ADVANCES IN AIR CONDITIONING TECHNOLOGY FOR NET ZERO ENERGY IN TROPICAL HOT AND HUMID CLIMATE
Efforts of DAIKIN’s Technology and Innovation Center (TIC) to Achieve Zero Energy Building (ZEB)
Key Words to Represent Daikin

- Founded in 1924
  94 years of History
- People-Centered Management
- Comprehensive AC Manufacturer
  that deals in both AC equipment and refrigerants
- More than 90 global production bases
- Overall Sales of More than 2 Trillion Yen
- 70,000 Employees
  Overseas employees approx. 80%
- Business Development in More Than 150 Countries
- 75% in Our Sales from Overseas

Pichon-kun
Founded as Osaka Kinzoku Kogyosho in 1924, Daikin Industries began manufacture of radiator tubes that cooled airplane engines and was the first company in Japan to develop fluorocarbon refrigerant and commercial air conditioners. Business expanded, and the company became a comprehensive air conditioning company.

**History of Daikin (1924-2005)**

- **1935**: Development of CFC refrigerant
- **1937**: Development of CFC type refrigeration equipment
- **1942**: Manufacturing start of CFC
- **1941**: Establishment of Yodogawa Plant
- **1951**: Development of a packaged AC
- **1958**: Advance into the residential AC business
- **1960**: Establishment of Kanaoka Factory in Sakai Plant
- **1970**: Establishment of Shiga Plant
- **1972**: Establishment of Daikin Europe N.V. in Belgium
- **1975**: Sales launch of a photocatalytic air purifier
- **1980**: Establishment of Daikin Industries Thailand
- **1982**: Sales launch of a multi-split type AC for buildings
- **1983**: Sales launch of “AirNet Service System,” an AC monitoring system
- **1993**: Sales launch of “Ururu Sarara,” a residential AC that humidifies without an external water source
- **1995**: Establishment of the China’s first production base in Shanghai
- **1999**: Sales launch of “EcoCute,” an air to water heat pump system
- **1999**: Forming global comprehensive alliance with Matsushita Electric Industrial Co., Ltd. (currently Panasonic Corporation)
- **2000**: Successful application of Streamer discharge technology
- **2004**: World’s first successful application of Streamer discharge technology
History of Daikin (2006 ~ ...)

2006
Sales launch of "Daikin Altherma," Air-to-Water Heat-pump for Space Heating and Domestic Hot Water

2007
Industry's first Sales launch of "DESICA," a humidity-control ventilation system that uses outside air without water supply

2008
Acquisition of major global air conditioning manufacturer O.Y.L

2009
Acquisition of German heating manufacturer Rotex

2010
Acquisition of U.S. residential unitary company Goodman

2011
Establishment of our largest scale production base in Suzhou, China

2011・2013
Opening of Solution Plaza “Fuha: Tokyo” and “Fuha: Osaka”

2012
World’s first Adoption of new refrigerant “HFC32” to AC

2012
Acquisition of Turkish air conditioning manufacturer Airfel

2015
Establishment of Technology and Innovation Center (TIC), a global R&D center

2016
Acquisition of U.S. filter manufacturer Flanders

2016
Acquisition of Italian commercial refrigeration manufacturer Zanotti
Daikin Technology and Innovation Center (TIC)

- Aim to create *kyoso* (協創, collaborative creation) innovation that incorporates internal/external technologies from other fields while pursuing core technology for Air Conditioning, Chemicals, and other businesses

1) Facility Name: Technology and Innovation Center
2) Total Area: Approx. 58K m², six-story building
3) Location: Settsu, Osaka (in the Yodogawa Plant)
4) Investment: Approx. 38.0 billion yen
5) Opened: November 25, 2015
6) No. of Employees: Approx. 700

The *Waigaya* Stage is located in the Office Tower of the building. The design enables and promotes open communication.

University professors and opinion leaders are invited as fellows, and rooms with different designs are available for their exclusive use. There are also satellite offices for Kyoto University and Osaka University.

