R&D Activities on Heat Pump Technology by NEDO

Yoshiteru Sato

Energy Conservation Technology Development Department,
New Energy and Industrial Technology Development Organization

13 November 2013

Contents

Whatôs NEDO

NEDO has a crucial mission to carry out addressing energy and global environmental problems and enhancement of Japanôs industrial competitiveness.

Chairman:Mr. Kazuo Furukawa

Organization: Incorporated administrative agency under the Ministry of Economy, Trade and Industry (METI)

Established in 1980

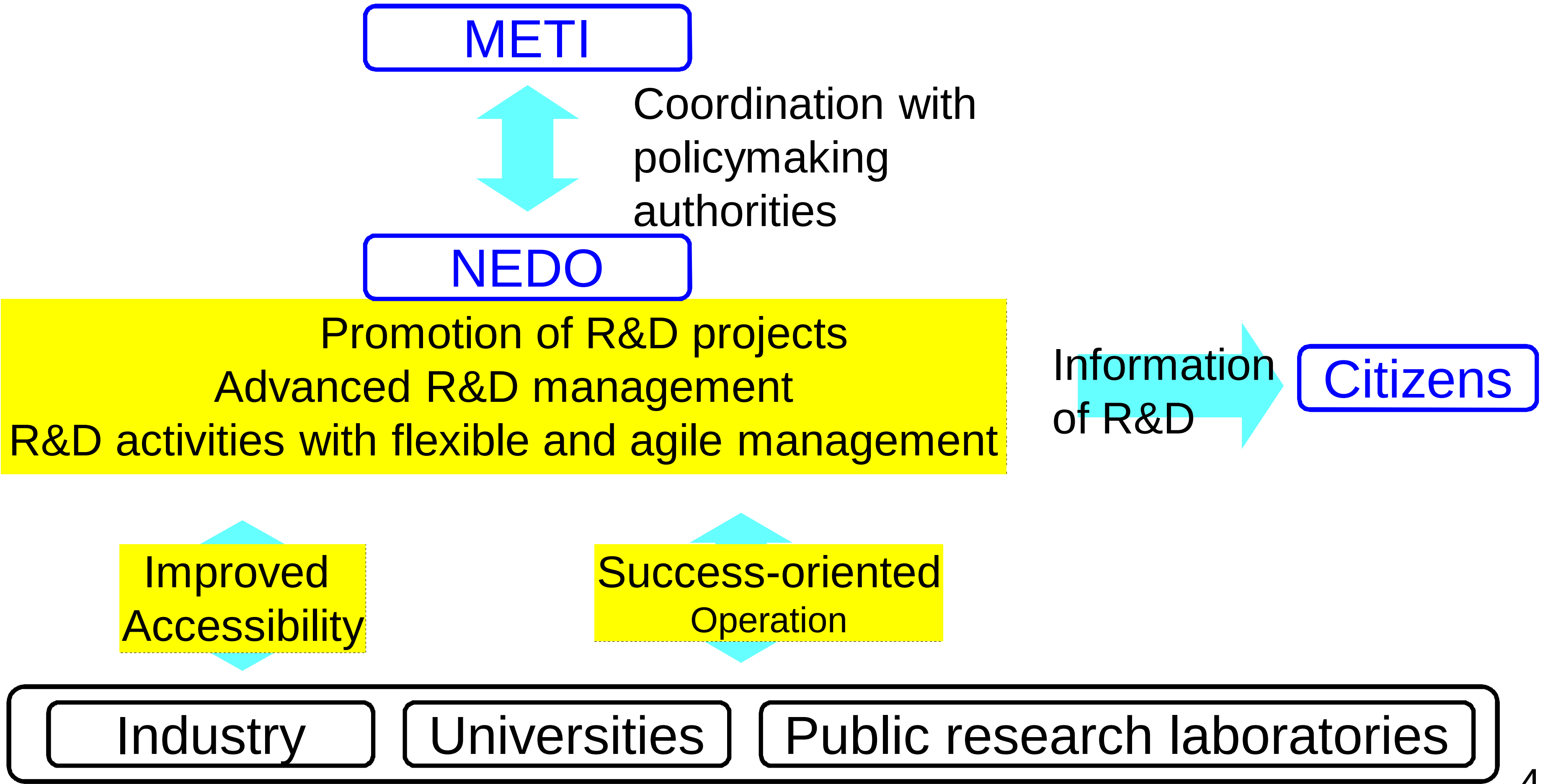
Location:Kawasaki City, Japan

Personnel: About 800

Budget: Approximately 1.2 Billion USD (FY2013), (100Yen/USD)

Status of NEDO

As an incorporated administrative agency under the jurisdiction of the Ministry of Economy, Trade and Industry(METI), NEDO draws on the combined efforts of industry, academia and government as well as its sophisticated management know-how.



NEDOÕs Role


Coordination with policymaking authorities
Combined efforts of industry, academia and government
Ministry of Economy, Trade and Industry
NEDO
Promotion of national projects
Autonomous and advanced project management
Promotion of technology development based on a flexible and agile project management scheme
Industry Universities
Project management
NEDO utilizes a professional and comprehensive project management approach to carry out such activities as discovery of technology seeds, promotion of medium- and long-term projects, and support for practical application.
Comprehensive coordination of industry, academia and government
NEDO coordinates technology development activities in collaboration with relevant institutes by integrating the efforts of industry, academia and government to achieve superior results.
Accomplishment of mission

Organization (as of July, 2013)

- Chairman — Auditors
  - Auditor support office
- President
- Executive Directors
  - Head office
    - General Affairs and Policy Planning Dept.
    - Personnel Affairs Dept.
    - Accounting Dept.
    - Inspection and Operational Management Dept.
    - Assets Management Dept.
    - Information and Systems Dept.
    - Evaluation Dept.
    - Public Relations Dept.
    - Energy and Environment Center
      - Energy Conservation Technology Dept.
      - New Energy Technology Dept.
      - International Affairs Dept.
      - Smart Community Dept.
      - Environment Dept.
      - Kyoto Mechanisms Promotion Dept.
    - Industrial Technology Center
      - Technological Development Promotion Dept.
      - Electronics, Materials Technology and Nanotechnology Dept.
      - Biotechnology and Medical Technology Dept.
  - Overseas offices: Washington, Silicon Valley, Europe, Beijing, Bangkok, New Delhi
  - Branch office: Kansai

