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Trends in the Japanese building ventilation market and drivers for change

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1 Introduction

The technology in building physics and mechanical engineering for building ventilation may not be totally new area and must have rather long history and much knowledge accumulation of their own. Nowadays, the distance between the engineering field and society looks becoming shorter, since there are stronger needs from the society than before to reduce the environmental impact of the buildings and to enhance the indoor environmental quality with cost effectiveness, at the same time. The technological solutions by the engineering filed should have been cost effective so far as they can satisfy the contemporary needs, and resultantly they always must have contained compromises. That must be a reason why there is still many problems to be solved in the field of building physics and mechanical engineering for building ventilation. In this paper, such re-emerging or new problems, which are being struggled by experts in Japan will be reviewed and introduced. The authors wish that it should be fruitful for experts in different countries to be able to share some of the problems and the strategies to solve them.

2 National trends in IAQ requirements and market characteristics

2.1 Requirements on ventilation of dwellings

When buildings are to be built or to be repaired in a large scale, it is mandatory to apply for building confirmation according to the Building Standard Law. Without complying with the law, any buildings can not be built nor repaired in a large scale. As for the building ventilation, there are three kinds of regulations.

Firstly, there is a minimum requirement for the supply of outdoor air for habitable rooms, which can be satisfied either of mechanical ventilation or natural ventilation by window opening. For the mechanical ventilation, a minimum ventilation requirement is set at 20 m^3/h per person, and for the natural ventilation the minimum ratio of the openings is set at 1/20 of the room floor area.

Secondly, for rooms in which fire is used, the minimum ventilation requirement is set in proportion to the quantity of gas products generated during combustion.

Thirdly, a new regulation has been added since 2003 as a countermeasure against so called "sick house problem". The detail of the regulation is to be described in chapter 2.3.

2.2 Requirements on indoor air quality of non-residential buildings

The Building Standard Law is shared by residential and non-residential buildings, and the same regulations for the ventilation as the residential buildings are applied to the non-residential buildings. In addition to the Building Standard Law, for the buildings larger than 3000 m^2 and grouped into categories such as department stores, auditoriums, libraries, museums, retail stores and offices, and for the buildings larger than 8000 m^2 and grouped into schools, the measurement of the items shown in Table-1 for every two months is mandatory according to the Enforcement Ordinance for the Maintenance of Hygienic Environment in Buildings.

Table 1: Items to be measured in the Enforcement Ordinance for the Maintenance of Hygienic Environment in Buildings

Airborne particle	<=0.15 mg/m^3	Every two months
CO	<=10ppm	Every two months
CO_2	<=1000ppm	Every two months
Temperature	17°C-28°C	Every two months
Relative Humidity	40%-70%	Every two months
Air Velocity	<=0.5m/s	Every two months
Formaldehyde	<=0.1mg/m^3	After building or repairing in a large scale

2.3 Regulation for solving so called "sick house problem

2.3.1 Introduction

The Japanese national scale survey had revealed that the indoor concentration of formaldehyde in considerably large number of dwellings had been higher than the concentration guideline. In response to the public demand for legal control of building materials and ventilation, the Japanese Building Standard Law has been revised and with related ordinances and notices it has become effective since July 1, 2003.

A revision of the Building Standard Law in response to a social problem of so called "sick house" was approved on July 12, 2002, and related ordinances and notices were promulgated. Especially, formaldehyde and chloropyriphos are focused upon in the revised law.

2.3.2 Performance the revised law requires

Before the revision of the building standard law, Japanese Ministry of Health, Labor and Welfare had determined the guideline for concentration limit of eleven chemical substances by July 2001. Though the guideline is not mandatory, the concentration limit of formaldehyde (0.08ppm), which had been proposed by World Health Organization, has been adopted in the revised Building Standard Law as performance objective. In detail, that limit is defined as the 30 minutes average concentration. The combination of material selections and ventilation design has to be realized in order to be able to keep the formaldehyde concentration lower than the target value throughout the year. In addition, the usage of chloropyriphos will be prohibited under the revised law.

2.3.3 Regulations for building materials

Building material standards in JIS (Japanese Industrial Standard) and JAS (Japanese Agricultural Standard) have been revised in accordance with the revision of Building Standard Law. Ranks of emission rate are shown in the leftmost row of the first table of Table-2. The safety side assumption was adopted when the requirement was determined. Based on the fact that the emission rate of formaldehyde increases as the temperature rises, the highest possible indoor temperature with air conditioning, 28 degree Celsius, is assumed, and no window opening is assumed, which is not always realistic but can be safety side condition.

The “First Type of Formaldehyde Emitting Building Materials”, which emits formaldehyde most, higher than 0.12 mg/m^2h, is prohibited as finishing materials in living spaces. On the other hand, the highest rank materials, of which emission rate is lower than 0.005 mg/m^2h, are imposed no limitation for their use. The “Second Type of Formaldehyde Emitting Building Materials” and “Third Type of Formaldehyde Emitting Building Materials” have their limitations for usage, depending upon ventilation rate of the habitable spaces.

Before the revision of the building standard, there was much “Second Type” in the market, but the present majority of used materials is the “Third Type”. It is not easy to find “First Type” or “Second Type” in the market, nowadays. The highest rank materials and “Third Type” have become major building materials. As for the ventilation capacity, the air change per hour between 0.5 and 0.7 seems to be the potentially major target in the practice. In the second table of Table-2, the values shown in the second column, which are 0.50 and “0.5 to 0.7 air change per hour”, are important. It means that “Third Type” can be used as much as a double area (reciprocal number of 0.50) of the floor area, when the habitable space is ventilated at a rate between 0.5 and 0.7.

The limitation of materials inside “inter-story spaces, etc.”, whose summary is given in the last part of Table-2 ((3)), means that the type of materials (not the amount) used inside such space has to be limited, depending upon what kind of ventilation system is adopted. The “inter-story spaces, etc.” can be defined as spaces behind interior finishing, such as the inter-story spaces, attic space, inside space of the outer walls and the partition walls, and storage spaces. If only “Third Type” or better type of materials is used inside inter-story spaces, etc., there is no limitation for the area of plane materials (only the plane materials, like plywood, insulation mat, etc. are controlled. The beam-shaped materials like pillars, beams, etc. are not controlled.). Taking the limitation for the inner space of the envelope into consideration, the usage of “Third Type” or better materials is recommended in order to avoid troublesome inexperienced practice for careful detail design of the envelope and the ventilation system.

