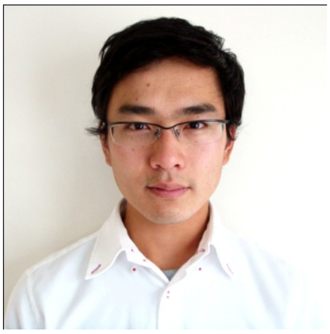
# A study on operational information hierarchy through an energy efficiency contest~Case in Taiki-cho “My Home” Energy Efficiency Contest 2010-2011~



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## Summary

This paper analyzes the role of operational information of residential architecture through a town-managed energy efficiency contest, the goal of which is to establish the locality and specificities of a given built environment and its residents as significant factors for evaluating operational improvements of energy use for detached houses.

**Keywords**: Operational Information Hierarchy, Design Information, User Driven Information, Information Relativity, Social Resource, Energy Monitoring, Information Visualization

## 1. Introduction

We have prepared a locally organized energy efficiency contest involving 80 households of Taiki, Hokkaido, a town of 2638 households in a cold climatic region of Japan. Within a period of three months, the contestants accumulated information from their household energy consumption to compete in their reduction of CO2 emission in quantity and in ratio, while raising awareness for energy efficient living in the town of Taiki and the surrounding region. The goal of this contest was to establish a methodology of informational management for reducing energy consumption in the operational stage of the residential sector, alongside the effort provided by the supplier side, in order to better manage the energy operation toward its carbon neutrality. The statistical data of Hokkaido published in 2008 showed that residential energy consumption marks 52% of civilian sector energy consumption, wherein 53% of the consumption was oil based (18% nationwide) [1], 60% of which was during the winter months of December to March. [2] There has been much effort from the supplier side, especially with electric infrastructures incorporating less environmentally loaded energy resources. However, as the above data exhibited, most of the energy consumption in Hokkaido is based on winter heating, where more focus should be given on oil-based energy consumption and its modes of operation by optimizing the current demands to our future outlook of the energy structure. From the point of view of the demand side, it is essential to reduce the unnecessary consumption in their operation of residences without sacrificing their daily necessity and productivity. However, it is difficult for most residents themselves to assess the appropriateness and effectiveness of the given information for their own residences. Dependent on each and unique current condition of the residences (design based information: its age, neighboring buildings, location) and their operational information (household structure, lifestyle and economical inclination), the effectiveness of certain products or methodology for energy saving, as well as appropriateness of regionally collected statistical data; like the figures given above, will considerably fluctuate. It is expected that frontier professionals will become necessary as mediators of information between individuated necessity and the solution provider, in order to establish a synchronic use of limited resources on both ends. Since the information surrounding residential architecture can be highly unique and individual, these professionals will require a methodology for information operation and its hierarchy that can register necessary information for its management. At the same time, in order for the residents to become active in their operational processes, we must structure a set of information that enables its utilization by the residents. As a way into drawing the relevance of unique operational information of the residents, we have analyzed the data collected throughout the energy efficiency contest. Different types of data were collected for the holistic evaluation of each household, which includes: energy and environment monitoring data, in-depth architectural and household data, psychological survey data and questionnaires, as well as numerous interviews held during the visits. In evaluating the relative position of this acquired information within the hierarchical order of a residential information set, the significance of operational information of the residents were drawn, marking how they are relevant for evaluating numerical data acquired through monitoring and documents. We intend for the case study detailed below to serve as a benchmark: A) to evaluate the effectiveness of various measurable data/criteria of the residents, B) to establish a methodology to assess the uneven parameters derived from the conditions of a given condition, C) to document the inclination of the residents toward improvements for energy efficiency.