Contents

Outline of ñStrategy for Energy Efficiency Technologies 2011ò

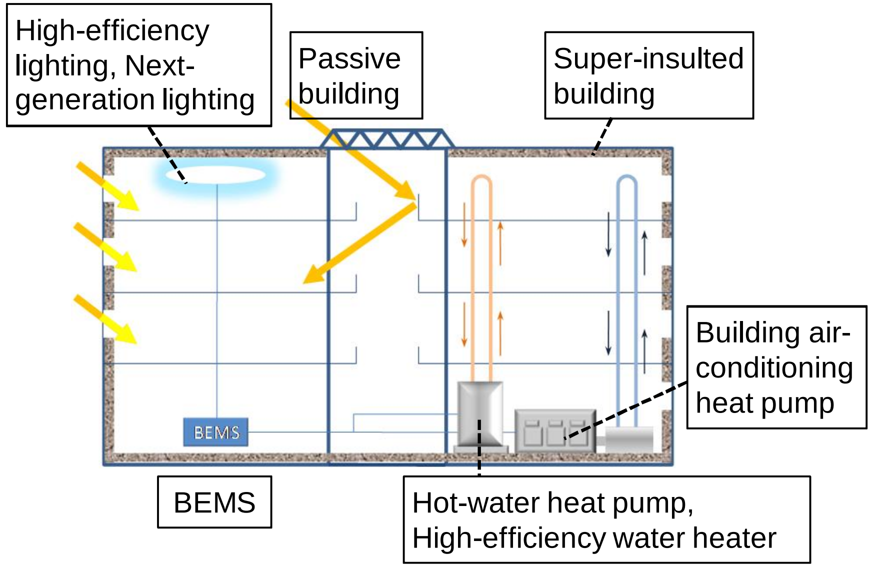
This strategy prioritizes wide-ranging energy efficiency technologies and selects key technologies that can meaningfully contribute to Japanôs energy-saving efforts.

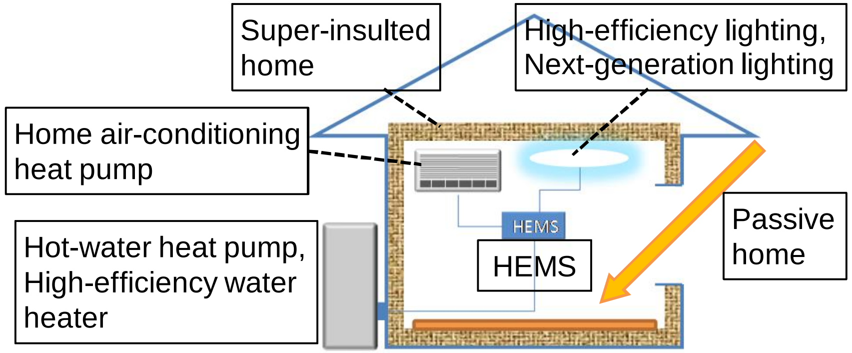
This strategy selected key technologies for residential & commercial, transport and industry sectors described schematic roadmaps. These key technologies will be expected to be technologies that are expected to achieve significant energy-saving effects by 2030, systems that can be combined with other technologies or integrated in new concepts to achieve significant energy-saving effects, or technologies that are expected to achieve significant energy-saving effects and are broadly applicable on a long-term basis.

Residential and Commercial Sectors

ZEB (Net-zero Energy or Emission Building) ZEH (Net-zero Energy or Emission Home)

Improving energy-saving efficiency for building frameworks and equipment in homes and buildings, and comprehensively designing systems such as load controls and integrated controls would reduce energy consumption amounts in homes and buildings to virtually net zero.





Energy-saving that suits personal comfort and preferences

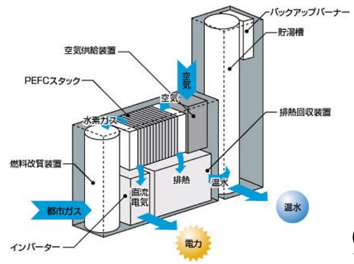
New concepts and methods to develop energy-saving efficiency that focus on utilizing and applying the different personal comfort levels and preferences, and continue to regard such differences with respect to development.
Technologies that optimize energy-savings for residential and office environments by using control technologies and sensor technologies based on the understanding of human movements.

Energy-saving Information Equipment and Systems

Developing energy-saving technologies for devices and equipment in order to reduce power consumption increases due to the use of IT equipment and other devices.
Example :
- Energy-saving next-generation network communication
- Energy-saving information equipment
- Technologies to reduce standby power consumption
- High-efficiency displays

Stationary Fuel Cells

Technologies that significantly reduce primary energy consumption by enhancing power generation efficiency and heat utilization technology development
Example :
- Solid oxide fuel cell (SOFC)
- Polymer electrolyte fuel cell (PEFC)



Transport Sector

Next-generation Vehicles

Next-generation vehicles such as electric vehicles have the potential for substantial improvements of fuel efficiency compared to conventional vehicles

Examples:
・Electric vehicles
・Plug-in hybrid vehicles
・Fuel cell vehicles







Intelligent Transport Systems (ITS)

Technology to promote optimization of traffic systems including people, freight and vehicles by utilizing information and communication technology and control technology.
ITS also includes developing technologies aimed at reducing accidents, mitigating traffic congestion, and promoting energy-saving and environmentally friendly systems.

Examples:
・Energy-saving driving support technology
・Transportation demand management technology (TDM)
・Traffic control and management technology
・Traffic information provision and management information technology
・Traffic flow mitigation technology

Intelligent Logistics

Technologies to improve energy saving efficiency and logistics by using communication technologies which coordinates and controls information relating to freight, and transportation facilities for processes such as door-to-door transportation, storage, loading and unloading.