2.3.4 Regulations for ventilation

- Application and limitation of natural ventilation systems

In the previous energy code for residential buildings and the previous evaluation criteria of the Housing Quality Assurance Act, natural ventilation systems in accordance with the prescribed design rules could be complied with the requirement, while local exhaust fan(s) for a bathroom and a kitchen was required in the energy code. The background assumption was that the largest risk for indoor air pollution was faced in winter, when occupants tend to shut the windows while heating. The window-opening behavior in medium seasons as well as in summer was seemed to be realistic. This assumption was in harmony with the regulation for windows’ size, which requires at least one twentieth of the floor area.

However, in the revised regulation, as mentioned above, summer situation with windows closed and air conditioners in operation is assumed. As a result, the natural ventilation system utilizing stack effect cannot be the independent solution, since the temperature difference between indoor and outdoor in summer becomes too small for reasonable size vents or stacks to allow sufficient ventilation rate. For example, average temperature difference of above 10 degree in Celsius under mean average outdoor temperature of 5 degree Celsius and indoor temperature of 17degree Celsius has been assumed to determine the necessary equivalent opening area of vents, while only 3 degree Celsius temperature difference can be expected in summer. In summer situation, the passive ventilation through vents and/or stacks is not enough without window ventilation.

Therefore, the installation of mechanical system is needed in any dwellings, but the natural ventilation system can still be used in heating season with mechanical systems switched off. It is a kind of hybrid ventilation system, which utilized buoyancy effect when it is available.

- Requirement for mechanical ventilation systems

The mechanical ventilation systems are grouped into three categories as before the revision of the Building Standard Law. The "First Type" of ventilation system is a balanced ventilation system with both of supply and exhaust fans. The "Second Type" and "Third Type" of ventilation system are the supply only ventilation system and the exhaust only ventilation system, respectively. The ventilation rate of the "First Type" is evaluated by its larger ventilation capacity among the supply and the exhaust.

The fan has to be selected correctly on the basis of the calculation of pressure loss along airflow path, especially when the duct is used. The calculation sheet is not necessarily requested at the application for confirmation to local government, but some local government may request it according to the policy of each building official. There has been another path to make the ventilation capacity approved without one by one calculation for each dwelling. The path is called "Katashiki-nintei", where any fixed combination of ventilation system components can be evaluated of its ventilation capacity for referenced one-story building with a plan of specific aspect ratio. The condition is regarded as safety side, because of longer duct is needed than usual situation including almost any two-story buildings. The approval by the "Katashiki-nintei" needs additional cost for the preparation and registration, but can save complicate works for pressure loss calculation, although the ventilation rate tends to be excessive. Once the approval by the "Katashiki-nintei" is obtained, only the maximum coverage of floor area by a ventilation system composed of fixed kinds of components is compared with the floor area of the dwelling, to which the ventilation system is going to be installed.

2.3.5 Characteristics of the regulations revised in 2003

In the following points, requirements for the ventilation design had been changed.

- Summer condition is focused upon, due to higher emission rate of formaldehyde caused by higher temperature. Thus, buoyancy driven natural ventilation cannot be independent and should be designed with a supplemental mechanical system.
- Formaldehyde emission from furniture is taken into account, when drawing the area limit of finishing plane materials and ventilation rate. The surface of the Third Type of Formaldehyde Emitting Building Materials used for the furniture is assumed to be three times of the floor area.
- When choosing "Third Type" of ventilation system, one of the following countermeasures to avoid incoming formaldehyde from "inter-story spaces, etc." has to be taken. The first option is to choose "Third Type of Formaldehyde Emitting Building Materials" or better one for the surface of such inside space of the envelope. The second option is to make such space depressurized lower than living space by sharing exhaust ventilation between from living spaces and from "inter-story spaces, etc. The third option is to make the border between living space and "inter-story spaces, etc." airtight. This option needs careful detailed design of the envelope not only for the outer envelope, but also for partition structure, which is inexperienced practice.
- Pressure loss calculation is mandatory, especially when using duct. To avoid the calculation, the selection of the ventilation systems without duct or the approval by the "Katashiki-nintei" is necessary.
- Heat loss and excessive dryness in winter due to higher ventilation rate had better be taken into consideration, though these effects are not described in new regulations. In the previous regulations in the energy codes, the ventilation capacity can be reduced by 0.1-0.2 ac/hr depending upon the envelope air tightness. However, in the revised regulation such rule is not adopted. Controllability of the ventilation rate to avoid negative effects in winter is only recommended.
- When applying the new regulation strictly, only habitable rooms like living room, dining room, bed room,

etc. are imposed legal control, when certain ventilation systems are chosen and partition doors are not with intentional door undercut or other intentional airflow path. This way to comply with the regulation is not recommendable from the viewpoint of safety side air quality control, but can be chosen.

2.3.6 Survey on the pollutant concentration before and after the revision of the Building Standard Law

The survey on the pollutant concentration in residential buildings was started in 2000 by Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The number of samples in each year ranges from 1181 (in 2005) to 2817 (in 2000). The passive sampler badge to absorb substances in the rooms was used and left during 1 day with window closed and mechanical ventilation switched on if available.

Figure-1 and Figure-2 show the result for formaldehyde and toluene in the 6 years. Even before the revision of the Building Standard Law in 2003, the decrease of the concentration had started. It seems to be because of voluntary actions taken by manufacturers of materials and builders, which were afraid of troubles. After the revision, the decrease of the concentration not only of formaldehyde but also of toluene continued, and the excessive concentration above the values in the guideline issued by Ministry of Health, Labor and Welfare was found in households of 1.5% for formaldehyde and 0.3% for Toluene in 2005.

