about two months in the service areas of TEPCO and Tohoku Electric Power Company. As a result, many buildings were put into a situation to restrict greatly the use of air conditioning systems, not to mention production activities. (See Figure 2)

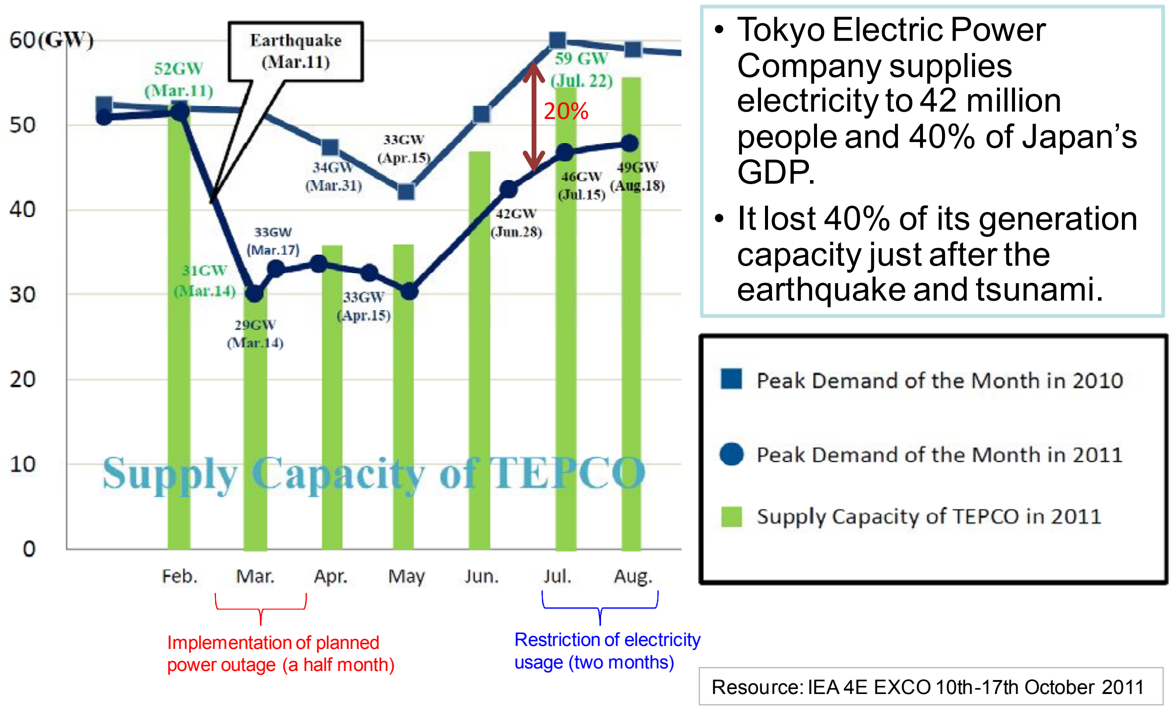


Figure 2: Status of ensuring supply capability of TEPCO after the earthquake

Then, against the background of social circumstances such as safety concerns, nuclear power stations in Japan stopped their operations one by one when they need to undergo periodic inspection. In May 2012, all of the 50 nuclear reactors in Japan were out of operation, leading to a state in which no nuclear reactors were in operation. However, as concerns over power shortage were rising in the service area of Kansai Electric Power Company, the company resumed operations of only Units 3 and 4 of Oi Nuclear Power Station in September 2012, which are scheduled to stop operations in September 2013. Resumption of operations of the two reactors as well as all other reactors will be decided by the government after these reactors pass the safety evaluation to be conducted by the Nuclear Regulation Authority.

Figure 3 shows the electricity demand and supply and capability margin forecasts of respective electric utilities for August 2013.