Laboratory facilities unrivaled in the world are available, including an anechoic chamber for AC equipment. Several project rooms are also provided for joint research with outside engineers.
Yodogawa Plant site area: 396,666m² (4,305,564ft²)

- Office: 20,000m² (215,278ft²)
- Laboratory: 28,000m² (301,389ft²)

TIC site area: 30,000m² (322,917ft²)
Total floor area: 48,000m² (516,667ft²)
Number of floors: 6F + B1F
Cross Section Indicates the Building Concept

Cross Section of North-South

- Laboratory Area (About 28,000 m²)
- Office Area (About 20,000 m²)

Cross Section of West-East

- Photovoltaic Panels (300kWp)
- Low-e Double Glass: Punching Eaves
- LED Task & Ambient Lighting
- HP Desiccant with CO2 Density Control
- Air Conditioning from Floor

- Guest’s Diner
- Reception Room
- Discovery Hall
- Meeting Space
- Lecture Room
- Meeting Rooms
- Future Lab
- Office

Highly Efficient VRF to Utilize Geothermal

- Water Heat Source VRF
- Geothermal Heat Exchanger

- Sun Trace, Mirror
- Cool/Heat Trench
- Cool/Heat Trench

- Discovery Hall
- Lecture Room
- Meeting Rooms
- Guest’s Diner
- Reception Room

- Office
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- Laboratory
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- Water Heat Source VRF
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**Fusion of Building Concept & Energy Savings**

Intending **ZEB (Zero Energy Building), Reduce 70% of Energy Consumption without Spoiling Comfort** as Workplace.

- **Top Light to Adopt Natural Lighting in the Midst of the Office**
- **Open Ceiling Utilizing Natural Lighting/Catching each other’s Eyes/Connecting Activities**

### About 60m×60m・2Floors・Large Office of 6,000㎡

- **About 60m×60m・2Floors・Large Office of 6,000㎡**
- **Future Lab**
- **WAI-GAYA Stage (Free Discussion Area)**
- **Open Lab Meeting Space**
- **Rooms for Concentration**
- **5F: Office**
- **3F: Co-Creation with Various Parties**
- **Meeting Space**
- **Office**
- **Open Lab**
- **4F: Office**
- **Meeting Room**
- **Office**
- **3F: Co-Creation with Various Parties**
- **Meeting Space**
- **Office**
- **Open Lab**
- **4F: Office**
- **Meeting Room**
- **Office**
- **5F: Office**
- **WAI-GAYA Stage (Free Discussion Area)**
- **Open Lab Meeting Space**
- **Rooms for Concentration**
- **Future Lab**
- **6F: Vision Make / Discussion Space**

**Section of Office Area**
Daikin Industries, Ltd. Technology and Innovation Center

LEED FACTS

LEED for New Construction Certification awarded 22/07/2016

Platinum 85/110

Daikin Industries consolidated approximately 700 R&D engineers from three bases in Japan of Daikin Industries. A mega-floor with high functionality was created utilizing two floors of 3,000m$^2$ and a central mezzanine in order to support true collaborative creation activities transcending departmental boundaries. In the office area, there is the Chi No Mori, a venue for collaborative creation with people outside the company, and the Future Lab, where residing outside fellows and researchers from universities and other companies engage in substantial dialogue for social innovation. In order to maximize acceleration of research activities for the Laboratory area, we made a large space with no partition walls to improve expandability and flexibility.

Combining Daikin's existing and newly developed technology, we constructed a facility system that aims for achieving ZEB for the Office area, and made environmental construction that balances high environmental functions endorsed by objective evaluations (LEED, CASBEE) and comfort as a workplace.

In LEED's new construction rating system (LEED-NC), a U.S. building certification system, TIC received the highest rank of Platinum Certification. This is second awarding of Platinum in Japan and a Japan first as a large-scale office building.