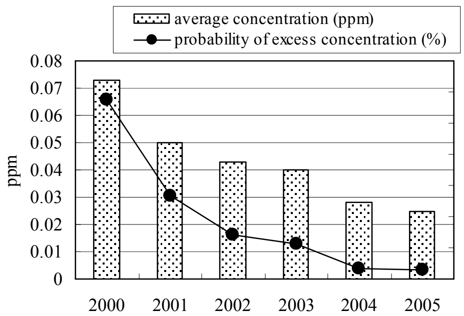


Figure 1 - Result of Survey on Formaldehyde Concentration

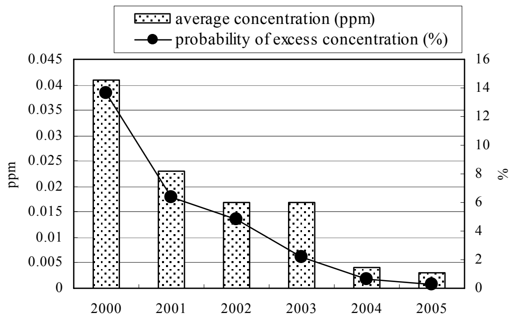


Figure 2 - Result of Survey on Toluene Concentration

2.4 Characteristics of ventilation market

Japanese investment in new construction of buildings is shown in Figure-3. There was a rapid growth in 1960s and 1970s, followed by steady situation in early 1980s and the second rapid growth in late 1980s and early 1990s. Since the early 1990s, the investment in the new construction had been decreasing until around 2001 or 2002, and turned to be increasing slowly by now.

Figure-4 shows the use of buildings newly constructed in FY2007, and Figure-5 shows the construction methods of the buildings. Majority of the Japanese new buildings are constructed by the steel frame or the wooden frame.

On the contrary, Figure-6 shows the investment in either of extension, reconstruction or renovation. The purposes of the renovation are shown in Figure-7, but the renovation works for HVAC is very few, according to this statistics.

In Figure-8, the trend of the Japanese market for residential ventilation fans is shown. The number of manufactured fans decreased in 1998, and slightly increased during 2004 and 2005. The HVAC and ventilation market mainly for non-residential buildings is shown in Figure-9. The market for the refrigerating machines for stationary use is approximately 140 billion yen, which is as large as the market for the residential ventilation fans. In Figure-9, the market for the refrigerating appliances for stationary use such as room air-conditioners is shown, and is approximately 1060 billion yen, which is much larger than the total market for HVAC components shown in Figure-9. It seems to reflect the frequent adoption of packaged air-conditioners not only in residential buildings but also in non-residential buildings.