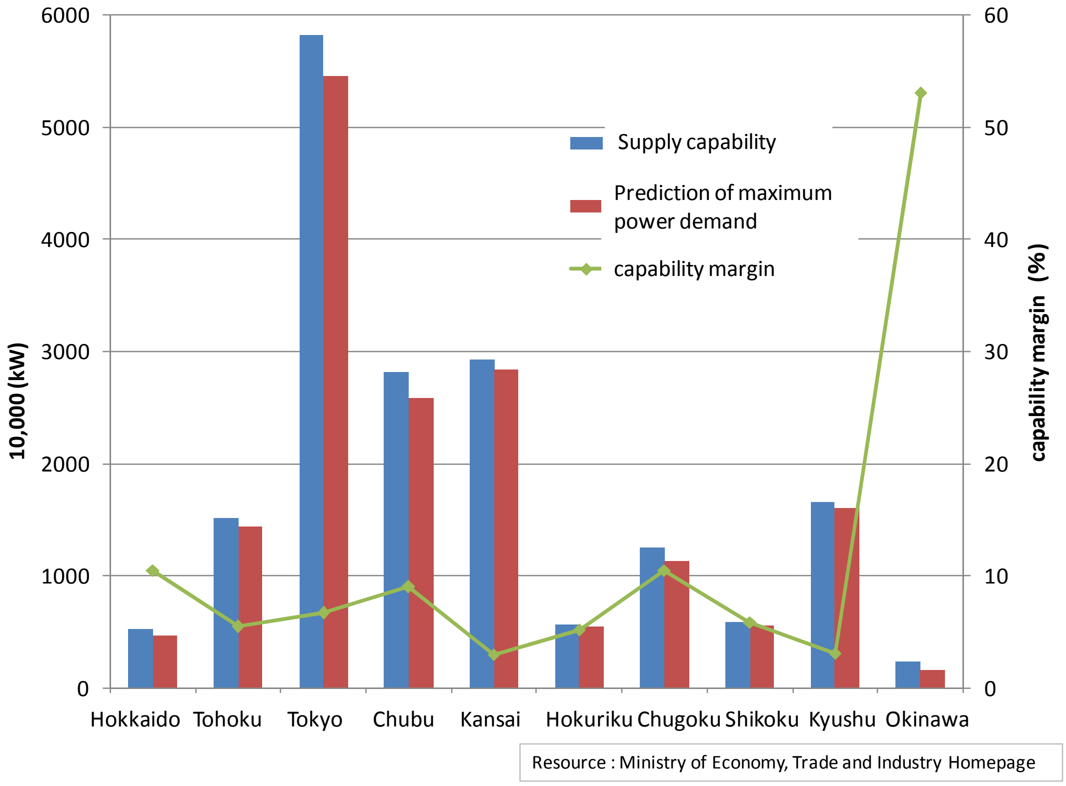


Figure 3: Electricity demand and supply forecast for August 2013 (by electric utility)

Role to be played by TES air conditioning system

Even in a tight electricity demand and supply situation described above, the buildings equipped with TES were sufficiently able to provide cooling. The people visiting a building with a TES might have questions: “Why is this building able to provide cooling?” or “Civil Power Consumption Restriction Code isn’t obeyed?” The aforementioned sticker is created with an intention to avoid criticism against antisocial practices that the people might have. It is needless to say that its true intention is to publicize the fact that such buildings are fully able to provide cooling, while contributing to “electricity saving (reduction of peak power)” as well as realizing energy saving.

Figure 4 presents the excerpts from the leaflets which select several buildings with measurement data before and after the great earthquake from various buildings equipped with heat pump and TES, in order to describe the situations “before and after electricity saving.” The leaflets were created by HPTCJ for distribution to the building owners and other people concerned to let them know the fact (that a building with a TES is able to reduce power load). Though many engineers understand the benefits of a TES as a theory, the fact is that they do (or did) not have opportunities to know the benefits based on data. We believe that the advantage of a TES would have a great impact when restriction on cutting the peak power is actually imposed.

Japan

Purpose：Office

Installation case of TES system coupled to heat pump

TES Category: Air Conditioning With ice storage

Peak electricity 14% reduction

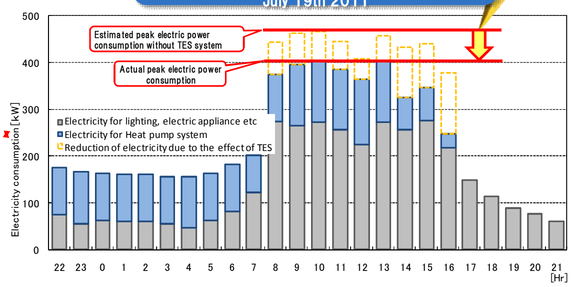
Chofu city

City hall

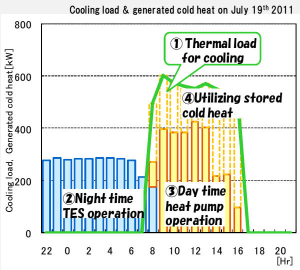
Total floor area	14,123㎡
Number of floors	8 floors, 1 basement floor

14% reduction of peak electricity is achieved !! (Summer daytime)

Electric Power consumption on typical summer day July 19th 2011



Explanation of TES operation coupled to heat pump unit



①Thermal load for cooling
Cooling operation hour is from 8 to 17.

②Night time TES operation
Entire cold heat, generated by heat pump night time operation(22pm-8am) is stored. This system allows storing about 30% of cooling load of the day

③Day time heat pump operation
Air source heat pump chiller is operated to cover base load. Day time operation mode is determined considering residue of cold heat in the tank and cooling load.
In this case the number of the operation unit is decreased from 14pm.