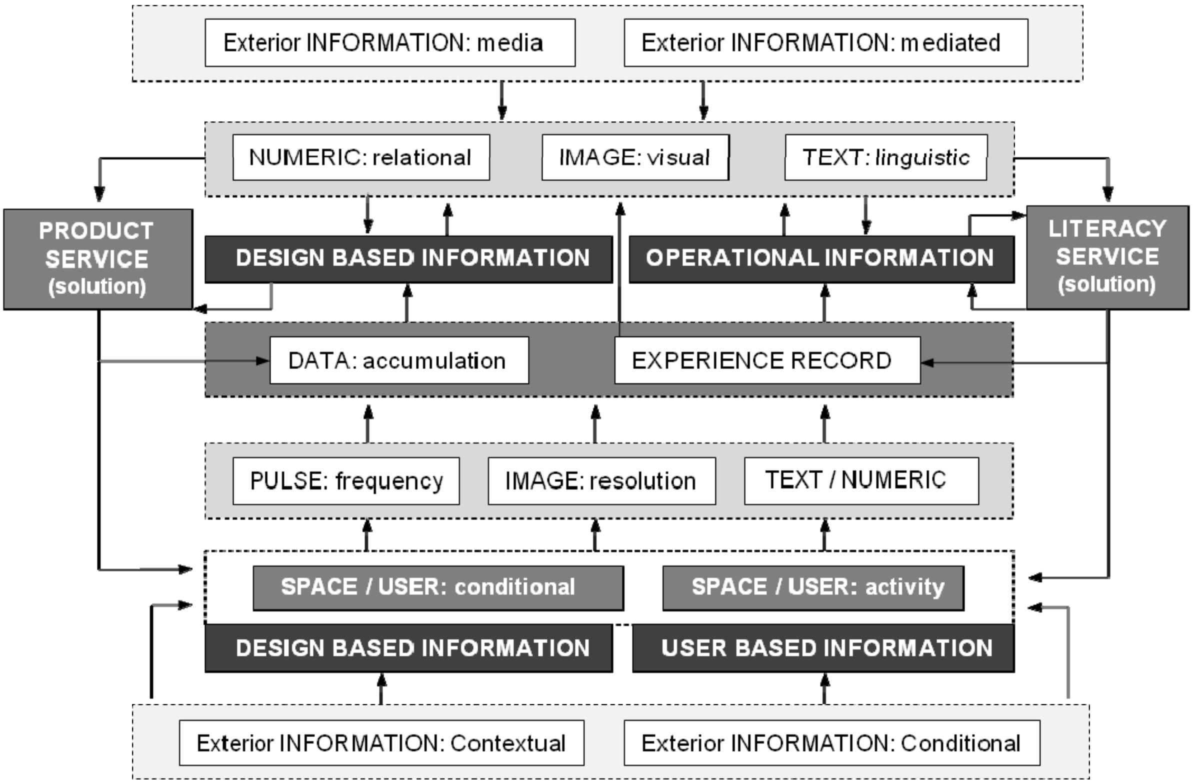


*Fig. 1 Operational Information within the residential architecture information loop*

## 2. Operational information and its hierarchy

### 2.1 The roll of operational information

Through observing two different types of information hierarchies, 1: design based information hierarchy, and 2: operational information hierarchy, some interdependencies between the prior and the latter can be identified. Traditionally speaking, design based information (DBI) and its information hierarchy has mainly been structured to provide information for production processes. Therefore, much in the way we consume the physical properties of buildings over time, the processes of consuming design based information can be thought of as reductive or subtractive. Operation based information (OBI) on the other hand, is produced by the user of the buildings and their information, where context based, unique information is produced throughout the period of building operation. OBI is productive or additive in this regard, resulting in rather complex information hierarchy and resulting interdependency to its DBI, especially in the operation of residential architecture where most of its operation is executed by the residents who are less related to DBI and its hierarchy. There have been many studies on acquiring operational information through statistical analysis or developing design languages [3], however, most of the studies incorporated the uniqueness of operational information into the hierarchy of design based information by way of abstraction, where the output resulted in typological or formal resolution. Meanwhile, in order for the residents to be proactive in optimizing their current energy consumption, it is necessary to have information hierarchy that feeds back information to the users so that the user may visualize unique and individuated demand of their own. This information loop is indicated with allows in Figure 1, where the information hierarchy in processes of data accumulation is shown. In the given figure, the role of literacy service or solution provider is situated as an agent to complete this information flow between the operational information and the residents. We have analyzed interdependencies between DBI and OBI throughout out the energy efficiency contest in town on Taiki in order to further develop methodologies for giving effective feedback toward individual residents, as well as in the scale of town management.