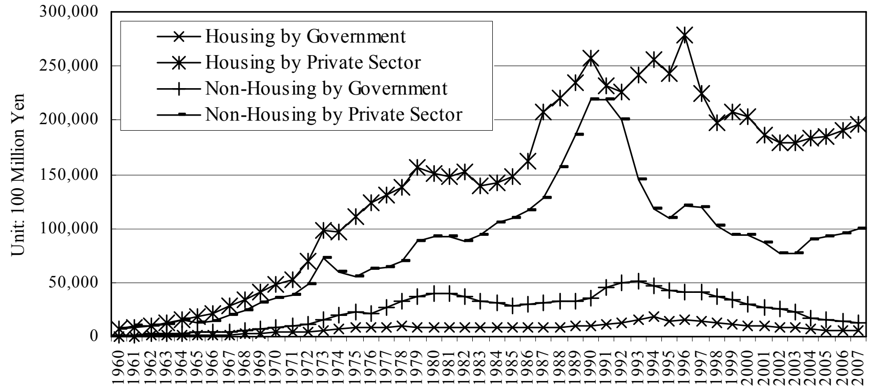


Figure 3 - Estimation of Construction Investment

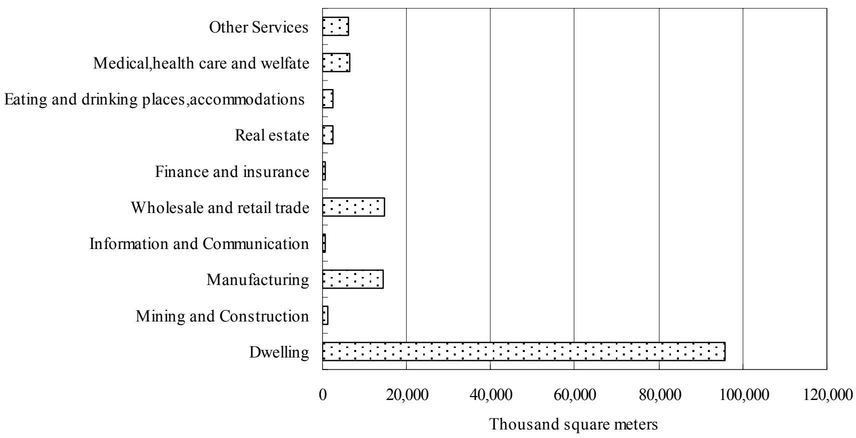


Figure 4 - Floor Areas for Building Types Started Construction in FY2007

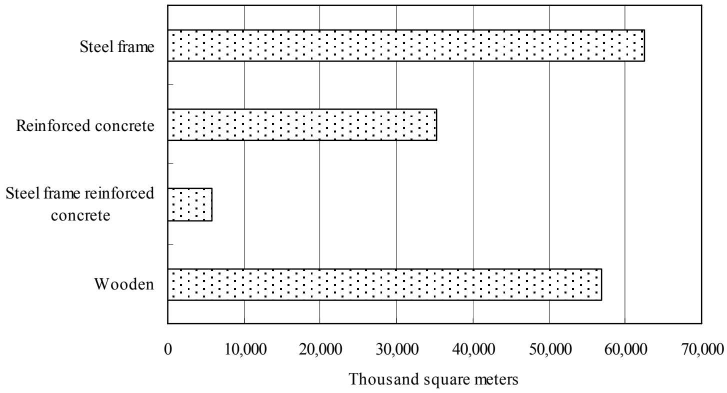


Figure 5 - Building Construction Started in FY2007

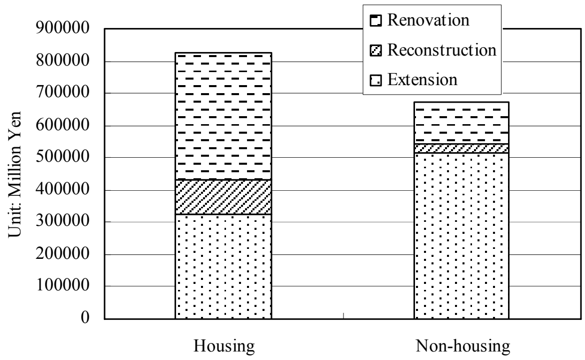


Figure 6 - Investment in Extension, Reconstruction or Renovation in 2005

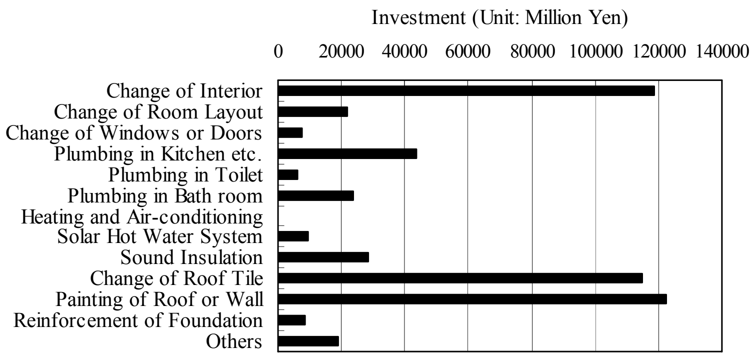


Figure-7 Investment in Different Categories of Renovation in 2005

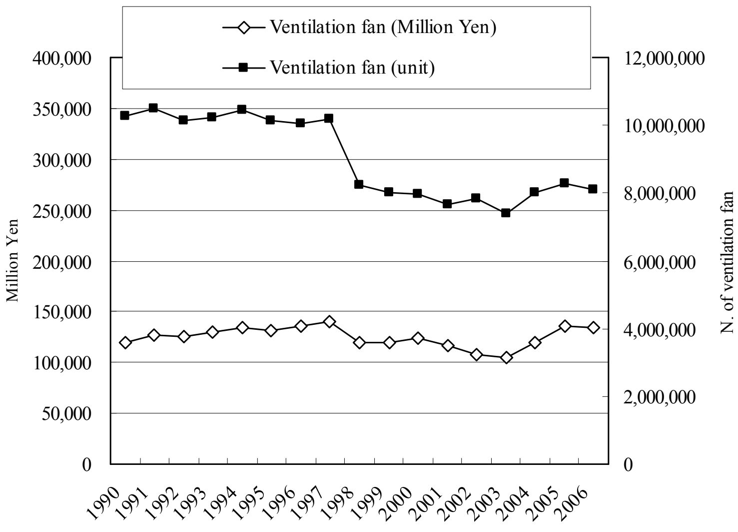


Figure-8 Value of Manufactured Goods Shipments in Japan

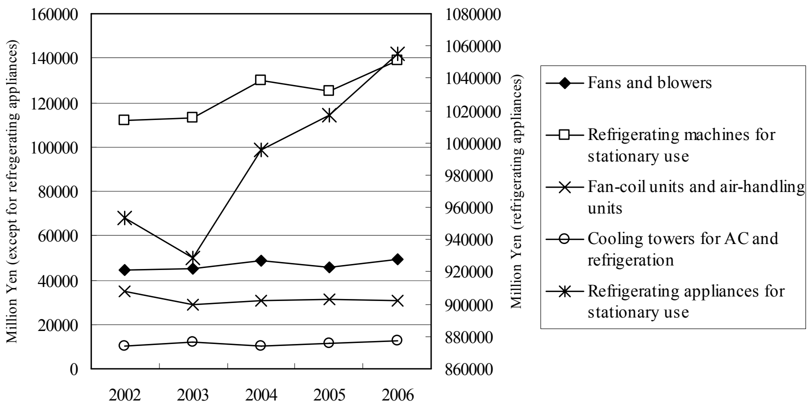


Figure-9 Value of Manufactured Goods Shipments in Japan

3 National trends in energy requirements and markets

3.1 The Energy Conservation Law in Japan

3.1.1 Grouping of Buildings

In the present regulatory system of Japan for energy saving, buildings are largely grouped into "houses" and "buildings". The "houses" includes apartment houses as well as detached houses. As other Japanese building regulations, the "buildings" in the energy regulation means various kinds of buildings other than residential buildings, although such definition of the "buildings" may be confusing if anybody uses usual definition of the term "building". The "buildings" is grouped into "office", "shop", "school", "hotel", "hospital" and "restaurant".

3.1.2 Two Major Evaluation Aspects: Building Envelope and Building Services

The umbrella law for energy conservation in Japan is "*Energy Conservation Law*", under which there are various ordinances describing more detailed rules and requirement. Among those, there are two performance-based building-related ordinances, namely, "*Criteria for clients on the rationalization of energy use for houses*" and "*Criteria for clients on the rationalization of energy use for buildings*". Both ordinances have two major evaluation aspects, *building envelope* and *building services*. In addition, there is another ordinance "*Design and construction guidelines on the rationalization of energy use for houses*", which consists of specification requirements.

The requirement for the building envelope consists of two major items, insulation and solar shading. The ventilation requirement for houses is also included to avoid worsening general indoor air quality due to air tightness and limited infiltration. There are a few points under discussion among Japanese experts on how to promote the utilization of the ordinances and what kind of items should be revised or added. There is tendency to search for more practical and applicable requirement for envelope design and construction. It is because rather strict requirement to prevent from condensation problems inside envelope could be accepted and practical enough in cold climate regions like Hokkaido, but on the contrary in milder climate regions there are still many houses built by a conventional construction method and builders, who are not familiar with energy/environment-oriented design and construction. Another topic as for the future revision is *cross ventilation* as a method for more comfortable thermal environment in summer and medium seasons, as well as higher requirement for solar shading.

The requirement for the building services of houses were newly introduced since April 2006, but only for common equipment of apartment houses, such as elevators, lighting for common corridors, etc. It means that any requirement of building services for detached houses and each unit of the apartment houses have not yet been included in the ordinances. This is another hot topic for future revision of the ordinances as mentioned later more in detail.

3.1.3 Performance Code and Specification Code

The ordinances for energy conservation law include both of performance code and specification code. As known broadly, the requirement for the performance code is expressed with indices and standard values, with which the energy performance of buildings has to be checked quantitatively by using expertise for the calculation, but various ways to comply can be allowed as far as criteria is fulfilled. On the other hand, the requirement for the specification code is expressed with allowable specifications for the design and construction of limited number, but practitioners can easily understand the requirement only with very limited and simple basic calculation.