④Utilizing stored cold heat
Cold heat, generated night time operation, covers certain amount of cooling load. Consequently, this TES operation allows decreasing day-time electric power consumption and decreasing heat pump capacity as well.

Purpose：Office

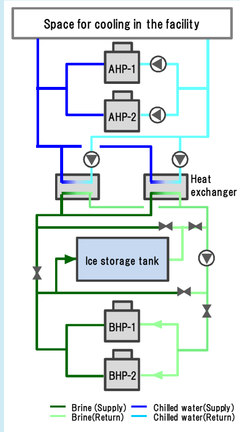
Installation case of TES system coupled to heat pump

Chofu city

Chofu city hall

Overview of heat pump system

Heat pump system configuration



In this facility, two air source brine heat pumps(BHP-1,2) are operated at night to store cold heat in the tank of internal ice melting system. Cold heat in the tank and two air source heat pump chillers(AHP-1,2) provide cold heat for space cooling in day time.

This TES system allows to provide enough cold heat without BHP-1,2 daytime operation.

Thanks to this TES system, total amount of electricity shift to night time is 11% of total amount of electricity in this facility.

[Heat pump unit specification]

Equipment title	Number of unit	Specification		
air source heat pump chillers AHP-1～2	2	Cooling capacity		205 kW
		Heating capacity		236 kW
air source brine heat pump BHP-1～2	2	Cooling Capacity	(Night time operation)	149 kW
			(day time operation)	190 kW
		Heating capacity		225 kW
Ice storage tank	1	Tank capacity/ TES capacity		65 m³/2,222 kWh

Overview of the facility

Location
West part of Tokyo metropolitan.

Motivation for TES
Chofu city lays emphasis to counter measure for global warming.
This system is introduced as ESCO project.

Remarks(Incentive, Award etc)
This system got a gold prize ESCO Award in 2007 owing to high saving energy performance.

ヒートポンプ・蓄熱センター

Purpose：Office

Installation case of TES system coupled to heat pump

TES Category: Air Conditioning With water storage

Peak electricity 29% reduction

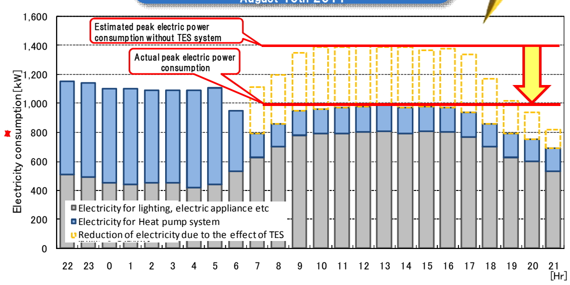
J-Power (Electric Power Development Co. ,Ltd)

J-Power head quarter office building

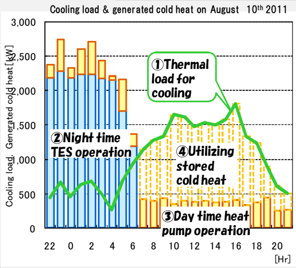
Total floor area	34,326㎡
Number of floors	16 floors

29% reduction of peak electricity is achieved !! (Summer daytime)

Electric Power consumption on typical summer day August 10th 2011



Explanation of TES operation coupled to heat pump unit



①Thermal load for cooling
Air conditioning system is operated all day for server room cooling.

②Night time TES operation
Cold heat, generated by turbo refrigerator in night time operation(22pm-8am) is stored. This system allows storing cold heat in the water tank about 70% of cooling load of the day

③Day time heat pump operation
Air source heat pump chiller is operated all day for server room cooling.

④Utilizing stored cold heat
Cold heat, generated night time operation, allows covering total cooling load except server room load.
Consequently, this TES operation allows decreasing day-time electric power consumption.

Purpose：Office

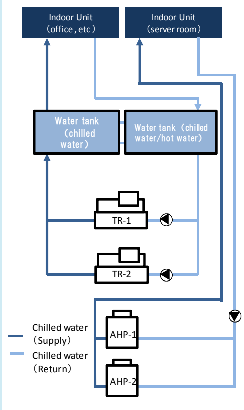
Installation case of TES system coupled to heat pump

J-Power (Electric Power Development Co.,Ltd)

J-Power head quarter office building

Overview of heat pump system

Heat pump system configuration



In this facility, two turbo refrigerator and two air source heat pump chillers are operated.
TRs are used for cold heat storage at night, while AHPs are used for server room cooling all day long in summer.
Hot water storage is operated by using TRs waste heat and AHPs operation in winter.

This TES system allows to provide enough cold heat for space cooling except server room owing to the effect of high storage water temperature difference in the tank.