## 2.2 Contest outline and town of Taiki

### 2.2.1 Contest outline

We have prepared a locally organized energy efficiency contest, requesting that the residents from the Taiki town of Hokkaido prefecture, Japan join an experiment in energy efficient living using three approaches. The groups and the numbers of invited households are as follows:

- 6 groups (one year “monitoring” group) who have second-interior-layer windows installed (n=6) for free, and either choice of solar panels (n=3) or heat pump based water boilers (n=3) installed with some subsidies, finally, energy and environment monitoring sensors installed on their existing homes. This group will be monitored for a year.
- 24 groups (window “reform” group) who have second-interior-layer windows and energy and environment monitoring sensors installed for free. This group will be monitored for 4 months, where 5 households will continue monitoring for a year.
- 70 groups (“creative solution” group) who will be informed with key issues of passive living and energy conservation techniques without any architectural modifications, who will report their energy consumption through the monthly bills and reading their meters manually.

We had 6/6 of the monitoring group, 24/24 of the reform group, and 50/70 of the creative solution group to join the contest by the opening date. These households will measure their energy consumption during the month of January as existing condition (“before”), and in February as “after” installing architectural modification, or with energy efficient living, comparing the degree of reduction in $CO_2$ emissions amongst the contestants. The event has taken the form of contest not only to raise incentive toward energy efficient living in the community, but also to establish local relativity of information and locally specific evaluation criteria for the town of Taiki toward better management of its housing sector in coming years.

### 2.2.2 Town of Taiki: data specificities

Town of Taiki is located within Tokachi plain, southeast of Hokkaido (N 42.30, E 143.16), where the annual total duration of sunshine is roughly 1900 hours, its annual total snow fall is over 800 cm, while its annual maximum depth of snow cover is less than 60 cm. The lowest temperature hits mid -20˚C, with average of -9 ˚C in January. It is relatively colder than other locations of Hokkaido, yet the extensive hours of sunshine identifies Taiki with locally specific resources and potential passive solutions to its building culture, beyond the commonly designed methodologies for “cold climatic region” and its design specification. Table 1 examines the comparison between the climate factors of the last year and that of this year. During the contest period, the low temperature was higher than last year, however due to the lack of snowfall, the high temperature was lower than the last year even though the sunshine duration was greater. From the oral survey on 30 households, this resulted in two views of the climate condition by the contestants, one group stating that it was a cold winter than last year; who responded to relatively cold high-temperature and the lack of snowfall, while the other group stated it to be a warm winter; who responded to relatively warmer low-temperature and the sunshine duration. Even though further articulate survey is necessary, there were tendencies for households with large windows to southern solar exposure answering that this was a warmer winter, while households in less well insulated houses felt it to be a cold winter. For the residents to mitigate the heating load and manage their own comfort, actual information in processes of operation must become more visible to the eye, rather than relying on the given general numbers by the media and their own perceptual figures. By formulating information of the given architectural condition, the subjective account of the residential environment may be able to refer back to actual conditional information, where the previous problems in understanding subjective values of architecture may be less dependent on the statistical analysis and more related to the individuated condition of architecture.