As for houses, the performance code is used mainly by large scale manufacturers such as prefabricated housing companies, local but large housing companies and design companies of apartment houses. When applying the performance code to houses, it is necessary to calculate either "heat loss coefficient" plus "summer insolation acquisition coefficient" or "annual heating and cooling loads". As for the specification code, there are requirements for "thermal resistance of insulation", "coefficient of over-all heat transmission of openings", "solar shading devices", "insulation material installation method", "air tight envelope construction method" and "ventilation systems".

3.1.4 Another Law Including Energy Performance Requirement of Houses

From the view point of quality assurance of housing overall performance, "*The Housing Quality Assurance Act and Japan Housing Performance Indication Standards*" were established in 2000 followed by revisions in 2004 and 2006. They include multiple aspects of the performance of houses, namely, "construction stability", "fire safety", "durability", "maintenance", "thermal environment", "indoor air quality", "lighting and visual environment", "acoustic environment" and "universal design". The act and the standard are not mandatory as the ordinances for energy performance are not, but they are intended to help buyers to recognize the quality of houses. Each aspect can have plural items with ranks. In the "thermal environment", there is a single item for energy performance of the building envelope with four ranks, one of which refers above-mentioned two ordinances, namely, "*Criteria for clients on the rationalization of energy use for houses*" and "*Design and construction guidelines on the rationalization of energy use for houses*". The houses complying with one of the ordinances is evaluated as the rank 4, the highest rank. The rank 3 and the rank 2 are roughly equal to 1992 and 1980 energy performance ordinances, and the rank 1 means lower performance than 1980 energy performance ordinances.

3.1.5 Programs to Help Energy Related Ordinances and Act to Take Effect on Houses

As mentioned above, there is no mandatory ordinance and act in Japan, which requires a certain level of energy performance of houses, although any person who plans to build an apartment house larger than 2000m^2 shall report to the administration office in charge in regard to measures for the envelope and building services. They can be enforced mainly through incentive programs. As one of those incentive programs, GHLC (Government Housing Loan Corporation) had long provided homebuyers housing loan with premium for quality housing in the form of lower interest rate and upgrade of maximum loan volume. In the criteria applied to such premium housing loan, energy related ordinances have been referred, and some of homebuyers using the government housing loan had followed the energy performance criteria in order to get lower interest and additional loan volume. However, the broad reform of special public organizations started by the former Prime Minister Jun-Ichiro Koizumi resulted in the change of the GHLC and postal saving system as a financial resource of the government housing loan. After April 2007, the GHLC has been reorganized as Japan Housing Finance Agency (JHF), whose main business is buying housing mortgages originated by private financial companies and selling Mortgage Backed Securities to investors. Though the number of housing loans, which the JHF is buying, is much fewer than the number of housing loan, with which the GHLC dealt before (total amount of the MBS in FY2007 is only 2.2 trillion yen, while it dealt with 9 trillion yen housing loan in FY2000), there is still premium framework only applicable to the MBS for houses of higher energy performance. The above mentioned situation of the JHF is still transitional, and reinforcement in the near future is expected as being found in the report of the Council on Social Capital Arrangement. In the report, it is said that the government housing loan has largely contributed to maintaining the quality of Japanese houses. It is also said that the maintenance of the quality of houses should be promoted by JHF through its business to assist housing mortgage securitization.

3.2 Other Programs as financial stimuli to Promote Energy Conservation in Houses

The highest umbrella of countermeasures across various fields for Kyoto Protocol in Japan is *the Kyoto Protocol Target Achievement Plan*, which was drafted by the Global Warming Prevention Headquarter and was approved by the cabinet meeting on April 28, 2005. Under the plan, not only Ministry of Land, Infrastructure and Transport (MLIT), but also Ministry of Economy, Trade and Industry (METI) and Ministry of the Environment (MOE) have implemented various policies for the global warming issue. The representative policies in relation to residential buildings are as follows.

- Project Concerning Houses and Buildings by NEDO
- To promote energy conservation and dissemination of conservation systems in the commercial sector, New Energy and Industrial Technology Development Organization (NEDO) partially subsidizes the planned introduction of energy-conserving, high-efficiency energy systems in houses and buildings. In addition, NEDO collects post-introduction data to provide performance, cost-benefit analysis, and other related information to assist in the further introduction of these systems. For the subsidy in this program, in FY2007, approximately 25.3 Billion Yen shall be allocated. That budget consists of 1.2 billion yen for houses with the highly insulated envelope and efficient appliances, 12.5 billion yen for “Eco-cute”, which is a CO_2 refrigerant heat pump water heaters, 2.7 billion Yen for latent heat recovery water heaters, and 3.4 billion yen for gas engine (cogeneration) systems.
- Promotion of Photovoltaic power generation by NEDO and New Energy Foundation (NEF)
- The NEDO and NEF continued the promotion by subsidy until FY2005. The cumulated capacity of the generation promoted by NEDO and NEF was 595 thousand kW by FY2003 (860 thousands as a total). The price of the solar cell was estimated 690,000 yen/kW in FY2003. After FY2006, in place of NEDO and NEF, many local governments (more than 300 local governments) have started subsidy for the photovoltaic power generation. For example, the city of Yokohama, of which population is 3.6 millions, plans the subsidy of 30,000 yen/kW (at a maximum 120,000 yen/house) for up to 400 houses.
- Demonstration of Residential Polymer Electrolyte Fuel Cell (PEFC) Systems for Market Creation by NEDO and NEF
- In order to facilitate the popularization of residential PEFC systems, a large-scale and broad-based experimental study of 1kW stationary PEFC systems is being conducted under this project by NEDO and NEF. The aim is to advance the practical application of fuel cells by identifying issues for future technological development from the data obtained through this real life, practical use of stationary fuel cells in ordinary houses. In FY2005 and FY2006, field monitoring was done in 480 and 777 households, respectively. The project budget in FY2006 was 3.30 billion yen.
- Energy Conservation Law for Electric Appliances and Other Equipment (Top-runner program) by METI
- Introduction of a Top-runner program, which seeks to advance currently available products to a level above the level of the most currently advanced products with regard to energy efficiency standards for electrical appliances (household appliances and Office Equipment, etc) or automobile fuel efficiency standards. Among the

household electric appliances, air-conditioners, refrigerators, television sets, etc. have their target energy efficiency.