[Heat pump unit Specification]

Equipment title	Number of unit	Specification	
Turbo refrigerator (Heat recovery) TR-1	1	Cooling capacity	1,230.7kW
		Cooling capacity (heat recovery)	1,125.2kW
		Heating capacity (heat recovery)	1,411kW
Turbo refrigerator TR-2	1	Cooling capacity At day time	1,266kW
Air source heat pump chiller AHP-1～2	2	Cooling capacity	315kW
		Heating capacity	315kW
Water tank (chilled water)	1	Tank capacity	1,200m³
Water tank (chilled water/hot water)	1	Tank capacity	1,300m³

Overview of the facility

Location
Tokyo metropolitan.

Motivation for TES
As a Electric power provider company, J-Power actively works for saving energy technology and decreasing peak electric power demand

ヒートポンプ・蓄熱センター

Figure 4: Example of cutting the peak power in daytime by utilizing TES

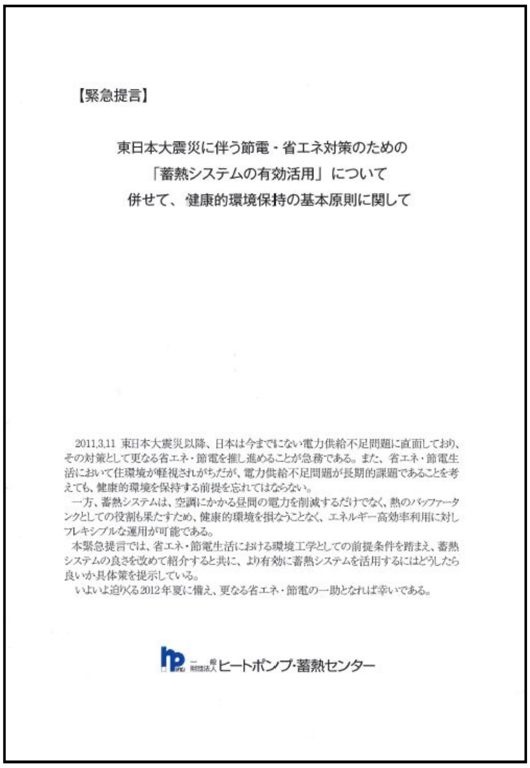
Urgent proposal

Also, HPTCJ officially announces on its website; "Urgent proposal: Effective use of a TES for saving electricity and energy after the Great East Japan Earthquake …as well as the basic principles of preserving a healthy environment." (See Figure 5)

The proposal consists of "1. Pre requisites from a standpoint of environment engineering for a life of saving energy and electricity," "2. Need to recognize the limit of setting an energy-saving temperature of 28℃," and "3. Need to recognize again the advantages of a TES."

In these descriptions, the following are being insisted:

1) With the basic principle of maintaining a healthy living environment, even in a case that comfort needs to be neglected at the time of emergency evacuation, policies and practices should be implemented under the principle of a healthy living environment, including adjustments to human actions (adjustments to clothing).
2) Although it is needless to say the universal significance of energy saving and CO_2 emissions reduction, it is required to consider the time of emergency evacuation and the time of daily living separately; and we should refrain from excessive expectations for natural energy and renewable energy.
3) The advantages of a thermal storage system, which can adjust quantitative or temporal balance between heat demand and supply, should be appreciated anew.



【緊急提言】

東日本大震災に伴う節電・省エネ対策のための
「蓄熱システムの有効活用」について
併せて、健康的環境保持の基本原則に関して

2011.3.11 東日本大震災以降、日本は今までにない電力供給不足問題に直面しており、その対策として更なる省エネ・節電を推し進めることが急務である。また、省エネ・節電生活において住環境が軽視されがちだが、電力供給不足問題が長期的課題であることを考えても、健康的環境を保持する前提を忘れてはならない。

一方、蓄熱システムは、空調にかかる昼間の電力を削減するだけでなく、熱のバッファータンクとしての役割も果たすため、健康的環境を損なうことなく、エネルギー高効率利用に対しフレキシブルな運用が可能である。

本緊急提言では、省エネ・節電生活における環境工学としての前提条件を踏まえ、蓄熱システムの良さを改めて紹介すると共に、より有効に蓄熱システムを活用するにはどうしたら良いか具体策を提示している。

いよいよ迫りくる2012年夏に備え、更なる省エネ・節電の一助となれば幸いである。

一般財団法人 ヒートポンプ・蓄熱センター

Figure 5: Urgent proposal

Utilization for disaster prevention

In addition, the benefits of a TES for non-energy purpose draw new attention after the occurrence of the great earthquake. In other words, an idea is emerging that we should use water in TES tanks for lavatory flushing and fire fighting in case of disaster. Figure 6 indicates an image of utilization of a TES tank in case of disaster.