*Table 1 Comparison between Last Year and the Energy Monitored Period*

Comparing 2010 to 2009

| Month | Ave. (˚C) | 2010 Ave. | High (˚C) | 2010- | Low (˚C) | 2010- | Sun (Hr) | Snow(mm) | Rain(mm) |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 1.4 | 3.3 | -0.2 | 17.2 | 1.6 | -7 | 2.1 | 0 | 4 |
| 12 | 3.9 | -2.2 | 5.4 | 12.3 | 0.6 | -20.7 | -53.3 | -20 | 54.5 |
| 1 | -2.5 | -10.6 | -6.6 | 2.4 | 1 | -25.6 | 3.1 | -41 | -12 |
| 2 | 1.5 | -6.2 | -4.3 | 8.2 | 5.2 | -22.8 | 20.2 | -38 | -2.5 |
| 3 | 0.7 | -2.2 | -1.9 | 9.5 | 1.8 | -16.4 | 26.7 | -79 | -53.5 |

* Japan Meteorological Agency, <http://www.jma.go.jp/jma/menu/report.html> Last Visited, 2011.3.30.

2.2.3 Inclination of the residents toward energy efficient living

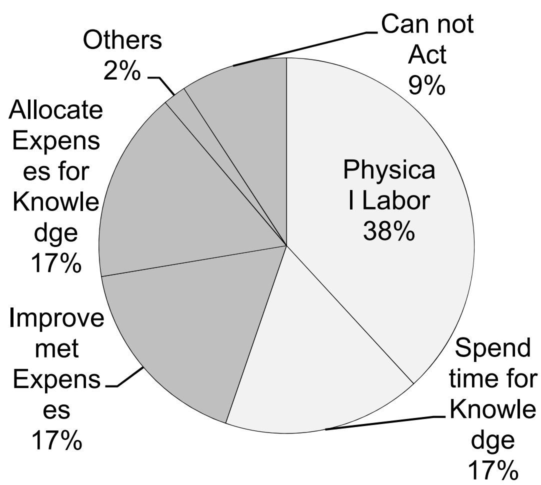


*Figure 2 What could be done?*

In the paper based questionare previous to the contest, the contestants indicated that they are more likely to devote their physical labor toward energy efficient living, rather than allocating expenses for improvement. (Figure 2, multiple answers, n=152) However, they have also mentioned their inability to allocate time for such activities due to their current economical status and the work schedules of daily lives. The given answer shows that currently, more people thougth to act upon energy efficient living through activity based processes than expense based processes. This inclination suggests that with the economic condition of the town considered, the operational information can largely effect the outcome of effort in reduction of energy consumption, while the effectiveness of product based reduction should further be articulated for its consumers.

### 2.3 Parameters of operational information in the case of Taiki and their interdependencies

2.3.1 Designed heating area and actual heating area

In order to articulate and respond to the above result of the questionnaire by way of suggesting