- Continuous Proposal by MOE on Environmental Tax
- The above mentioned broad programs, 1) to 4) ,by METI have been realized, because of abounding fund, of which source is the Special Account for Measures to Improve Energy Supply and Demand Structure. In 2003, the Act for the special account was amended so that the account could be jointly operated by METI and MOE. After that, a part of the Special Account for Measures to Improve Energy Supply and Demand Structure has been allocated also to policies of MOE for reducing the emission of CO_2 due to energy use. In FY2006, the budget for those policies by MOE was approximately 25 billions yen, among which 0.28 billions yen was used to assist local groups trying to promote energy saving technologies for houses. It means that the fund for MOE is still very limited. In addition, the budget operated by MOE is mainly used for indirect promotion of countermeasures to the global warming rather than direct supply of subsidy to compensate additional expenses when buying energy saving products.
- In addition to such resource preparation, the MOE has been stressing increasingly the necessity of the environmental tax. According to the MOE, the introduction of the tax is assumed to synchronize with tax reduction when buying energy efficient electric appliances and building services. Increase of the amount of tax for each average household is expected to be about 2,000 yen per year, and the total increase of revenue is estimated to be 360 billions yen.

3.3 Market impact

The scale of Japanese building industry is shown in the construction investment (Figure-3). Total investment is roughly 30 trillion yen in 2007, which is more than the investment in automobiles. Even though only limited parts of the buildings are related to the energy performance, increasing requirement for higher energy performance is producing new markets and businesses. For example, total weight of manufactured insulation components has increased by 1.53 times between FY1990 (235,710 ton) and FY2006 360,096 ton), while the number of built detached houses decreased between the FY1990 (622,293 houses) and FY2006 (500,100 houses). The amount of manufactured or imported double-glazed glass and plastic sash are rapidly increasing as shown in Figure-10.

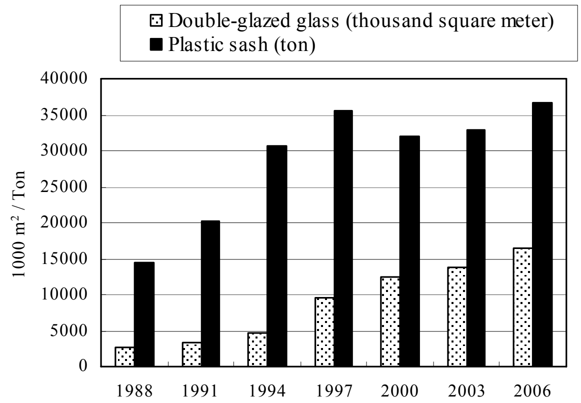


Figure-10 Manufactured or Imported Components for Windows

4 National trends in air tightness requirements and markets

4.1 Residential buildings

In the revision of Energy Conservation Law in 1992, the regulation for the air tightness was introduced for the first time in Japan. The requirement was only for the cold regions, of which heating degree days (D_{18-18}) is larger than 3000. In the revision in 1999, the requirement for the air tightness was extended to all climatic regions. For the colder regions and milder regions, the standard values are 2.0 cm^2/m^2 and 5.0 cm^2/m^2, respectively. The reasons why the air tightness is necessary have been interpreted by the following four items.

- To maintain the effectiveness of the insulation installed in the cavity of the envelope, which tends to be ventilated through holes and slits existing around connecting parts between floors and walls or between walls and ceilings, in case of the post and beam construction method.
- To prevent humid indoor air from incoming into the envelope in order to avoid concealed condensation and resultant damage
- To reduce infiltration in order to reduce

the heat loss.

- To reduce infiltration in order to improve the temperature distribution, especially vertical one

The measurement method of the envelope air tightness is prescribed in JIS, and the instrument for the measurement has already been spread and popular. The newest result on the status of the air tightness of the Japanese detached houses is shown in Table-2. It is noteworthy that the current post and beam construction has much higher air tightness than the traditional one, which has been assumed to have the specific leakage area (SLA) of 10-20 cm^2/m^2. The SLA is defined as the equivalent leakage area (reference pressure difference is 9.8 Pa) divided by total floor area of the house (1 SLA is roughly equal to 1.36 N_{50}). The reason of the improvement is attributed to more frequent usage of kinds of boards, such as plaster board, plywood, etc. The interpretation can be supported by the fact that the two-by-four construction, which employs the plywood on the exterior surface of the two-by-four frame and the plaster board on the interior surface of the frame, has much higher air tightness as shown in Table-X. The infiltration rate is estimated for winter and summer conditions as shown in Figure-11, by using the following equation.

$$Q = 1.06 \times (0.00921 \times |\Delta T| + 0.0357 \times R \times V^2)^{0.62} \times (SLA \times S)^{0.857} \qquad (1)$$

Q : infiltration rate (m^3/h) ΔT : temperature difference (K)

R (wind shielding coefficient) : 0.1 (urban area) 0.4 (suburban area)

V : outdoor velocity (m/s) C : Specific Leakage Area including vents if available (cm^2/m^2)

S : total floor area (m^2)

Table 2: Result from the field measurement on the air tightness of wooden detached houses in mild climate regions (Sawachi et al. 2004)

	Specific Leakage Area (cm^2/m^2) Equivalent N_{50} (ACH) in blankets [ ]		
	Mean value	Maximum	Minimum
Post and beam construction, Lower insulation level (N=30)	4.9 [6.7]	9.6 [13.1]	1.3 [1.8]
Post and beam construction, Medium insulation level (N=30)	5.8 [7.9]	9.8 [13.3]	3.2 [4.4]
Two-by-four construction Lower insulation level (N=10)	2.2 [3.0]	3.8 [5.2]	1.3 [1.8]
Two-by-four construction Medium insulation level (N=10)	2.1 [2.9]	3.9 [5.3]	1.0 [1.4]