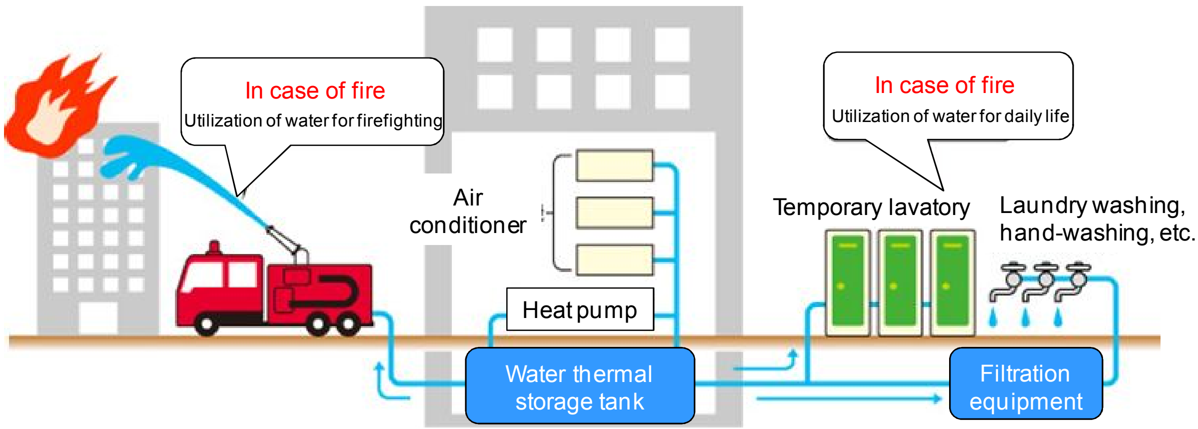


Figure 6: Image of thermal storage tank utilization in case of emergency

Figure 7 shows “Linked Vertical TES tanks” installed at the campus of the university where I work. The tanks are effectively used for heating and cooling purposes, while usually serving as Linked Vertical TES tanks to reduce electricity demand in peak period by decreasing transport power for dispersed secondly pumps. But when disaster occurred, the tanks can supply their water for general purposes only by using gravity to the classroom buildings (which are assumed to be used as a disaster prevention and evacuation site with numerous lavatory facilities). Furthermore, we have another idea that the other tank (rain water tank) should also be used for sewage water storage if sewer systems become out of service.

Figure 7: Linked vertical TES tanks

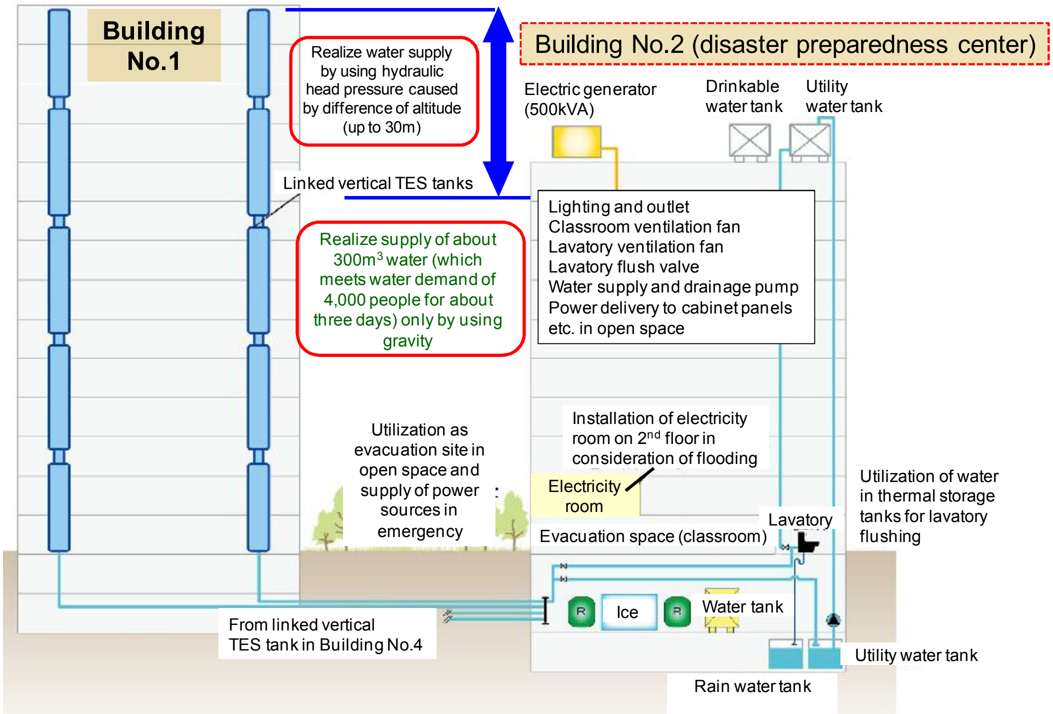


Figure 8: TES tank utilization scheme in case of emergency (Tokyo Senju Campus of TDU)