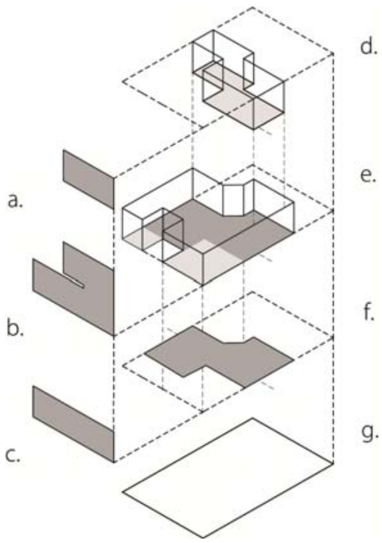


*Fig. 3 Heated Space*

effective methodologies for the residents of Taiki toward energy efficient living, the actual usage of the heating device was measured. Out of the 64 returned basic questionnaires, 8 houses used central heating, whereas 56 houses used different heating methodology for each of their rooms in their houses. Since the actual heating area is unique in every case, it became a significant factor for the individual households to identify their energy consumption records and its relation to monitored data. Especially in the 24 houses in reform group, we have mapped the actual heating area that were redefined through the everyday life by the residents, in order to consider actual effectiveness of their heating methodology and its resource consumption, as well as assessing the effectiveness of the installed interior windows. The list of the observed differences is shown in Table 2 below. The lowercase alphabet corresponds to those in Figure 3. Figure 3 indicates an example of the difference found through the onsite observation and interviews. Within the diagram, volumes indicated in d and e was combined to define the continuously heated volume in actual operation. The letters indicate; a: typical section of second floor volume, b: typical section of the continuous volume, c: typical section of the area given in “f”, d: continuous volume ($2^{nd}$ Floor), e: environmentally continuous area actual ($1^{st}$ Floor), f: environmentally continuous area designed, g. building footprint. As shown in e / g column, the ratio of heated area to the building foot print differs tremendously across the given cases, lowest at 22.57% and the highest at 75.29%. Consequently, instead of evaluating the usage of heating related energy consumption on the scale of the houses and its building footprints, the actual operational figures should be identified with the operational figures, determined by each resident.