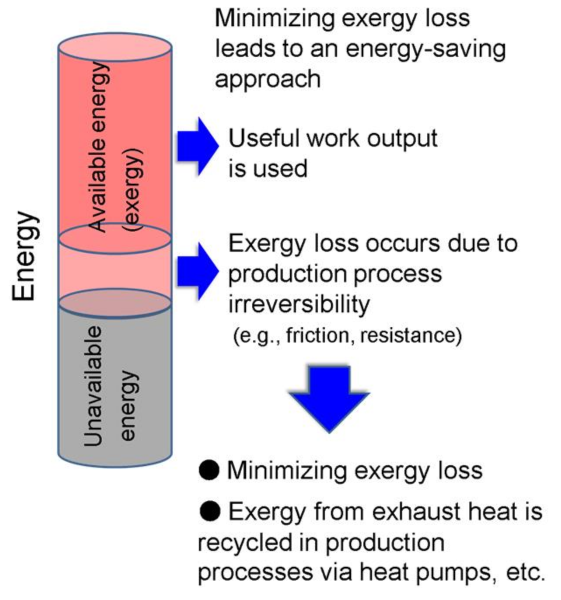
Examples:
・Visualization of locations and delivery status of freight, vehicles and storage, delivery management, quality management, and storage management.
・Provide options for energy-saving methods of transportation
・Matching technologies between freight information and transportation information
・Traceability technology for actual transfer conditions
・Measuring techniques for environmental performance
・Modal shift
・Node intelligence
・System integration and unification of facilities and freight handling for transport freight and the coordination of storage facility information
・Freight Information using microchips and IC tags
・Location information via GPS
・Visualization of energy consumption
・Optimal distribution coordination of automobiles, railways and vessels
and node upgrades
・Consolidated freight transportation via platoon driving

Industrial Sector

Technologies to minimize exergy loss

Technologies to minimize the loss of exergy (available energy) being used in various production processes

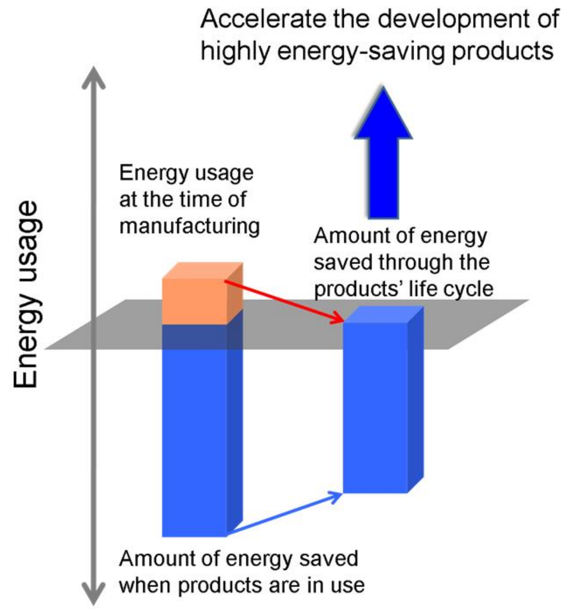
Examples:
・Energy-saving production
・Innovative iron-making technology
・Industrial heat pumps
・High-efficiency thermal power generation



Technologies to improve system energy efficiency

Technologies that are expected to achieve significant energy-saving effects when used in conjunction with other technologies or new concepts (flexible heat utilization by means of heat storage, heat transportation, etc.)

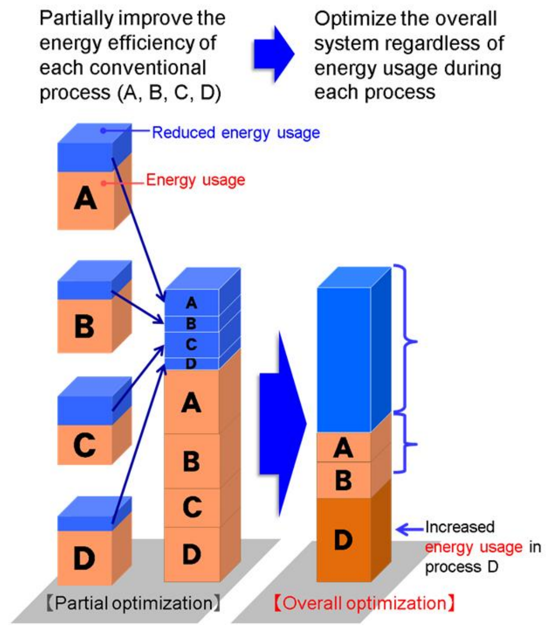
Examples:
・Cross-industry energy networks
・Laser processing



Technologies to manufacture energy-saving products

Technologies to manufacture products, which is not particularly energy-saving, but will offer significant energy-saving effects to the manufactured products

Examples:
・Ceramic manufacturing technology
・Carbon fiber/composite material manufacturing technology



Cross-sector

Next-generation Heat Pump Systems

System to achieve high-efficiency, low cost heat pumps and reduce greenhouse gas emission by developing systemization and innovative element technologies for heat pump.

Systemization technologies:
  Technologies for utilizing unused heat, technologies for collecting and storing high-efficiency heat, technologies for streamlining low load areas, etc.

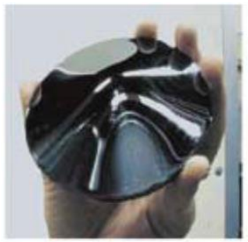
Innovative element technologies:
  Technologies for high-efficiency refrigeration cycles, development of new refrigerants, high-efficiency heat exchange equipment, technology for high-efficiency compressors, etc.

Examples:
・HPs for home, office buildings and factory air-conditioning
・HPs for car air-conditioning
・Industrial use HPs
・HPs for hot water
・HPs for refrigerators, freezers, etc.

Power Electronics

Technology that supports high-efficiency electric power supply used by all fields, and meets the soaring energy consumption demand as a result of IT development.

Examples:
・Wide-gap semiconductors
・High-efficiency inverters



Next-Generation Heat and Power Networks

Comprehensive energy-saving technologies including heat networks designed for the efficient use of heat, next-generation energy management systems designed to optimize energy use within certain regions and next-generation energy transmission and distribution networks, which support the introduction of renewable energy.

Examples:
・Next-generation energy management systems
・Next-generation energy transmission and distribution networks
・Next-generation district heating networks
・Cogeneration
・Industrial fuel cells（SOFC）
・Heat transport systems
・Heat storage systems

Contents

1. Introduction of NEDO
2. Strategy for energy efficiency technologies
3. Outcomes of R&D on Heat Pump
4. Challenges in Heat Pump Technology Development
5. R&D project on ñNext-generation Heat Pump Systemsò
6. Proposal-based R&D Activities

Compact CO_2 Heat Pump Water Heater

Key points

- A strategically emphasized project under the ñStrategic Development of Rationalization Technology for Energy Useò initiative for the full penetration of residential-use water heaters, with cold-climate performance and narrow-space installation (downsizing) as important challenges
- The utilization of an ejector technology for the development of a compact CO_2 heat pump water heater that integrates a heat pump unit and hot-water storage tank and yet takes only about 2/3 of the installation space compared to conventional water heaters

The utilization of an ejector technology for the development of a compact CO_2 heat pump water heater, under the "Strategic Development of Rationalization Technology for Energy Use" initiative (FY2005ï 2007)