Conclusion

As situations at the time of and after the great earthquake are described so far, now is the time for us to pay more attention to the benefits of a “TES air conditioning system which is designed to assist the heat pump” as an energy efficient equipment, in terms of higher efficiency of equipment and systems, energy saving, CO2 emissions reduction, peak load levelling or disaster response.

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Overview on cool storage industry development in China

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Abstract

Advanced in "peak load shifting", grid load balancing, and operation cost saving by taking advantage of the price difference between peaks and through, cool storage air-conditioning system has got wide application in recent years. This article addresses the contribution of cool storage air conditioning system to both nation and consumer under the current Chinese energy and electrical situation, introduces time of use (TOU) policy and cool storage incentives policy of central and local government as well as the industrial standard code. The application character of cool storage air conditioning technology in China mainly on water storage and ice storage are presented. Latest achievements and hot point in technology research are introduced. The existing problems in application and methodology of system evaluation are summarized. Suggestion for future development in support system and application are proposed.

Introduction of China building energy consumption and electrical demand

Power consumption and installed electricity capacity grows rapidly with the increasing of urbanization and industrialization levels in China. Total electricity consumption increases from 1.35 trillion kWh in 2000 to about 4.19 trillion kWh in 2010. The total installed electricity capacity increased from 357 million kW to 792 million kW from end of 2002 to end of 2008. Annual average production increased from 70 million kW to 2011's 1.05 billion kW.

With the rapid growth of installed electricity capacity, widespread power shortage situation has been eased to some extent. However, due to the increase of power demand and variation in the electricity structure, power shortage still exists, in the form of low grid load factor, electricity deficiency at its peak, and non-fully utilization of electricity at its trough.

Electricity structure analysis reveals that industrial electricity consumes a larger proportion, which accounts for about 73% in 2011, while building electricity accounts for only 21%. Although not as high as the industrial one, building electricity consumption occupies a bigger proportion in the peak electricity load, and we see a growing trend.

With the rapid increase in the domestic construction floor area, together with the proportion of public buildings (higher power consumption), comfort level and city heat island effect, the demand for central air conditioning grows accordingly, as well as the proportion of building cooling power consumption. In the summer peak period, building cooling electricity load accounts for more than 30% of the city peak load. According to field measurement data, cooling power consumption account for 45-65% for public buildings. The gap between peak and valley period increases gradually, with more serious problem of unevenness in grid operation.

Values of cool storage air conditioning

1. National level

If excessive power facilities were constructed only to ensure electricity for peak enormous costly power facilities would be either at idle state or low load factor for most of the time, which thereafter carries the cost into electricity rate. In addition, construction of those excessive power facilities would inevitably consume large amount of materials and energy, putting on negative influence to the environment.

Application of cool storage technology is an alternative to new construction for power plants, which requires much less investment, and shorter construction period. Through effective “peak load shifting”, the pressure of high electric demand and power facilities could be eased significantly, and the full use of existing generating capacity could be taken advantage of to meet user' needs.

To achieve "peak load shifting" , application of cool storage technology on the user side can not only reduce the peak electricity demand for electricity production, but also improve the load level in the valley period. This would not only ease the pressure on peak power demand and unit kurtosis modulation operation, but also stabilize unit load levels of power plant and improve plant operating conditions.

Stable and efficient operation of generators under economic conditions could reduce units installed capacity under poor operating conditions or shorten running time and achieve holistic energy-conservation. Therefore, application of cool storage technology could reduce the number of units in use during peak demand period, reducing primary energy consumption, and emission of smoke and dust, CO2 and other noxious substances.

Application of cool storage technology could help save investment, reduce operating costs, conserve energy and protect environment on the system level..

2. Consumer level

On the consumer side, advantages of cool storage air-conditioning are:

1) To reduce the operation cost of the air-conditioning system by taking advantage of the price difference between peak and trough.
2) To reduce the installed capacity and power for chiller and auxiliary equipment, and improve equipment operating factor.
3) To reduce the primary power investment;
4) To improve the refrigeration system reliability as emergency cold source (sink);
5) Possibility to obtain subsidies or other incentives, in line with national policies;
6) Whether a cool storage air conditioning system was adopted, it depends largely on time-of-use (TOU) pricing, government subsidies and other incentives other than the inherent conditions of the project itself.