*Table 2 Comparing the actual heating area, and its heating hours during before and after, CO2∆*

| ID | residents | d ＋ e | e | g | e/g | before | after | average temp∆. | CO2∆ |
|---|---|---|---|---|---|---|---|---|---|
| | (n) | (m3) | (m2) | (m2) | % | (hr.) | (hr.) | (c°) | (%) |
| A | 1 | 75.59 | 30.85 | 73.6 | 41.91% | 24 | 21 | 0.81 | 46.13% |
| B | 2 | 104.67 | 42.21 | 124.6 | 33.87% | 24 | 24 | 2.07 | 58.46% |
| C | 3 | 137.38 | 57.24 | 93.1 | 61.47% | 24 | 24 | -0.25 | 26.10% |
| D | 6 | 132.6 | 57.65 | 116.4 | 49.53% | 20 | 20 | -0.45 | - |
| E | 2 | 63.82 | 26.08 | 88.5 | 29.47% | 24 | 24 | 1.06 | 26.96% |
| F | 3 | 101.53 | 42.31 | 104.6 | 40.45% | 24 | 21 | -0.03 | 54.33% |
| G | 3 | 79.34 | 33.06 | 106.0 | 31.19% | 11 | 11 | -2.64 | 14.83% |
| H | 3 | 154.38 | 59.83 | 79.5 | 75.29% | 15 | 15 | -0.18 | - |
| I | 2 | 134.91 | 47.69 | 91.9 | 51.87% | 4.5 | 4.5 | -1.26 | 26.05% |
| J | 4 | 87.05 | 36.58 | 53.4 | 68.43% | 24 | 24 | -1.46 | 51.54% |
| K | 4 | 141.83 | 56.73 | 96.4 | 58.85% | 24 | 5 | 0.82 | 60.92% |
| L | 3 | 84.93 | 35.39 | 76.0 | 46.56% | 24 | 24 | 1.07 | 37.96% |
| M | 2 | 160.11 | 76.25 | 141.7 | 53.81% | 24 | 24 | -0.16 | 1.82% |
| N | 2 | 51.88 | 23.58 | 72.6 | 32.48% | 16 | 16 | 0.59 | 11.12% |
| O | 2 | 78.09 | 33.95 | 69.1 | 49.13% | 24 | 7 | -1.13 | 44.93% |
| P | 3 | 147.94 | 46.70 | 82.5 | 56.61% | 2 | 2 | 0.01 | 35.81% |
| Q | 2 | 99.92 | 41.60 | 102.9 | 40.43% | 6 | 6 | -0.88 | 58.70% |
| R | 2 | 34.76 | 15.80 | 70.0 | 22.57% | 17 | 11 | -1.44 | 57.40% |
| S | 2 | 95.71 | 39.90 | 83.4 | 47.84% | 16.5 | 16.5 | 0.20 | 29.27% |
| T | 3 | 47.63 | 19.90 | 84.6 | 23.52% | 16 | 16 | -1.46 | 33.27% |
| U | 2 | 151.9 | 58.60 | 110.0 | 53.27% | 24 | 24 | -0.87 | 73.33% |
| V | 3 | 87.75 | 35.10 | 104.3 | 33.65% | 18.3 | 18.3 | 0.63 | 34.81% |
| W | 3 | 256.34 | 79.30 | 106.1 | 74.74% | - | - | 0.77 | 15.94% |
| X | 1 | 74.52 | 32.40 | 83.4 | 38.87% | 24 | 24 | -1.50 | 45.47% |
| average: | 2.63 | 107.69 | 42.86 | 92.28 | 46.49% | - | - | - | 38.42% |