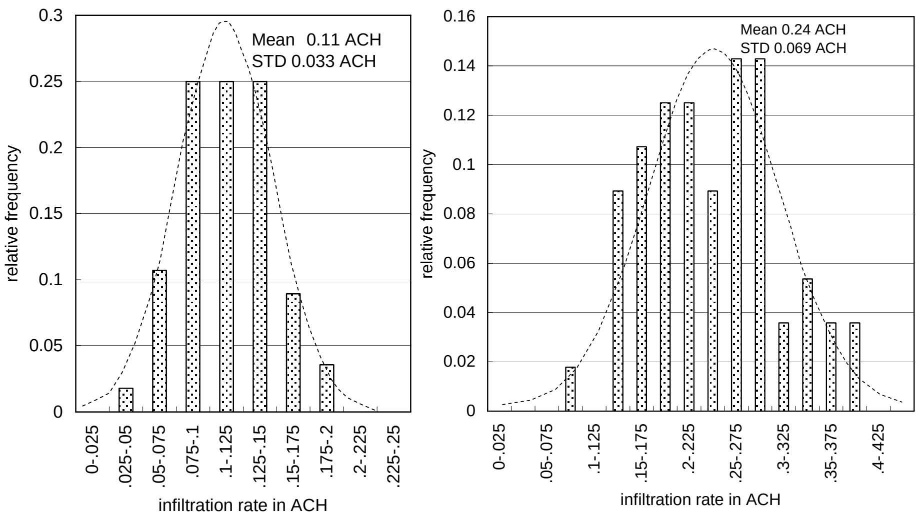


Figure-11(a) Distribution of estimated infiltration rate for the post and beam construction method (2 storied wooden detached houses) for summer (left) and winter (right)

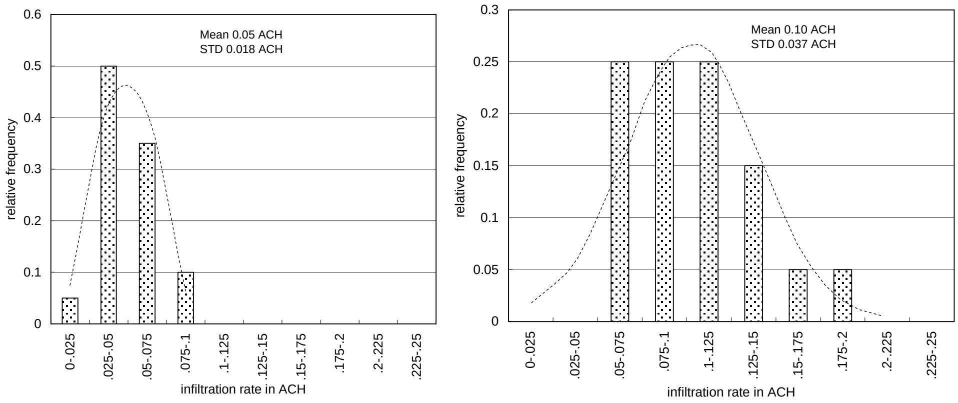


Figure-11(b) Distribution of estimated infiltration rate for the two-by-four construction method (2 storied wooden detached houses) for summer (left) and winter (right)

As for multi-family residential buildings, the survey was conducted for 62 new units, which were built in 1992. The results are summarized in Table-3.

Table 3: Result from the field measurement on the air tightness of multi-family residential buildings built by PC panel construction and RC construction (Kurabuchi et al., 1992).

	Specific Leakage Area (cm^2/m^2) Equivalent N_{50} (ACH) in blankets [ ]		
	Mean value	Maximum	Minimum
PC panel construction (N=21)	1.01 [1.37]	1.33 [1.81]	0.75 [1.02]
RC construction (N=41)	1.23 [1.67]	1.98 [2.69]	0.8 [1.09]

4.2 Commercial buildings

The information on the air tightness of commercial buildings is not enough. According to the existing research, even though the number of the samples is very few, there is a relationship between the construction method and the air tightness of the wall, as shown in Table-4. There is no requirement in the energy related regulations.

Table4: Classification of the construction methods of the commercial buildings in terms of the wall air tightness (Hayakawa and Togari, 1988)

	class	Air leakage	Construction methods
A	Tight wall	$Q=0.72\Delta P1/1.5$ ($m^3/h\cdot m^2$)	Cast-in-place RC construction
B	Average wall	$Q=1.44\ \Delta P1/1.5$ ($m^3/h\cdot m^2$)	S or SRC construction Metallic curtain wall
C	Loose wall	$Q=2.88\Delta P1/1.5$ ($m^3/h\cdot m^2$)	PC panel

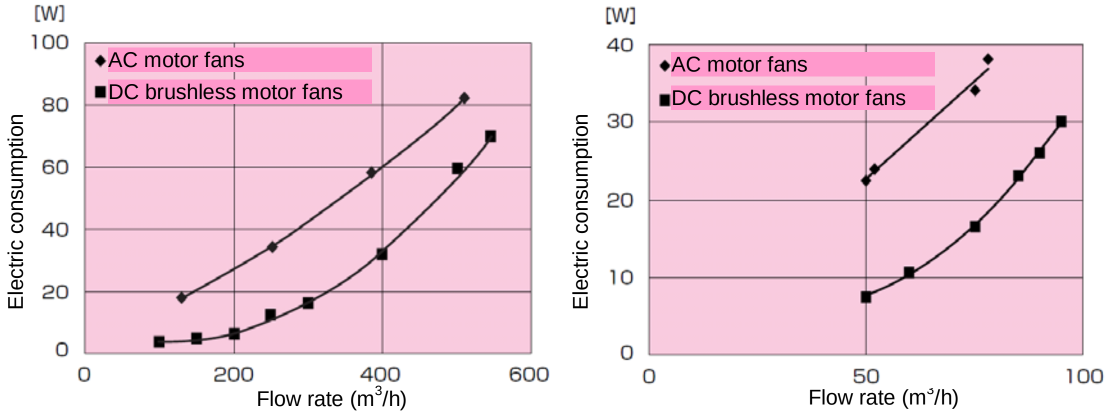
(ΔP in mmAq or kg/m^2, Q expressed in air leakage for a unit wall area)

5 National trends in innovative systems and markets

5.1 Improvement of energy efficiency of fans for residential use

Brushless DC motors have become utilized as motors for ventilation fans, even though the price of the fans with the brushless DC motors is still more expensive than that of fans with AC motors. Figure-12 shows the difference of electric consumption between fans with the DC and AC motors.

