博士論文

アジアの都市における住宅エネルギー消費量とライフスタイルとの関連性に関する研究

STUDY ON THE RELATIONSHIP BETWEEN HOUSEHOLD LIFESTYLE AND ENERGY USE IN ASIAN CITIES

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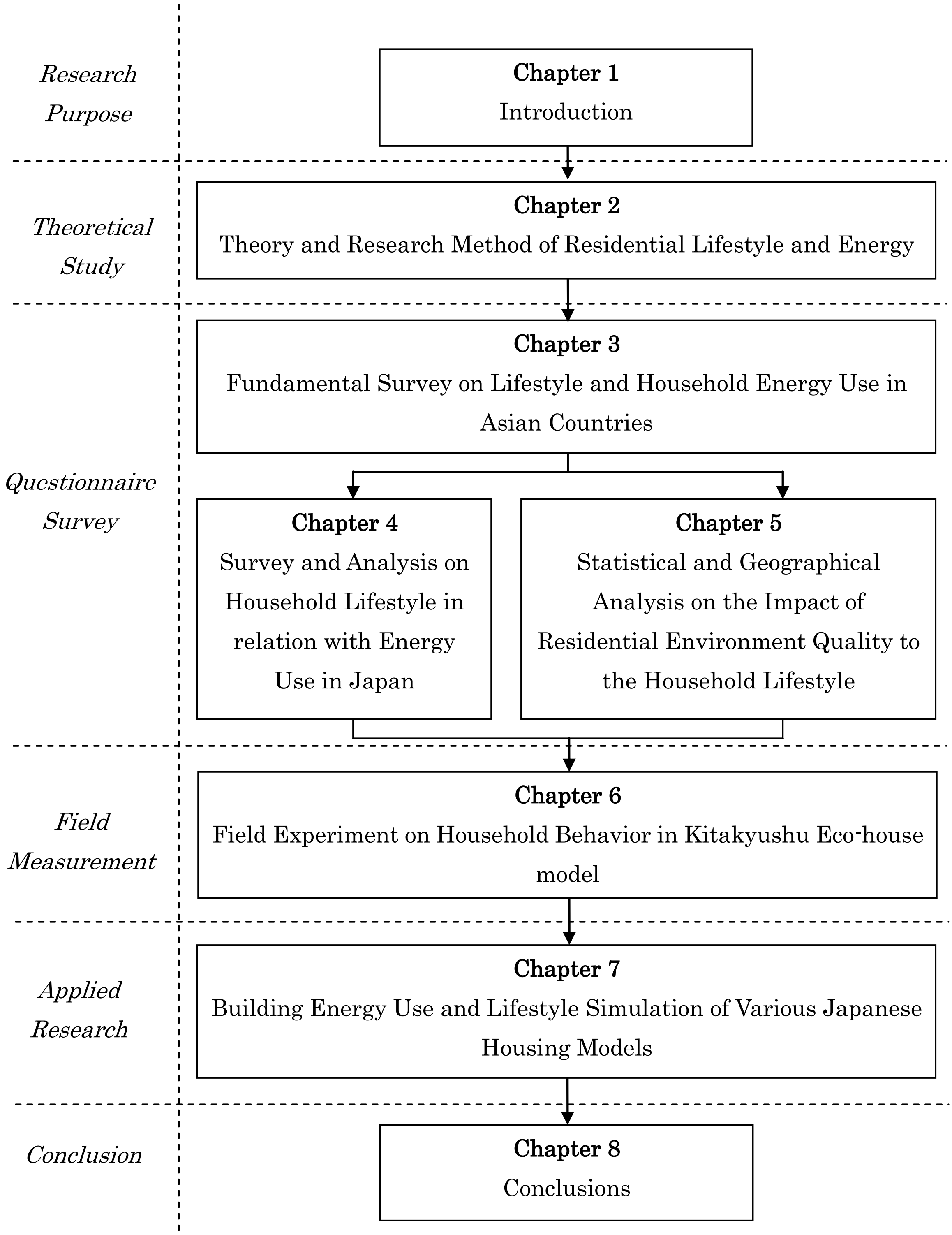