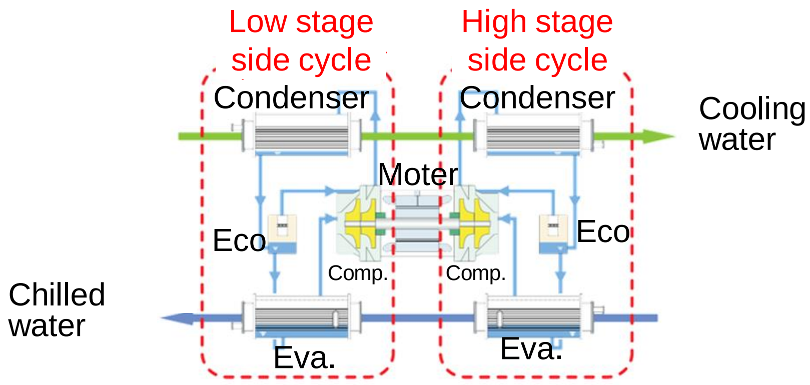
Commercialization status

- R&D efforts resulted in the commercialization of a compact, natural-refrigerant heat pump water heater that integrates a heat pump unit and a hot-water storage tank. Energy-saving and high-efficiency, the ñEcoCuteòhas posted sales of 3 million units in 2011.

Worldôs Most Efficient RTVF Chiller

Key points

- Development of a high-efficiency chiller for energy-saving and reduction of CO_2 emissions in large air-conditioning facilities of large buildings and factories under the ñStrategic Development of Rationalization Technology for Energy Useò initiative
- Double chill cycles, a high-speed gearless compressor, and an inverter-driven high-speed motor are combined to achieve the worldôs best efficiency of COP = 7.0 (a 41% reduction in CO_2 emissions per year from conventional types) in this compact and lower-cost chiller.



Double refrigerating cycle flow

RTVF050V

Commercialization status

- On sale since FY2009 targeting factories and large commercial complexes

Kudos received

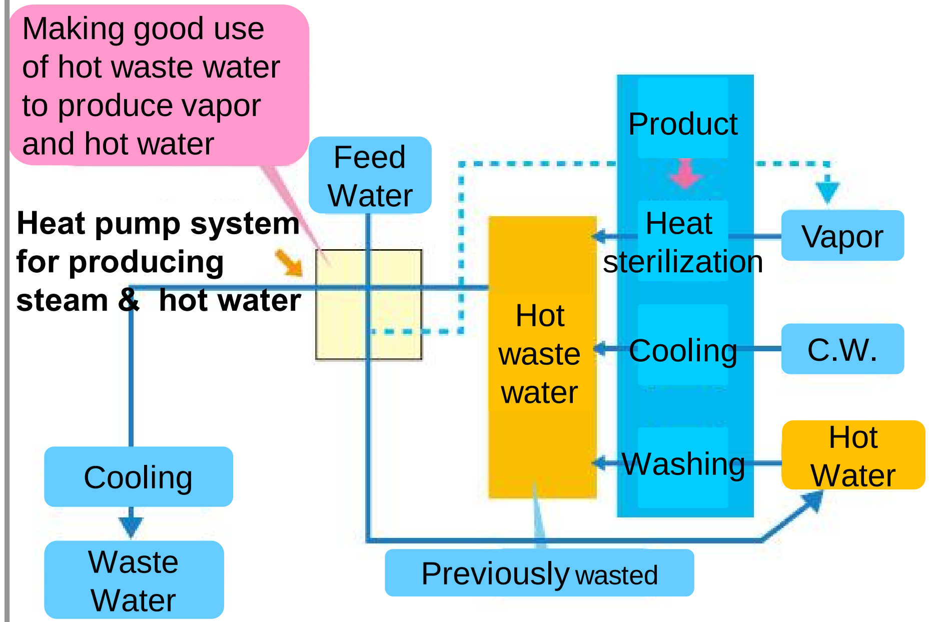
- In 2009, the refrigerator won the ñDirector-Generalôs Prize, the Agency for Natural Resources and Energyò at the 30th Excellent Energy Saving Equipment Commendation of the Japan Machinery Federation.

Contents

For industrial use

With their ever-improving performance, heat pumps are becoming ready to replace heating systems based on conventional boilers.

- Development of a high-temp heat pump that utilizes waste heat or of a high-temp heat pump that produces high-temp steam and cold at the same time to offer factories an alternative to conventional boilers

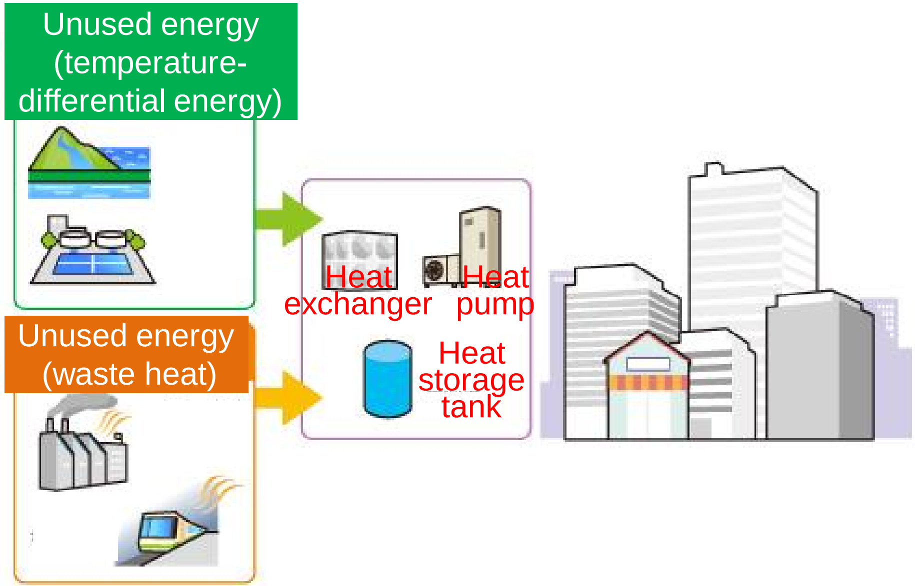


From the official website of the Heat Pump and Thermal Storage Technology Center of Japan

For air-conditioning of commercial buildings (including factories) and water heating

Heat pumps are capable of utilizing unused neighboring heat sources.