In addition, because some kinds of fans with the AC motors have been improved of their energy efficiency, it has become possible to select more energy efficient fans with the AC motors.



(a) Ventilation Unit with Heat Recovery Element

(b) Ventilation Unit without Heat Recovery

Figure 12 - Comparisons of Electric Consumption of Ventilation Equipment with AC and DC Fans

5.2 Hybrid ventilation systems for residential buildings

There have been trials to develop the hybrid ventilation systems for detached houses. They have been utilizing the stack effect for natural ventilation. In the existing official guideline for the Energy Conservation Law for residential buildings, the requirement for the effective opening area of the vents is described for the houses with and without exhaust stack, as shown in Table-5.

There is a variety of instruments for mechanical ventilation combined with the above natural ventilation.

For multi-family residential buildings, only a few R&D's have been done. Figure-12 shows an example, in which wind pressure has been utilized as natural forces. Basically, a penetrating duct is used with self-regulating dampers installed near both ends of the duct. By shutting one of the dampers located in down stream and negative wind pressure side, the penetrating duct shall be pressurized and supplied into habitable rooms is the outdoor air, which is to be exhausted through door undercuts and vents installed on the exterior walls.

Table 5: Requirement of effective opening area for vents or for vents and exhaust stack(s)

Climatic Region	Required effective opening area for vents	Height difference between the top of the exhaust stack and the vents			
		6m	8m	10m	12m
I (D_{18-18}>=3500)	$4cm^2/m^2$	$2.5cm^2/m^2$	$2.2cm^2/m^2$	$1.9cm^2/m^2$	$1.8cm^2/m^2$
II (3500>D_{18-18}>=3000)	$4cm^2/m^2$	$2.8cm^2/m^2$	$2.5cm^2/m^2$	$2.2cm^2/m^2$	$2.1cm^2/m^2$
III, IV, V (3000>D_{18-18}>=500)	$4cm^2/m^2$	-	-	-	-

Note: effective opening area is expressed per unit floor area of the house.

There is a variety of instruments for mechanical ventilation combined with the above natural ventilation.

For multi-family residential buildings, only a few R&D's have been done. Figure-12 shows an example, in which wind pressure has been utilized as natural forces. Basically, a penetrating duct is used with self-regulating dampers installed near both ends of the duct. By shutting one of the dampers located in down stream and negative wind pressure side, the penetrating duct shall be pressurized and supplied into habitable rooms is the outdoor air, which is to be exhausted through door undercuts and vents installed on the exterior walls.

5.3 Hybrid ventilation systems for commercial buildings

Also for commercial buildings, there are some trials to develop and apply the hybrid ventilation systems. The photograph is an example of components for such hybrid ventilation systems.

6 Other points of attention or trends

6.1 Summer comfort

Japan has relatively mild or hot climate in average comparing with many other industrialized countries. As already shown in Figure-XX, the domestic market for air-conditioners of stationary use is more than 1 trillion yen. However, the energy consumption for cooling in residential buildings is very limited comparing with that for heating. It is attributed to the utilization of natural ventilation for cooling indoor space. It is very difficult to depend on the natural ventilation in the daytime of the hottest season, but is not difficult to utilize it during the nighttime or except for the hottest season.

The history of the researches for the natural ventilation for cooling is quite long in Japan. Recently, the utilization of the network models to estimate the natural ventilation rate has been tried by several researchers in Japan. At the same time, acquisition of wind pressure data has been tacked by some researchers.

6.2 Acoustic

It seems that Japanese customers are rather sensitive to noise due to building equipment. MLIT (Ministry of Land, Infrastructure, Transport and Tourism) and the Center for Better Living have made a standard for the noise by residential ventilation equipment, in which there are three ranks for noise level as shown in Table-6.

Table 6: Ranks of mechanical noise by residential ventilation equipment except for range hoods (The Center for Better Living, Japan)

Ranks	Noise level
Average product	<=45 dB(A)
Low noise product	<=35 dB(A)
Quiet product	<=30 db(A)

6.3 Quality of products/systems

It can be said that the standards for residential ventilation equipment and components have not yet been developed satisfactorily, from the viewpoint of their reliability to realize and to keep good ventilation performance for longer period. For example, the standard measurement protocol for pressure loss of thinner duct, such as ϕ50mm to ϕ150mm or ϕ100mm have not yet been made. According to the fundamental research by the authors the Reynolds number of the airflow through those ducts is usually in the range between 10000 and 60000, in which the friction factor (λ) can change and the equation in the form of $Q=a\cdot\Delta P^{1/n}$ should be applied. There is a need for standard protocols for pressure loss characteristics of different kinds of ventilation components. A proposal for such standard protocols has been proposed by the authors in Japan, but it is still in discussion partly due to industry being reluctant to accept more complicate procedures.

In addition to the design stage of the ventilation systems, the stages for installation and maintenance should be taken care of better than the present situation. Such problems and solutions were discussed in the first international workshop on residential mechanical ventilation held in May 2007 (Tajima and Sawachi, AIR, vol.28, No.4, September 2007)

7 Conclusions

There are two important surrounding conditions for the building ventilation market in Japan. Those are increasing social needs for higher environmental quality of indoor space and for lower energy consumption, both of which must be common to other industrialized countries and areas. In order to respond to those needs, the system of regulations and standards should be developed further and educational activity to transfer new knowledge to practitioners is needed.

8 References

1 MOE: Gist of the Kyoto Protocol Target Achievement Plan, http://www.env.go.jp/en/press/2005/0427b-01.pdf

2 NEDO: Project for Promoting the Introduction of High-efficiency Housing/Building Energy Systems, http://www.nedo.go.jp/english/activities/portal/gaiyou/p99045/p99045.html

3 NEF: http://happyfc.nef.or.jp/ (in Japanese)

4 The Energy Conservation Center, Japan: http://www.eccj.or.jp/top_runner/index.html

This information paper is one of the outcomes of the workshop 'Trends in national building ventilation markets and drivers for change', held in Ghent (Belgium) on March 18 and 19 2008. This workshop was an initiative of AIVC, organized by INIVE EEIG, in collaboration with REHVA and with the European SAVE-ASIEPI and SAVE Building Advent Projects. The workshop was supported by the EPBD Buildings Platform.

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The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.