博士論文の構成

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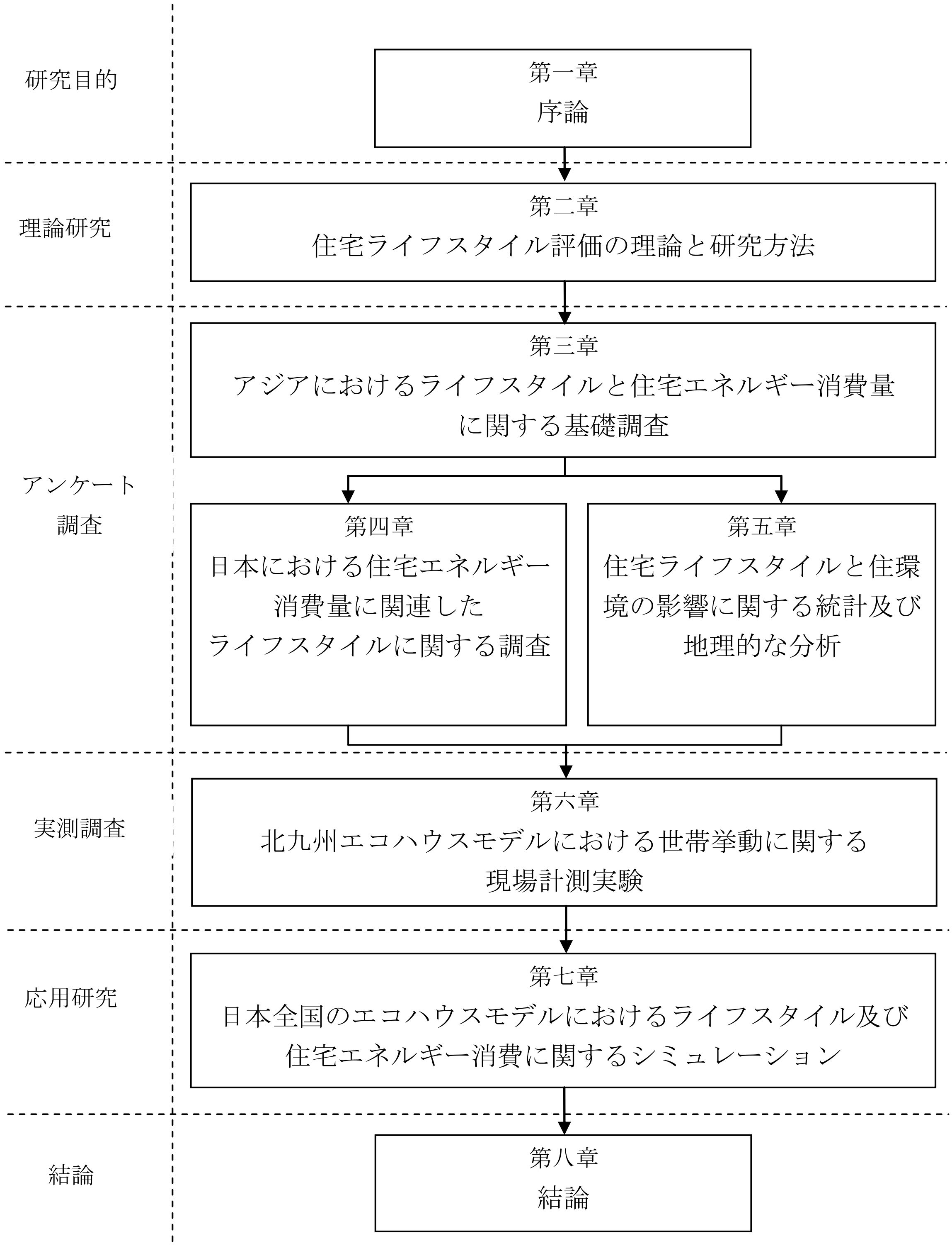

Abstract

Recent years, the world demand for oil and gas have increased rapidly especially in Asian society, and the crisis of energy becomes unavoidable in the future if there is no significant movement on energy conservation. Developed countries such as Japan have applied nuclear power plant which has high capacity on producing power, but some human error had cost big disaster to our environment. In another hand, the economic growth and the increase of people living standard have resulted to the increase of household energy consumed appliances, and this becomes difficult to control. Based on that experience, we conducted a study which is trying to find the effective way to lower household energy use through analysis of residential lifestyle approach and investigation on the residential living environment characteristics. In addition, by characterizing the physical environment, we also identified what kind of efforts that could be influential in making the lifestyle changes.