The TOU policy and cool storage incentives policy in China

1. The TOU policy and cool storage incentives policy in China

Chinese electrical price mechanism is experiencing the transition from government pricing to market competitive pricing. Currently, the electricity pricing policy and price levels are determined mainly by relative administrative government price departments (mandatory hearing required to be held by law for residential electricity price adjustment). Electricity price consists of Transmission, Distribution price and Sales price from electricity production and management aspects. Sales price catalog system is very complex and sorted by provincial units usually, and varies significantly by regions and industries.

To encourage consumer taking advantage of peak load shifting, and ease the pressure of peak power shortage, after carrying out a number of pilot provincial program since 2002, the central government begin to introduce the TOU system gradually. So far, TOU pricing have been practiced countrywide with exception of only a few provinces.

Take 1-10kV "general commercial and industrial electricity" TOU for summer as an example, current peak (Peak), flat, and valley electricity price for some provinces is shown as follows (some provinces has basic tariff).

2. Cool storage incentive policy

In addition to widespread implementation of TOU in China, some provinces have implemented a preferable electricity price specifically for thermal storage system. For example, there is additional price cut of 0.024 yuan / kWh for thermal storage system. There are also specialized cool storage tariff concessions for major projects in some areas, such as Guangzhou Higher Education Mega Center.

Power companies in some areas have introduced various subsidy policies to encourage cool storage technology applications. For example, State Grid Beijing Electric Power Company implemented subsidy policy for peak shift, in the size of 500 yuan / kWh for some cool storage projects over a certain period of time.

Being a macro policy, cool storage air conditioning system has been advocated by the state. For example in 2010, National Development and Reform Commission and other five departments jointly developed the "power demand side management approach", which requires "all levels of administrative pricing department should promote and improve the TOU system to encourage valley price usage for cool storage."

In addition, China is now vigorously promoting green building demonstration and subsidy, as a green building energy-saving technology, cool storage technology has received recognition and promotion in the national standard " Evaluation Standard for Green Building ".

Table 1. Electricity price of some provinces - 1-10kV "general commercial and industrial electricity (yuan/kWh)

Province	Peak	Flat	Valley	PVCR
Anhui	1.4125	0.8788	0.5422	2.61
Zhejiang	1.406	1.108	0.596	2.36
Shaanxi	1.19805	0.8123	0.42655	2.81
Hebei	1.2082	0.7433	0.3367	3.59
Gansu	1.1467	0.7683	0.3899	2.94
Beijing	1.4009	0.7995	0.3418	4.10
Tianjin	1.2898	0.8443	0.4188	3.08
Shanghai	1.202	0.749	0.285	4.22
Shandong	1.28384	0.8024	0.32096	4.00
Hunan	1.51596	0.8422	0.37899	4.00

Cool storage application and research in China

Application and research of cool storage in China started just recently. Only a few of stadiums adopted water storage technology in 1980s, the application effect is not ideal. With the introduction of national electricity policy adjustments and TOU strategy, projects application of cool storage technology began to increase gradually. During Ninth Five-Year Plan, China Academy of Building Research organized critical research on ice storage air-conditioning products and technologies ("Nine Five-Year" national key scientific and technological project), which has played an important role for development of domestic ice storage technology.

In 2008, industry standard "Technical specifications for cool storage air conditioning system" JGJ158-2008, prepared by China Academy of Building Research and other 13 units, was formally promulgated and implemented. This standard has important guiding and practical significance for the design, construction, commissioning, acceptance, operation and management of cool storage air conditioning.

In recent years, the number of cool storage air conditioning projects in China has made significant growth. According to statistics, the number of cool storage project has arrived in about 400 in 2005; Up to 2012, the projects which has operated and under construction has reached about 980, with a total capacity of about 17.5 million kWh.

The characteristics of cool storage air-conditioning project in China could be summarized as follows:

1) From the point of view of geographical distribution, cool storage air conditioning have been well applied in Shanghai, Guangdong, Jiangsu, Zhejiang and other southern regions, and the application in northern areas are mainly concentrated in Beijing, Tianjin and other densely populated developed regions with electricity shortage.

2) In terms of application type, although external coil ice-melting system occupy the highest proportion, a variety of other system have been developed in recent years. Localization of ice storage devices production has been greatly enhanced, and a number of domestic manufacturers have developed their own devices and achieved decent application effect in many projects. Some international manufacturer of ice storage equipment have also established their production lines in China. In addition, due to the advantages in overall efficiency and less complexity, water storage system achieved rapid growth in recent years. As of now, the number of existing water storage air conditioning project has reached 178, according to statistics.