- Utilization of unused heat sources such as factory waste heat, sewage heat, and groundwater for the development of a heat pump for the air-conditioning of commercial buildings and water heating

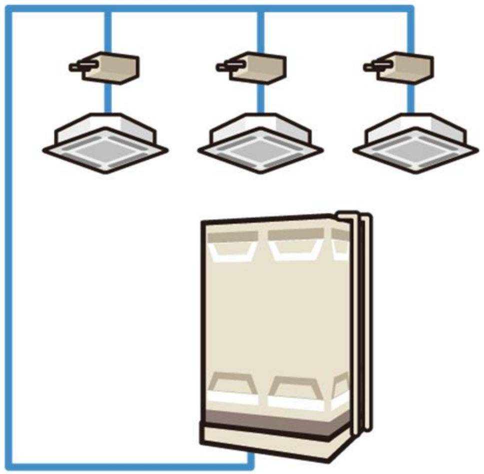


From the official website of the Heat Pump and Thermal Storage Technology Center of Japan

For air-conditioning of commercial buildings (including factories) and water heating

The efficiency of an air-conditioner in its low-load region tends to be lower than that in the half load or the rated performance, even though it is in this very low region that the air-conditioner runs for a long time.

- Development of a heat pump that maintains high efficiency even in its low-load region

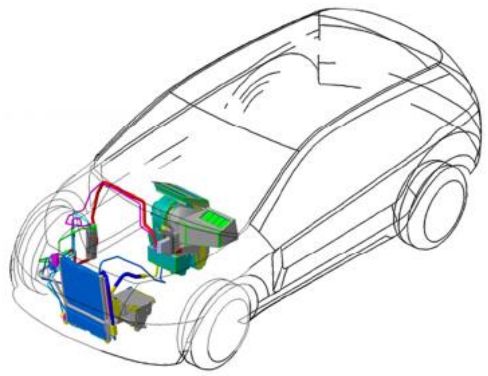


From the official website of the Heat Pump and Thermal Storage Technology Center of Japan

For automotive air-conditioners

Electric vehicles generate smaller amounts of waste heat compared to internal combustion engines, which is why electric heaters make up for shortage of heat. But that takes away from EVsôcruising ranges.

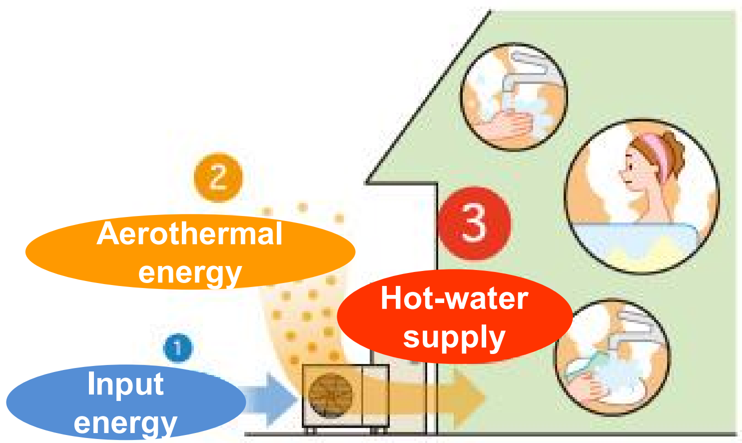
- Development of a heat pump for air-conditioning to enhance the energy efficiency of EVs



From Mitsubishi Heavy Industries technical review; Vol. 48, No. 2, (2011) For residential/commercial water heating

- Need to further strengthen Japanô s world-class heat pump water-heater technologies

- Development of a high-efficiency heat pump for water heating



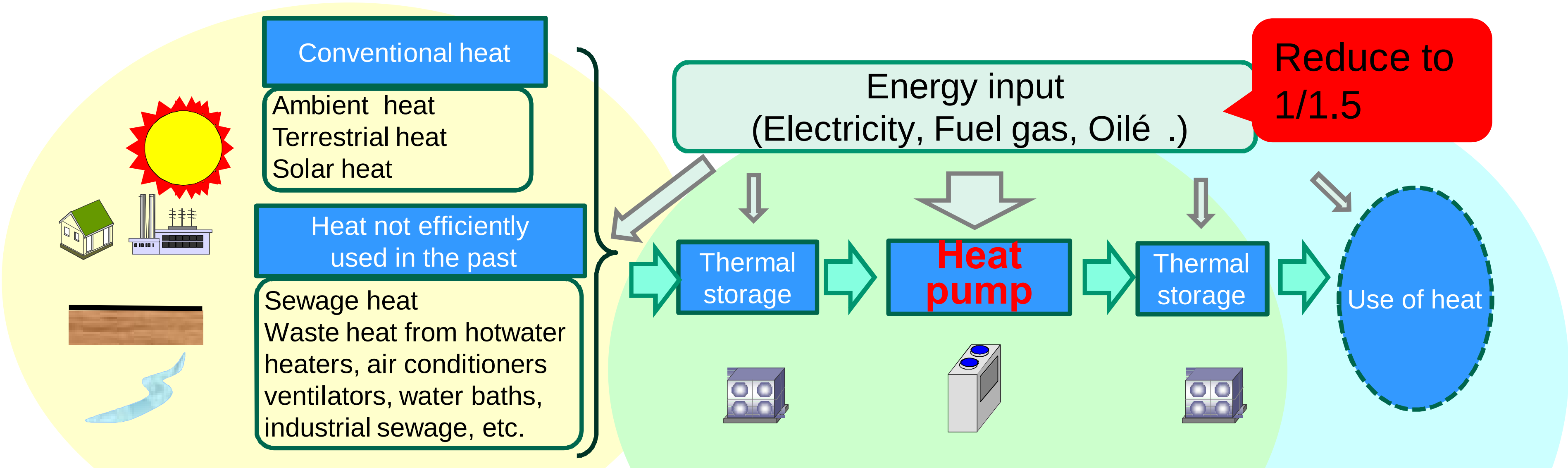
From the official website of the Heat Pump and Thermal Storage Technology Center of Japan

- Review of development challenges to continue, in accordance with Japanô s national energy-saving policies and technological development both within the country and overseas

Contents

Aims

To realize the ultra-high-efficiency heat , the development of the pump alone is not sufficient. A wide array of experts in various fields such as architecture, machinery, and materials need to work to amalgamate their technologies (universities, equipment manufacturers, measuring instruments manufacturers, control device manufacturers, design and installation specialists such as housing manufacturers, general contractors, sub-users, etc.)



Research points

ÅHow to efficiently collect and transfer heat from sources
ÅHow to efficiently combine any type of heat
ÅHow to efficiently generate heat in response to fluctuating demand by also using thermal storage
ÅFitting the system into available space in buildings

Status and Approach

Heat pump systems are presumed to take various forms depending on the subject of application (air-conditioning, hot-water supply, high-temperature heat, etc.) and the conditions of application (usage conditions of unutilized heat, locality (e.g., cold climates), low loads, etc.).