The main purpose of this study is to conduct a comprehensive analysis on the residential housing energy use. The influential factors affect household energy use were investigated through questionnaire surveys distributed to more than 4,000 households, in China, Thailand, Indonesia, and Japan. The field measurement on Japanese ecological house model energy use was also conducted to understand the performances of passive and active technology related with the lifestyle of the occupants. Further, the residential building energy use simulation was also conducted in order to study various cases in practicing the ecological house for sustainable development in Asian countries.

In **chapter one** (INTRODUCTION), the important of this study were explained. The main purpose of conducting this paper is to have comprehensive analysis in many aspects of residential lifestyle factors which directly impact the energy use in the household sector. The study of literature in the scope of this research field were reviewed and discussed. There are many researchers from various discipline have put attention on the household energy use, but mostly were focused on investigating the physical characteristics such as building characteristics, family characteristics, and also housing equipment, but only a few have focused the research on occupants activity and behavior. Thus, the research on lifestyle factors with the parameter of energy use still needs to be developed. This paper also provided a large number of feedback and unique

database which are new contributions to this research field. This study also adds a new method on evaluating the people daily behavior and physical attributes by analyzing the statistical results, geographical information system, and simulation studies.

In **chapter two** (THEORY AND RESEARCH METHOD OF RESIDENTIAL BEHAVIOR ASSESSMENT), the theoretical studies have been conducted. The method to assess the household lifestyle and behavior in residential housing from many research fields were reviewed and discussed. This study mainly adopted the Quantification Theory I which is has been used in some social science types of research to find the influential factors extent to the dependent variable. Meanwhile, the four concepts from WHO of satisfaction regarding the environment quality measurement were also adopted in order to find its correlation with people behavior and energy use in housing. In addition, the conceptual framework and integration between statistical data and Geographical Information System were discussed in detail.

In **chapter three** (FUNDAMENTAL SURVEY ON LIFESTYLE AND HOUSEHOLD ENERGY USE IN ASIAN COUNTRIES), the present housing unit characteristics, household characteristics, ownership of domestic electrical appliances, use of indoor thermal equipment, and monthly energy use trend in three Asian countries (Indonesia, Thailand, and China) were revealed. In this chapter, the study began with collecting data through questionnaires survey which were distributed to some cities of three developing countries. Asia has been chosen as the study area due to the highly ongoing economic growth in decades. Based on questionnaire results from all households in the three countries, we conducted statistical analyzes to find the major factors influencing the energy use in households. Finally, the research results will be used to indicate the energy use and develop an idea for energy conservation in Asian countries. Further, the research also tried to discover the new way of changing the people's lifestyle considering to the present living condition.

In **chapter four** (SURVEY AND ANALYSIS ON HOUSEHOLD LIFESTYLE IN RELATION WITH ENERGY USE IN JAPAN), based on fundamental questionnaire results from households in three Asian cities, as the follow-up, the seven districts of Kitakyushu City in southern Japan has been chosen as a model. We conducted statistical analyzes to estimate the impact of lifestyle on household energy demand.

This study found that the household energy use increases according to the house floor size, electric air-conditioner ownership, residence year, daily cooking period, and family size. In the other hand, comparative analyzes on different types of house and its energy use behavior were also conducted in order to find which households groups have the potential on energy conservation. From total valid feedback, more than 65% of houses are the multi-dwellings. In relation with energy use, the multi-dwelling type consumes 35% less energy than the detached house type. The study also found that only 11% of households are using electric-only energy sources while 89% are using the combination of gas and electricity. Furthermore, based on the physical attributes and behavior characteristics, a Hierarchical Clustering Analysis was conducted to understand which group of households consumes more and less energy, then the results were evaluated and discussed.