Design/Supervision: Nikken Sekkei and NTT Facilities
Construction: Takenaka Corporation
Location: 1-1 Nishitotsuya, Settsu City, Osaka Prefecture
Building Type: Research Facility / Office Building
Structure and Floors: S/SRC -1+6 P2
Building Area: 11,839.00 ㎡
Total Floor Area: 47,911.86 ㎡
Efforts for ZEB have been focused on the Central Office, which are a part of the Office area of TIC. (The left-hand side of the photo shows the Laboratory, which was excluded from the ZEB evaluation because it is used for a variety purposes such as for test facilities.)
Trial for ZEB by Energy Conservation

Energy Consumption of Normal Buildings

- Existing Technology
- Highly Efficient VRF System
- Utilization of Natural Energy
- Flexible Utilization of Heat
- Sophisticated Sensing Technology
- Energy Creation

Evolve from 1st Phase

1st Phase 2015年

2nd Phase 2020年

Target Value at the Completion of Construction in 2015

Total Energy Consumption: -70%

Energy Consumption for Air-Conditioning: -76%
We set a target of reducing energy consumption by 70%.

Initial ZEB Target

1,502 MJ/m² per year (417 kW.h) - Standard building
451 MJ/m² per year (125 kW.h) - TIC target

Note: The left side depicts energy consumption in a standard office building. Our goal for TIC is to reduce that figure by 70%.
The ZEB rank graph is published by The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.

• This graph depicts ZEB ranks that are used in Japan.
• It shows the energy consumption rate on the X-axis and the renewable energy supply rate on the Y-axis, compared to the energy consumption of a standard office building.
Comfortable Space and Sustainable Environment

—Progress and Verification Modelling—

3. Effective use of heat
   - Heat trunk line
   - Water-cooled VRV, Solar heat collection
   - Geothermal, Free cooling

4. Effective utilization of renewable energy
   - Solar trackers

5. Improvement in thermal envelop performance
   - ZEFFLE Infrared
   - Reflective coating

Other technologies introduced
- High thermal insulation (Low-e)
- Natural ventilation
- Natural lighting
- Cool heat trench
- Lighting control, Solar power generation, Lithium batteries

1. Ultra-high air-conditioning efficiency
   - VRV, DESICA

2. Optimum control
   - Pulverized vapor technology, TBAB thermal storage, Mode AC operation, Sensor grids

n-ZEB
Variable Refrigerant Volume (VRV)

- Humidity Control for High Energy Savings
- Changes evaporation temperature according to required capacity

![Ultra Compact Outdoor-Air processing Unit](DESICA)

- Performs humidity control (Amount of humidity processing is controlled by humidity sensor)

High Efficiency in Partial Load and Low Capacity Ratio

![Ultra-High AC Efficiency](Efficiency vs Load Rate Graph)

- Direct cooling adsorption and direct heat regeneration enables high dehumidification performance by low regeneration temperature
- Regeneration is achieved by condensation waste heat of the heat pump.
Introduction to VRV

VRV X SERIES

Concept
- Actual energy saving
- Improve performance at partial load
- Higher efficiency
- Further improve the COP
- All models equipped with K compressor

1. Automatic refrigerant charge function (to make the refrigerant amount appropriate and secure high reliability)
2. VRT Smart Control
3. K Compressor (Inverter)

Note: comes with inverter compressor
Energy Saving Advanced Technology

1. New Scroll Compressor

Refrigerant leakage is minimized during low-load operation

- Operation loss due to refrigerant leakage is reduced by the proprietary back pressure control mechanism to ensure stable low-load operation

*Graph shown above is for illustration purpose only.*
2. Energy Saving VRT Smart Control

**VRT** adjusts refrigerant temperature to individual building and climate requirement, thus further improving annual energy efficiency while maintaining comfort.

**VAV** (variable air volume) controls the airflow rate of indoor units automatically, to attain detailed energy-saving control.

**VRT + VAV = VRT Smart**
Energy Saving Advanced Technology

2. Energy Saving VRT Smart Control

VRT Smart Control (Fully Automatic Energy-saving Refrigerant Control)

- Combines air volume control (VAV: variable air volume) for indoor units with conventional VRT control
- Optimizes compressor speed by calculating the required load for the entire system and optimal target refrigerant temperature based on data sent from each indoor unit
- Coordination with the air volume control reduces compressor load and minimizes operation loss based on detailed control
- Ensures energy savings and comfortable air conditioning to meet actual operating conditions