2.3.2 Hours of heating and hours of inhabitation

To further articulate the way in which the energy was utilized, and to identify unique methodology for each of the households, the questionnaire and interviews were further taken, where we have indicated the hours in which the residents heated their continuously heated space discussed in 2.2.1 during the contest period, which has also been indicated in Table 2. From these observations and comparison to monitored data, it was still difficult to determine what exactly made it possible to reduce 73.33% $CO_2$ emission on household U, for instance, and likewise many other situations. Since then, further discussion was conducted with the participants to identify unique creative solution, in which they have invested on their own. From the interviews, it became clear that household U has stopped their use of central heating in the after period, switched to localized heating with combination of sub-heating units such as electric carpets, personalized heater and so on. They have also quickly recognized the effect of double skinned windows, decided to invest in thermally insulated film to apply on to the other windows of their house. This radical solution enabled household U to cut $CO_2$ emission by 73.33% without losing their comfort, while they have also indicated their realization on over heating the house previous to this contest. Through understanding this phenomenon by drawing its structure of information flow (Fig.4), we can begin to construct some interdependencies amongst information related to energy consumption within residential architecture, mainly focusing on how to deal with user oriented operational information that did not became apparent with the sensor technology based information.

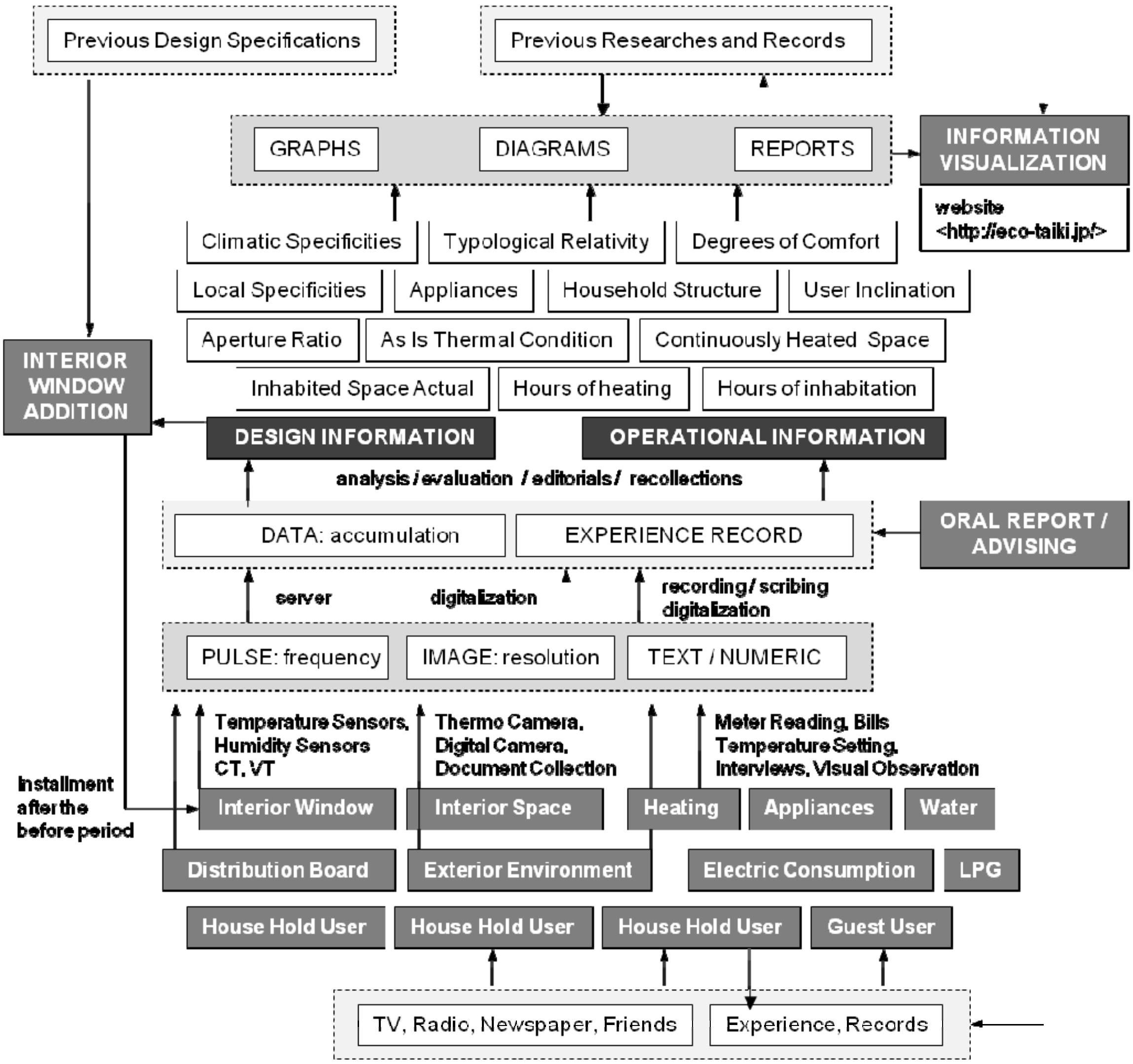


*Fig. 4 Information hierarchy of the window reform group*

2.3.3 Information hierarchy in the window reform group.

Figure 4 indicates the information hierarchy in the window reform group, where it indicates sets of information we have acquired from the residents for purpose of analysis and to prepare individual report of the contest. Especially focusing on the role of user oriented operational information, Figure 5 was drawn to indicate interdependency of information that can begin to portrait the necessary information hierarchy depicting the actual scenarios of everyday life. These interdependencies indicate that for some of the information visualization technologies to be able to provide effective service in the area of residential architecture, one is necessitated to obtain user oriented operational information to redraw its informational parameters for operational evaluations.