In **chapter five** (STATISTICAL AND GEOGRAPHICAL ANALYSIS ON THE IMPACT OF RESIDENTIAL ENVIRONMENT QUALITY TO THE HOUSEHOLD LIFESTYLE), a study on the method of evaluating residential environment condition in relation with the people lifestyle in using the neighborhood facilities. Subjective evaluations on the residential environment through questionnaire survey were performed in order to grasp the resident's behaviors and preferences. In 2013, questionnaires were distributed to more than 4,000 households of younger families located in seven districts of Kitakyushu City, Japan. In this paper, we analyzed the result of questionnaires with statistical software and discussed a unique result with Geographical Information System (GIS) software. As results, several findings could be described as follow: 1) almost of residents were unsatisfied about the safety, even the safety level score has increased during 10 years in the same area; 2) more than 60% of households group were realized their comprehensive wish on living condition, which mean the target of residential environment plan and design nearly achieved; 3) the convenience level of neighborhood facilities could be clearly explained by combining the statistical analysis results and GIS database; 4) in relation with the household energy use this study found that household with high score of satisfaction inconvenience has spent less energy use. This study may also contribute some strategies on efficient planning and development of the sustainable community.

In **chapter six** (FIELD EXPERIMENT ON HOUSEHOLD BEHAVIOR IN KITAKYUSHU ECO-HOUSE MODEL), based on the results from the previous chapter in this paper, the investigation on low energy housing was conducted. Recently, resident's behavior related with the use of electrical home appliances such as air conditioner, kitchen equipment, cleaning equipment, etc. have become hard to control. On the other hand, the innovations on future houses that can provide its own energy and supply the energy to the local community are continuously developed. Based on this phenomenon, we conducted the survey and investigation on low-energy house model in Kitakyushu City. The house is utilized with advanced technologies such as hydrogen fuel cells, solar panels, and heat pump to maximize the use of recycled energy in the household. In this study, firstly, the physical characteristics of Kitakyushu Eco-house model were explained and reviewed. Based on previous researches and literature studies, we conducted the experimental study by designing some lifestyle patterns of household and set some attributes. Then the energy use of each scenario of lifestyle was measured in during one year. The results of the measurement then evaluated and discussed.

In **chapter seven** (BUILDING ENERGY USE AND LIFESTYLE SIMULATION OF VARIOUS JAPANESE HOUSING MODELS), as a follow-up of chapter six, the simulation on Japan Eco-house was conducted. Firstly, the twenty-two model houses were reviewed in terms of building attributes, heating-cooling system, and passive-active technology. Secondly, the simulation on building energy load was conducted and its results were discussed. Thirdly, the multiple regression analyzes were conducted to find out the major factors influencing the energy use, heating, and cooling load. Finally, based on the various model of Eco-house in Japan, the simulation on Eco-house energy use was conducted in other Asian countries such as Indonesia, Thailand, and China. The results of this paper will provide estimations as tools for architect, developer, and local government to develop best design solution in terms of energy performance.

In **chapter eight** (CONCLUSIONS), the summary and the main findings of the whole study in this paper were presented. Finally, the future prospects of this field study were also proposed.

論文概要

近年、石油と天然ガスに対する世界的な需要が、特にアジア圏の社会において、急速に増大している。したがって、省エネルギーに関連した重要な指針が行われない場合、将来におけるエネルギー危機は避けられない。日本のような先進国では、電力生産性に高い能力のある、原子力発電を適用してきた。しかし、複数の人為ミスにより、我々の環境に対し、非常に大規模な災害がもたらされた。一方で、経済成長や人々の生活水準の向上は、家庭用電気製品による家庭用エネルギー消費を促進し、エネルギー消費の制御が困難になっている。こうした研究背景に基づき、我々は、住宅におけるライフスタイルアプローチに対する分析及び住宅の生活環境特徴の調査を通し、家庭用エネルギーの省エネに対する効率的な方法を明らかにする研究を実施した。加えて、具体的な環境を特徴付けることにより、我々はライフスタイルを変化させる際における、有力な可能性のあるライフスタイル運用方法の種類について識別した。

本研究の主目的は、住宅のエネルギー利用に関連した広範囲に及ぶ分析である。中国、タイ、インドネシア、日本の各国における 4000 以上の家庭に対し、配布したアンケート調査を基に、家庭用エネルギー使用に影響力のある要因因子について調査した。居住者のライフスタイルに関連したパッシブ・アクティブ技術による可能性を理解するため、日本のエコハウスモデルにおいて、エネルギー利用に関する現場計測を実施した。また、アジア諸国における、持続可能な発展のため実践されているエコハウス内での様々な条件を研究するために、住宅の建築エネルギー利用に関するシミュレーションを実施した。