Note:
- If a system has indoor units subject to both VRT smart and VRT control, the system is operated under VRT control.
- If a system has both outdoor-air processing air conditioners and outdoor-air processing type indoor units, VRT smart control and VRT control are disabled.
2. Energy Saving VRT Smart Control

Overview of VRT Smart Control (system control flow)

- Different automatic energy-saving refrigerant control applies depending on the indoor units connected.
3. Automatic Refrigerant Charge Function

Other technologies to increase efficiency and enhanced system performance includes

- Automatic Refrigerant Charge Function
- Reduced Standby Power Consumption
3. Automatic Refrigerant Charge Function

VRV IV Refrigerant Charging Method (Manual)

1. Calculate necessary refrigerant amount from design drawing
2. Recalculate refrigerant amount from final installation drawing
3. Charge refrigerant
4. Regularly check refrigerant weight on weighing scale
5. Complete by manually closing valves when proper weight is reached

Automatic Refrigerant Charge Function

1. Calculation of necessary refrigerant amount from design drawing
2. Pre-charge of refrigerant*
3. Start of automatic refrigerant charge operation
4. Automatic completion by proper refrigerant amount
5. Monitoring refrigerant charging is unnecessary
6. No recalculation of charge amounts due to minor design changes locally
Case Study: Green Building Project

Installed unit: VRV Hi-COP 22HP model

Capacity:
- C.O.P 4.43
- Overcharged system
- Charged amount 42 kg

- Charged amount 26 kg

- C.O.P 5.29
- Rectified System

Unstable Operation

Stable Operation
4. Reduced Standby Power Consumption

The **Standby Power** in air conditioning system can be applied in:

- Power being applied to the compressor windings
- Power applied to the control panel, thus creating constant communications between indoor and outdoor components of the unit
- Power being applied to a crankcase heater for preheating refrigerator oil when the air conditioner is stopped

**Reduced Standby Power Consumption**
4. Reduced Standby Power Consumption

Enhanced Performance

Compressor Operation

VRV IV compressor with crankcase heater

Crank case heater (VRV IV logic)

VRV X/A compressor without crank case heater

Compressor Heating (VRV X/A logic)

Standby Power consumption is high.

No crank case heater

25°C

Compressor turn on ONLY when ambient temperature falls below 25°C
Enhanced Performance

4. Reduced Standby Power Consumption

- Compressor is running on 3 phase power supply
  - When compressor is not running, it becomes open phase power supply ➔ only 2 phase power supply
  - Heating process by open phase power supply so can remove crank case heater
  - Using compressor heating instead of crank case heater
  - ME has the same technology as Daikin

Image from ME catalogue
Enhanced Performance

4. Reduced Standby Power Consumption

- The advanced oil temperature control reduces standby power consumption by up to 82.7%* annually compared to conventional models.
- Standby power needed for preheating refrigerator oil, which consumed substantial standby power, was reduced to save energy when the air conditioner is stopped.

Operation calculation conditions: VRV A series 14 HP
Location: Singapore
Operation time: 08:00–18:00 on weekdays
## Enhanced Performance

### 4. Reduced Standby Power Consumption

#### VRV A standby power consumption

<table>
<thead>
<tr>
<th>HP</th>
<th>VRV A (kWh per annum)</th>
<th>VRV IV Standard (kWh per annum)</th>
<th>Standby Power Consumption Reduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>6, 8</td>
<td>54.22</td>
<td>202.95</td>
<td>73.3%</td>
</tr>
<tr>
<td>10, 12</td>
<td>55.85</td>
<td>202.95</td>
<td>72.5%</td>
</tr>
<tr>
<td>14</td>
<td>70.32</td>
<td>405.9</td>
<td>82.7%</td>
</tr>
<tr>
<td>16, 18</td>
<td>137.13</td>
<td>405.9</td>
<td>66.2%</td>
</tr>
<tr>
<td>20</td>
<td>138.89</td>
<td>405.9</td>
<td>65.8%</td>
</tr>
</tbody>
</table>

#### VRV X standby power consumption

<table>
<thead>
<tr>
<th>HP</th>
<th>VRV X (kWh per annum)</th>
<th>VRV IV Hi COP (kWh per annum)</th>
<th>Standby Power Consumption Reduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>6, 8</td>
<td>55.85</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>70.32</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12, 14, 16</td>
<td>111.70</td>
<td>405.9</td>
<td>72.5%</td>
</tr>
<tr>
<td>18, 20</td>
<td>167.56</td>
<td>608.8</td>
<td>72.5%</td>
</tr>
</tbody>
</table>

*Above mentioned reduction of standby power consumption is due to new control logic and removal of crankcase heater.