Given this situation, four basic technological challenges have been chosen and approaches to solving them have been clarified, while allowing the variability among systems. The challenges chosen are as follows:

(1) Utilization of various unutilized heats: Combining various types of unutilized heat (solar, sewage, terrestrial heat, etc.) and thereby realizing a greater utilization of each type can compensate for the unstable nature of heat sources.

(2) Efficiency improvement in actual operation by attuning to the actual load: A certain level of efficiency is kept whether the load is high or low and efficiency is secured even under frigid or other adverse environmental conditions.

(3) Maximum utilization of generated heat: The maximum utilization of cold and heat generated by heat pumps within the system, discharging as little of them as possible

(4) Efficient generation of high-temperature heat: Efficient generation by HP systems of high-temperature heat (about 180° C), for which there are high demands in industrial fields but which has not been realized thus far

Selection of Themes

Various proposals put forward on application subjects and application conditions have been screened by a stage gate review, and the following six themes have been selected.

Residential Sectors

R&D of frost-free vapor-compression heat pump systems hybridized with desiccant (Tokyo Univ., TEPCO, Shin Nippon Air Tech. Co., Ltd)

- Air Conditioning
- Cold District

Commercial Sectors

R&D of innovative energy-saving controls of next-generation multiple air-conditioning systems for buildings (Chubu Electric, Nihon Sekkei, Mie Univ.)

A heat pump system that improves annual efficiency by fitting the actual air-conditioning load (Hitachi Appliances, Hitachi, Ltd.,)

- Air Conditioning
- Low-Load

R&D of the groundwater source high-efficiency heat pump air conditioning system (SHIMIZU CORPORATION, Shinshu Univ.)

- Air Conditioning
- Ground water

Industrial Sector

Technology development of system utilizing sewage heat and heat transportation potential in urban sewer pipeline (Osaka City Univ., Chuo Fukken Consultants, KEPCO, Sogo Setsubi Consultant)

- Air Conditioning
- Hot-water Supply
- Heat Transportation
- Sewage Heat

Development of high-density cold energy network (Tokyo Denki University, Tonets Corporation)

- Air Conditioning
- Heat Transportation

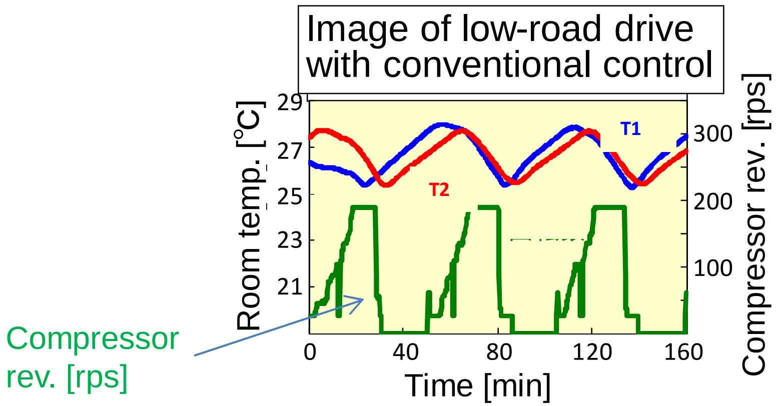
Schedule

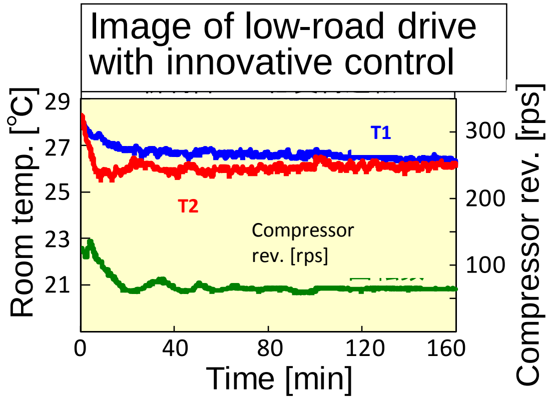
FY	2010	2011	2012	2013	2014	2015	é	2020
Budget (JPY mil.)	400	800	800	140				
	Next-generation heat pump system R&D FS/design		demonstration evaluation					
Action plan					Product development by corporations, etc.	Commercialization		

FY	Target	Target result
2010	To clarify design requirements for realizing 1.5× or more efficiency	Carried out nine R&D themes and study the viability of a heat pump system 1.5× or more efficient. - Stage gate review (six themes)
2011	To establish a detailed demonstration testing system for achieving the target	Established the verification testing system for heat pump systems that was designed in fiscal 2010.
2012	To verify using the demonstration testing system	Evaluated the demonstration testing system for heat pump systems that was established in fiscal 2011 based on the specified evaluation method to confirm 1.5× or more efficiency.
2013	To identify and solve issues through a long-term run	To perform demonstration for the purpose of establishing a system for improving actual-operation efficiency with the use of sewage heat and waste heat transport, and a system for improving the efficiency of heat transfer in regional air-conditioning, etc.

R&D on innovative energy-saving control of multiple heat pump systems for next-generation buildings

- Real-time load forecast that can mitigate efficiency drops due to the start/stop of compressors in low-load regions and the development of innovative control of multiple air-conditioners for buildings with capacity control based on the real-time forecast built in
- Demonstrate that annual energy consumption efficiency improves approximately 1.7 times with the new control compared to the conventional control





Indoor units estimate necessary capacity based on load. → Indoor fan airflow and target temperatures for evaporation/concentration to outdoor unit are calculated. → The outdoor unit processes the target temperatures for evaporation/concen-tration coming from indoor units. → Compress or control