第 1 章（序論）では、本研究の主要内容について述べる。本研究の目的は、家庭部門におけるエネルギー利用に直接的に影響をもたらす、住宅のライフスタイル要因のあらゆる側面についての総合的な分析の実施である。この研究分野範囲内における研究文献は、検討・議論が行われてきた。家庭用エネルギー利用に注目している、様々な分野に所属した研究者が大勢いる。しかし、ほとんどが建物特徴や家族構成、又は住宅設備のような物理的特徴に焦点を当てたものであり、居住者の活動の調査に焦点をあてたものは少ない。このように、エネルギー利用のパラメータによるライフスタイル要因の調査は、展開されていく余地があるといえる。本論文では、この研究分野への新しい貢献として、多数のフィードバック及び興味深いデータベースを紹介した。本研究では、人々の日常の振る舞い及び身体的特質の評価方法として、統計結果、地理情報システム（Geographical Information System）、シミュレーション研究を用いた分析新たな方法としてを適用した。

第 2 章（住宅行動評価の理論と研究方法）では、理論研究を実施した。住宅内における、

住宅ライフスタイル及び行動を多角的な研究分野から評価する方法は、検討・議論されてきた。本論文では、従属変数への影響因子の範囲を発見するため、社会科学分野で多く利用されている、「数量化理論 I」を主に適用した。一方で、人々の行動と住宅におけるエネルギー利用の相関関係を発見するため、WHO に定められた環境品質測定に関する満足度から、4 つの概念を適用した。加えて、概念フレームワーク及び統計データと地理情報システム（Geographical Information System）の統合結果を詳細に述べた。

第 3 章（アジア各国のライフスタイルや家庭のエネルギー利用に関する基礎調査）では、現在の住宅単位の特徴、世帯特性、家電製品の所有、室内熱機器の使用及びアジア 3 ヶ国（インドネシア、タイ、中国）における月毎のエネルギー利用の傾向について、明らかにした。この章では、3 つの発展途上国の各都市に配布したアンケート調査によるデータ集計を基に研究を開始した。アジアは数十年で非常に継続的な経済成長をしているため、研究対象地域として選出した。3 ヶ国における全世帯のアンケート結果を基づき、我々は、家庭におけるエネルギー利用に影響を及ぼす主な要因を発見するため、統計分析を実施した。最終的に、この調査結果については、エネルギー利用の指摘及びアジア諸国における省エネルギーに対するアイデアを発展のために利用していく。さらに、多くの研究者たちもまた、現在の生活状況を考えることにより、人々のライフスタイルを変化させる新たな方法を発見しようと試みた。

第 4 章（日本におけるエネルギー利用に関連した住宅ライフスタイルに関する調査及び分析）では、アジア 3 都市における世帯についての基本的なアンケート結果に基づき、フォローアップとして、日本南部にある北九州市の 7 地区をモデルとして選択した。我々は、家庭のエネルギー需要におけるライフスタイルの影響を推定するため、統計分析を実施した。本研究では、住宅規模、電気エアコンの所有、居住年数、日々の調理時間及び家族構成により、家庭用エネルギー利用が増加することが明らかになった。一方で、様々なタイプの住宅及び各タイプのエネルギー利用及び行動に関する比較分析について、省エネルギーの可能性がある世帯グループを発見するために実施した。総合的に有効なフィードバックから、65%以上の住宅は集合住宅であることが分かった。また、エネルギー利用に関連して、集合住宅の種類の消費は、戸建住宅の種類よりも 35%低いという結果となった。本研究により、89%の家庭がガスと電気によるエネルギー源の利用を行っている一方で、11%の家庭は、電気によるエネルギー源を使用していることが分かった。さらに、どの家庭のグループが、より少ないエネルギーを消費するかについて調査するため、身体的な特質と行動特徴を基に、階層的クラスタリング解析（Hierarchical Clustering Analysis）を実施、