**Data used in catalogue**
High Performance Heat Pump Desiccant

- Temperature and Humidity Individual Control (THIC)
- The new device with the absorbent coating on the surface of the heat exchanger enabled the direct cooling and heating of adsorbent.

*New Type of Heat Exchanger Combined with Absorbent*

Available in Japan
High Performance Heat Pump Desiccant

<Dehumidification>

Every interval 4-way valve (refrigerant) & Damper (air)

Humidity of outdoor air is absorbed

The humidified air is throw to outdoor

Humidity of outdoor air is absorbed

The humidified air is throw to outdoor
The energy consumption of summer was reduced by almost half.

a) Set temperature was 28 deg C

b) Set temperature was 26 deg C
In case that the Temperature & Humidity Individual Control (THIC) system is installed in the high quality buildings, total amount of the energy consumption throughout a year will be reduced by more than 70%.
Comfortable Space and Sustainable Environment
—Progress and Verification Modelling—

**Effective use of heat**
- Heat trunk line
- Water-cooled VRV, Solar
- heat collection
- Geothermal, Free cooling

**Effective utilization of renewable energy**
- Solar trackers

**Improvement in envelope thermal performance**
- ZEFFLE Infrared
- Reflective coating

**Ultra-high air-conditioning efficiency**
- VRV, DESICA

**Optimum control**
- Pulverized vapor technology, TBAB thermal storage, Mode AC operation, Sensor grids

**Other technologies introduced**
- High thermal insulation (Low-e), Natural ventilation, Natural lighting, Cool heat trench, Lighting control, Solar power generation, Lithium batteries

**Comfort**
Outdoor Air

Cooling Tower

Solar Heat Collection

Water Source Outdoor Unit

Indoor Unit

Cool / Heat Trench

Underground Heat Exchange

VRV water cooled with cooling water piping connection

Boiler

TIC Entrance (Air Wall)
CONCLUSION
Energy Savings And Comfort

1. Passive technology
   - Natural ventilation
   - Natural illumination
   - Sunlight shielding
   - Thermal insulation
   - For building structure

2. Positive technology
   - Ultra-high efficiency AC
   - Ultra-high efficiency Lighting

3. Renewable energy

ZEB

Energy saving

Comfort
We set a target of reducing energy consumption by 70%.

Initial ZEB Target

Standard building

TIC target

Note: The left side depicts energy consumption in a standard office building. Our goal for TIC is to reduce that figure by 70%.
Our energy consumptions reduction rates for 2016 were minus 72% totally.
With on-site renewal energy

Standard data

1,502 MJ/m² p.a. (417 kW.h)

Result

263 MJ/m² p.a. (73 kW.h)

451 MJ/m² p.a.

-200

-200

263 MJ/m² per year

451 MJ/m² per year

▲ 72%

▲ 82%

▲ 10%

When the amount of renewable energy supplied by the Solar panels, 10% is added, the energy consumption including renewable energy supply totals minus 82%.

Air conditioning and Ventilation
Lighting
Hot water and sanitation
Elevators
Solar generation

2016 result

1,502 MJ/m² p.a. (417 kW.h)

263 MJ/m² p.a. (73 kW.h)

451 MJ/m² p.a.

-200
TIC achieved “Nearly ZEB Level II”

The ZEB rank graph is published by The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.
Based on the payback period of each technology at the time of facility design of TiC and the energy consumption reduction percentage, high cost performance technology was introduced. We will aim for even further energy savings in the future in the belief that it is important to improve the effectiveness of each technology.

We aim to develop technology that is highly cost effective in order to realize widespread adoption of ZEB and hope to continue moving forward while benefitting from your kind advice.
Thank You