Coordinated control

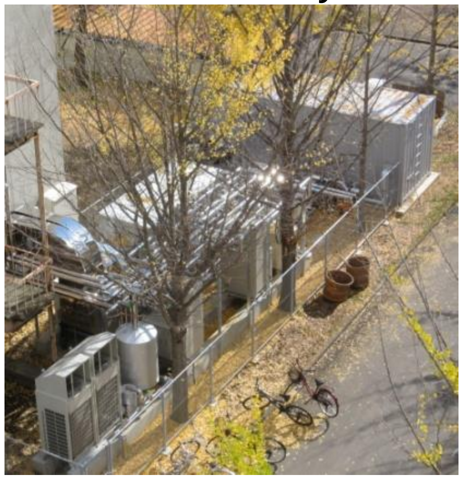
Indoor

Outdoor

R&D on high-efficiency heat pump air-conditioning system for groundwater control

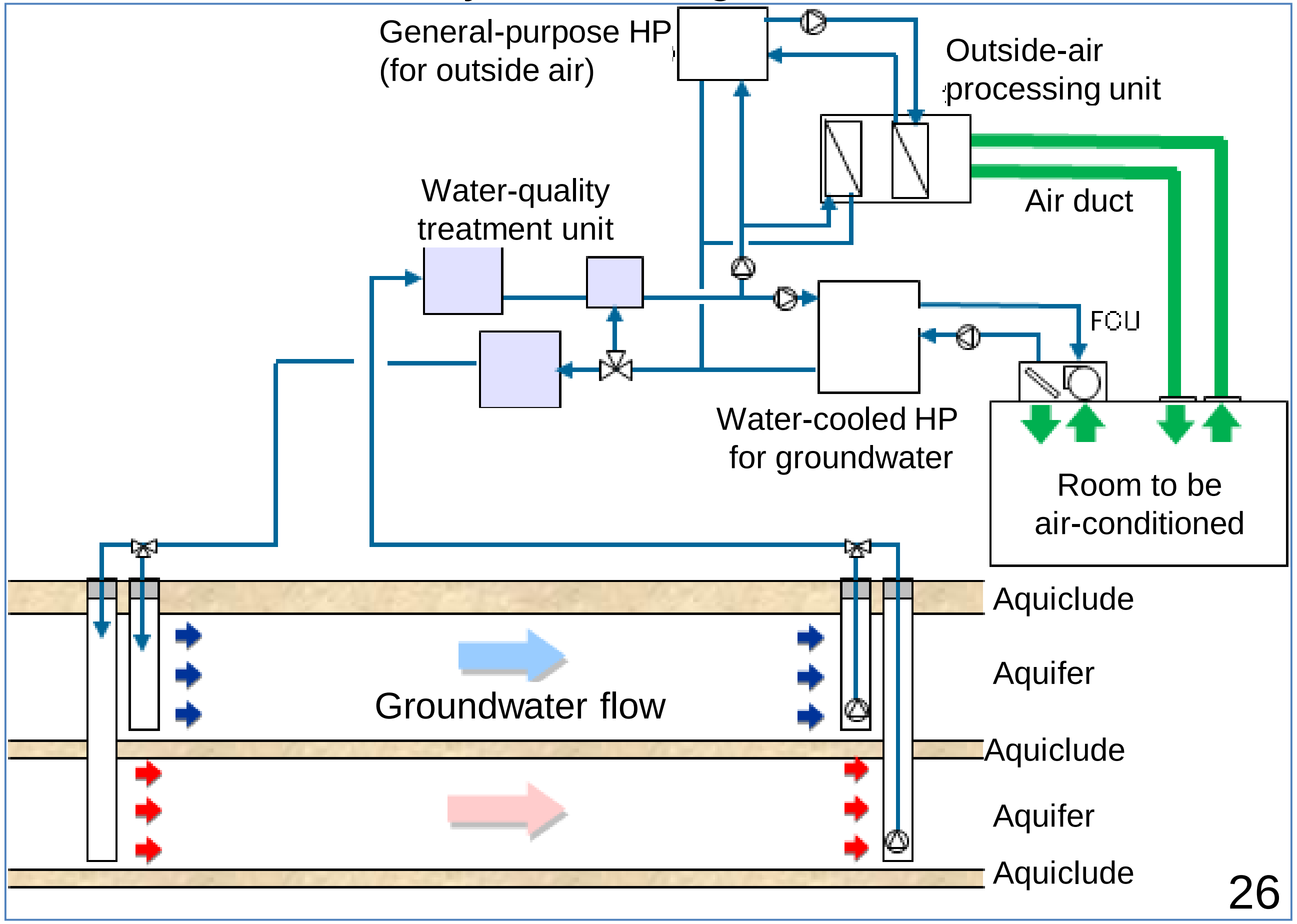
- Development of a high environmental performance system that controls groundwater quality and flow to achieve heat storage effects
- Demonstration tests completed successfully, with the realization of 1.5× efficiency improvement from the conventional air-conditioning system in the pipeline