3) In terms of project scale, cool storage projects trends towards large-scale. In district cooling projects, the advantages of cool storage air conditioning become more and more clear. This can be seen from:

   a) Based on different cooling load distribution characteristics between buildings, coincidence factor could be taken in design stage to reduce total installed capacity and improve the cooling equipment part load ratio;

   b) The purchase of equipment can follow the region construction development progress;

   c) Helps to reduce investment in civil engineering, equipment installation and control system per unit volume;

   d) High demonstration effect, which is beneficial for application of preferential electricity price cut or subsidy policies;

   e) Favor for centralized maintenance and operation, and introduction of professional operations team, such as ESCO providing energy management contracting service.

4) Cool storage projects could be applied widely in conjunction with other energy-saving technology in compound forms, e.g., the joint application of cool storage and heat pump technology.

5) From longitudinal comparison, though the cool storage technology has experienced a substantial development in recent years, its overall proportion among all central air conditioning project is still very low. According to estimates, application of cool storage air conditioning system only account for only 1% to 2% in new construction of public building annually. There still lies long road to go for development of cool storage technology, in another way, there still lies great development potential.

In recent years, domestic cool storage air-conditioning technology has also made significant progress in research and development, and the related research focuses on the following aspects:

1) System simulation and evaluation, including load calculations, dynamic system modeling, estimate of operating cost, and life-cycle evaluation.
2) System optimization;
3) Development of cool storage device;
4) Research on operation mode, control strategy, and load prediction model;
5) Combination with terminal system with low temperature air supply and large temperature difference;
6) Combination with ground source heat pump system;
7) Application of cool storage system in district cooling;
8) Combination with combined cooling-heating-power (CCHP)

Problems and Challenges

1. Evaluation of cool storage system

From the perspective of user side, energy consumption of cool storage air conditioning system has not decreased compared to conventional air conditioning system, but increased slightly in many cases, which led to the misunderstanding of "economical but not energy efficiency". As of such, cool storage air-conditioning technology has not been listed for promotion as an energy saving technology by some domestic policies, norms and technical guidance.

However, the energy efficiency of cool storage air conditioning system is not reflected directly on the user-side energy consumption, but indirectly on improvement of power generation efficiency and optimization of energy structure. From analysis in sector 2.1, the argument of "economical but not energy efficiency" fail to take for following into consideration, to say the least: saving on energy for power plant construction; improvement on power generation efficiency, reduction of energy consumption by generators; potential reduction of proportion for coal-fired power in power grid.

Surely, different with other energy-saving technologies, it is difficult to quantify energy conservation mentioned above for individual projects. This calls for development of a more objective, reasonable and comprehensive evaluation method to assess energy and environmental benefits of cool storage system, therefore to advance its further development.

2. Incentives and support efforts

As mentioned ahead, proportion of cool storage air conditioning system application is still very low in China. Therefore, it is necessary to build more effective incentive policies and enhance relative supportive system.

Cool storage air conditioning system depends largely on TOU. Current TOU has played a positive role on user load shifting, balancing between power supply and demand, but there are still some problems, such as: small difference of peak-valley rate(especially with consideration of base electricity rate); application scope is limited; great policy differences between areas, lags of incentive policy implementation in some areas; imbalance of interest between power generation and distribution enterprise etc. Following measures should be taken to solve the above problems: promotion of market-oriented pricing mechanism; forming peak and valley price linkage mechanism for power generation and sales; smoothing all links of the power system to provide incentive to the power company.

From the national macro-policy perspective, China is involved in the adjustment of economic structure and mode transform. Specifically to the power system, it is necessary to shift from blind expansion of power generation capacity and excessive investment towards optimization of grid structure and improvement on operational efficiency. Therefore it is necessary to strengthen the demand side management, and to greatly improve the application of cool storage air conditioning technologies through various channels.

3. Application technology of cool storage air-conditioning

Cool storage technology in engineering applications is more matured now in China. Related standards and code, specifications, and technical manuals are increasingly sophisticated, and the level of engineering applications has dramatically increased. It in turn improves the ability of a number of design firms, equipment manufacturers, and installation companies, and promote the healthy and orderly development of the cool storage industry. However, compared with advanced level internationally, design, operation and control link is still extensive, leading to inefficient or defective system. This requires a further enhancement of the technological level of the industry, refinement on all aspects of the technical requirements, and promotion on reasonable and rational development of cool storage technology.

On the other hand, some projects are still at a poor performance even with a good design, selection of equipment and well installation due to poor operation; Some other projects with different party of investor and occupant, resulted in disconnection between construction and operation. Compared with conventional systems, operation and control of cool storage system is more professional, making a good choice for energy management contracting approach. In addition, it is also be an effective solution through the improvement of storage air conditioning control system to reduce the complexity of operations and management.

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