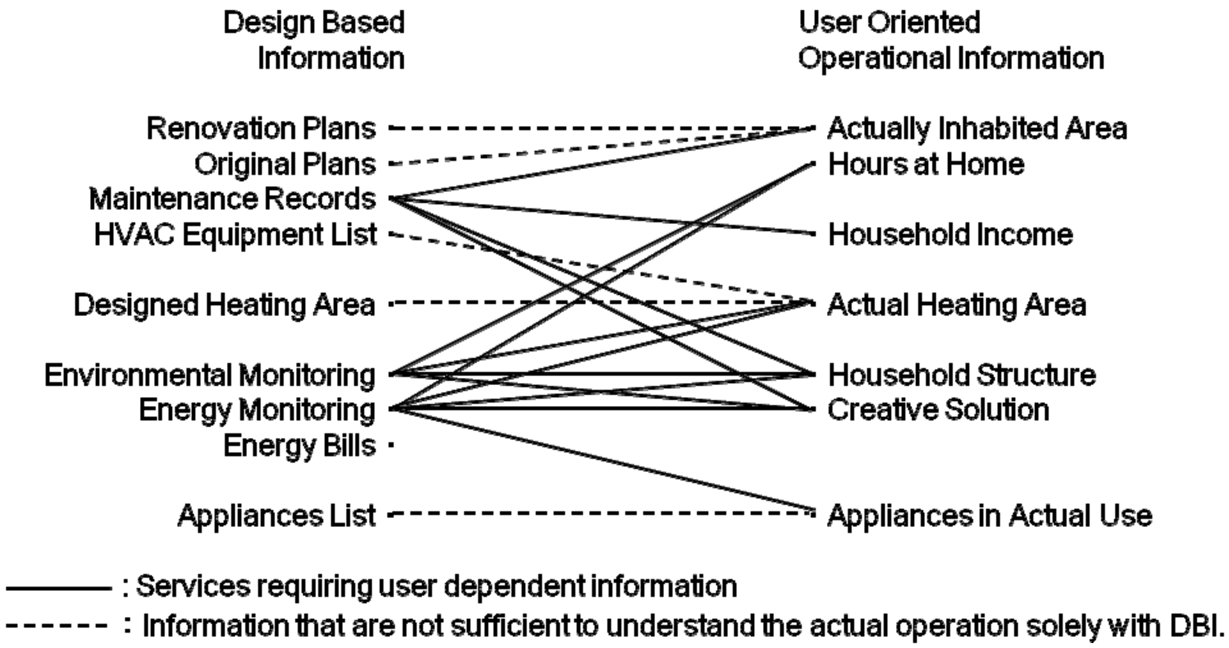


*Fig. 5 Interdependencies of User Oriented Operational Information*

## 3. Discussions

### 3.1 Long term operational information of users

3.1.1 How can we continue the effort?

The duration of the contest was limited to three months, except for the one year monitoring group, and continuing 5 households in window reform group, where consequently the information acquired was limited to the range possible and comfortable for the contestants to provide within the given period. However, in order for the residents to truly grasp the condition and inclination of their own operation and its informational hierarchy, it is necessary for them to accumulate multiple years of information. This is especially important in understanding the user oriented operational information in Figure 5, where they are dynamic information that will keep updating throughout the years of inhabitation. Turning back to Figure 4, indicating that this information has ability to feedback to experiential record of residents, the long term operational information can enable user to articulate their own demands, indicating the necessary information for the professionals to understand the unique context of the households.

This outlook suggest the understanding of the user experience and resulting criteria as significant structural element within the information hierarchy of energy management and accounted sustainability of residential architecture in its operation. From the point of view of users of the products and services, users also are necessary to establish their own literacy and operability of information given from outside and those produced by themselves. These information are resources for the users to "stage" their own decisions, while utilizing the unique and actual information to evaluate the given generic information set, assessing the applicability of such information to the individual condition of themselves. From the point of view of the service provider, it is necessary to gaze in the future, exactly how much information is necessary to provide effective service, and what granularity of information is necessary. This will lead to a discussion whether the energy monitoring system for residential architecture building type is rather effective in technology embedded mode, or in diagnostic mode, which necessitates further research and field experimentation.

### 3.2 Future outlook for the local information management

In the scale of town management, information set discussed in this paper may become social resource, where the actual demands of the residents as well as the return of investment from certain operation can be calculated with actual figures, instead of pronouncing their policies with vague concepts and words. Subsequently, the distribution of subsidy toward reduction of $CO_2$ emission should be accounting the actual operational information as well as design specification and its predicted effectiveness, where the locally effective methodologies for energy efficient living are identified. The contest indicated above can be one of the method to initiate the processes of building locally specific environmental information set, where it not only prepare the town management with clear directives, but also to raise an collected initiatives of the residents toward demand based reduction of $CO_2$ emission. However, the actual economical effect and the actual figure of reduction in $CO_2$ emission of Taiki in next couple years must be recorded and studied to further articulate the local effect of information hierarchy suggested in this paper. For now, town of Taiki has decided to issue in-town subsidies for installing secondary interior windows following the contest and its apparent effectiveness in reducing CO2 emission as well as their heating bills over the course of winter.

### 3.3 Conclusions

To further articulate the relationships of operational information within the architectural information hierarchy and to evaluate its significance for the users themselves, we must,

- quantify the actual effect of long term operation based information to the everyday operation of the residents,
- identify methodology for the users themselves to manage their own operational information.

### 3.4 References

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