Aerial view of system



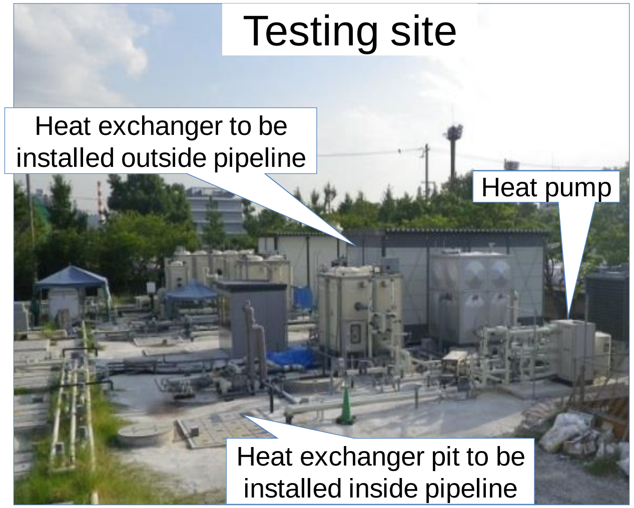
Water-quality controller

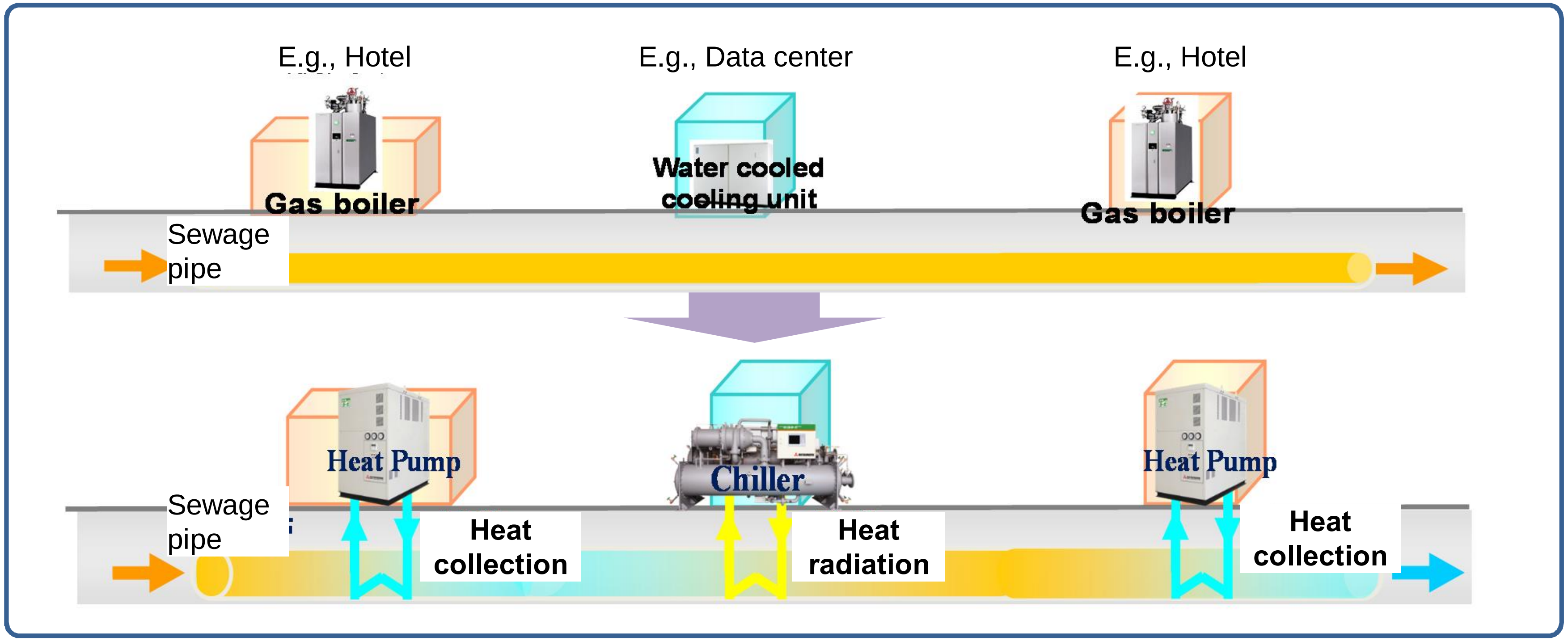
System configuration



R&D on technology for sewage heat use and heat transport utilizing urban sewer pipeline network

- Development of a sewage heat-utilization system that utilizes heat from sewage pipelines that run near buildings for water heating and air-conditioning, seeing urban sewage flowing underground as an ñuntapped heat sourceò that has to be utilized manifold more times
- Installation of multiple sewage heat-utilization systems along sewage pipelines for the development of sewage transport technology for collecting and radiating heat at different points





Contents

1. Introduction of NEDO
2. Strategy for energy efficiency technologies
3. Outcomes of R&D on Heat Pump
4. Challenges in Heat Pump Technology Development
5. R&D project on ñNext-generation Heat Pump Systemsò
6. **Proposal-based R&D Activities**

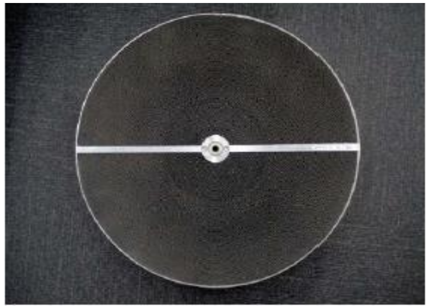
Category	FY2010	FY2011	FY2012	FY2013	FY2014
Residential･Commercial Building･Factory Air conditioning		R&D of Heat Pump System with Desuperheater for Effective Cooling, Heating, and Hot Water Supply Combined with Desiccant Ventilation System Using Wakkanai Siliceous Shale			
		Demonstration of the Air-conditioning Energy Conservation Effect by using New HVAC System Enabled the Latent and Sensible Heat Individual Control with the Direct Expansion Air Conditioner and Development of the Method to Simulate the Energy Consumption of the System			
			R&D of the Liquid Cooling Air-conditioning System for Commercial Buildings		
			Development of the packaged air-conditioning system towards ZEB realization		
			R&D of the heat pump system using a micro fin adsober		
Hot water system			R&D of the high efficiency heat pump system which incorporated an Al heat exchanger corresponding to the unused heat		

<table>
<tr><th>Category</th><th>FY2010</th><th>FY2011</th><th>FY2012</th><th>FY2013</th><th>FY2014</th></tr>
<tr><td rowspan="3">Industrial use</td><td colspan="3">R&D of Steam Generation Heat Pump System</td><td></td><td></td></tr>
<tr><td></td><td colspan="3">R&D of Adsorption Steam Recovery System for Generating High Temperature Steam from Unused Hot Waste Heat</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">R&D of High Temperature Heat Pump System</td><td></td></tr>
<tr><td rowspan="2">Automotive air conditioner</td><td></td><td colspan="3">R&D of the high efficiency power recovery system which utilized two phase vortex technology</td><td></td></tr>
<tr><td colspan="3">Research and Development of Heat pump system for HVs, PHVs.</td><td></td><td></td></tr>
<tr><td>Refrigerator ï freezer, show case</td><td></td><td colspan="3">R&D of energy saving refrigeration, the frozen systems such as convenience stores</td><td></td></tr>
<tr><td rowspan="2">New method heat pump</td><td></td><td colspan="3">R&D of hybrid compression cycle which operated by a carbon dioxide refrigerant</td><td></td></tr>
<tr><td></td><td colspan="3">R&D of Magnetic Heat Pump Technologies</td><td></td></tr>
</table>

High Efficiency by Air-Conditioning of Latent/Sensible Heat Separation

Development of a desiccant system

- Ongoing development efforts of a heat pump system integrated with a desiccant unit, equipped with a desiccant rotor made of Wakkanai Siliceous Shale (WSS) for residential air-conditioning, hot-water supply, and ventilation
- Successful development of a compact prototype system that does not even take 1.0 m^3
- The prototype was installed on an office floor for verification testing, which proved that the desiccant unit successfully and entirely removed latent heat load from outside air, with the heat pump registering a high air-conditioning COP value of 5.8 at that time.
- Commercialization efforts underway as a theme in the practical application development phase



WSS rotor

Desiccant ventilation system

The development of a high-efficiency heat pump system for the space cooling, heating, and domestic hot-water supply using a desiccant ventilation system with Wakkanai siliceous shale," under the "Strategic Development of Rationalization Technology for Energy Use" initiative (FY2008–2010)

Adsorption Chiller Utilizing Factory Waste Heat

Development of a heat pump system equipped with a microfin adsorber

- An adsorption chiller that generates cold air from the evaporation of water is expected to achieve a power-saving of 80% compared to general spot-cooling units.
- Made compact with the ñmicrofin structureò that efficiently conveys heat to the adsorbent