その結果を評価・議論した。

第 5 章（家庭用ライフスタイル居住環境の質の影響に関する統計及び地理的な分析）は、近隣の施設利用における人々のライフスタイルに関連した、居住環境の状態を評価する方法に関する研究である。アンケート調査を通じた、居住環境の主観的評価が居住者の行動や嗜好を把握するために実施された。2013 年に、日本・北九州市の 7 地区に居住している、比較的若い 4000 世帯に対し、アンケート調査を配布した。本論文では、我々は、統計ソフトによるアンケート結果の分析及び地理情報システムにより、結果を議論した。結果として、いくつかの調査結果を次のように記述することができる。1)殆どの居住者は、同じ地域において、10 年間に安全レベルが上昇しているにも関わらず、安全性に不安があることは分かった。2) 世帯のグループの 60%以上は、居住環境計画と設計の目標をほぼ達成するという、生活状況における総合的な願望を実現しました。3) 近隣施設の利便性のレベルは、統計分析結果と GIS データベースを組み合わせることにより、明らかにできる。4)家庭用エネルギーの利用の関連性について、本研究では、より少ないエネルギー利用を実施しつつ、利便性に関する満足度の高い世帯を発見した。この研究はまた、効率的な計画と持続可能な社会の発展に対し、いくつかの戦略を寄与することができるといえる。

第 6 章（北九州エコハウスモデルの世帯の挙動に関する現場計測実験）において、本研究の前章に基づき、低エネルギー住宅に関する調査を実施した。近年、居住者の行動は、エアコン、厨房機器、洗浄装置等の家庭用電気製品に関連しており、制御が困難となっている。一方で、住宅のエネルギー提供及び地域コミュニティへのエネルギー供給を可能とする、将来の住宅における革新は、持続的に発展している。この現象に基づき、我々は、北九州市における低エネルギー住宅モデルの調査を実施した。この住宅では、水素燃料電池、太陽電池パネル、また、家庭でのリサイクルエネルギーの利用を最大化にするヒートポンプ等の高度技術が適用されている。本研究では、はじめに、北九州エコハウスモデルの物理的特徴については、先の章に紹介したとおりである。先の調査及び文献研究に基づき、我々は、幾つかの家庭におけるライフスタイルパターン及び属性について設定した上で、現場計測実験を実施した。この実験では、ライフスタイルの各シナリオのエネルギー使用量について 1 年間測定を実施し、得られた結果を評価・議論した。

第 7 章（ビルエネルギー使用量および様々な日本の住宅モデルのライフスタイルシミュレーション）では、第 6 章のフォローアップとして、日本におけるエコハウスのシミュレーションを実施した。最初に、22 のモデル住宅について、建物属性、加熱冷却システム、及びパッシブ・アクティブ技術の観点から評価した。次に、エネルギー負荷を仮定した上

でシミュレーションを実施し、結果を議論した。また、エネルギー使用、加熱・冷却負荷に影響を与える主な要因を調べるために重回帰分析を実施した。最後に、日本における様々なエコハウスモデルに基づき、エコハウスのエネルギー利用調査に用いたシミュレーションをインドネシア、タイ、中国等の他のアジア諸国で実施した。本研究結果については、建築家、開発者及び地方政府による、エネルギーパフォーマンス面における最高の設計ソリューションを開発するためのツールとして、提供していく。

第 8 章（結論）では、要約本稿による、全体の研究の主な調査結果について公表した。最後に、今後の本研究分野における展望について、述べた。

Dedication

For my Son

Preface

Buildings and environment are the key elements on conducting this dissertation book. How the people behave with their living environment is being a concern for the authors since the issue of the energy crisis has risen recent years. While many researchers put more attention in finding the future energy resources, the Author was trying to propose the effective way to change the situation.

This book described the interrelationship between people behavior, building characteristics, and energy use of the very basic living space, a home. Reviews on the present situation were also discussed and it would be very useful as a baseline to predict the future trend of household lifestyle.

In the process of conducting this research, the Author feels a significant change inside, such as the view on how important to save the energy wherever it is, the way on analyzing the real life problem, and the strength on keeping the idealism.

This dissertation could not be finished without support and help from the research advisors, friends, and family. This study, which is conducted from five years ago, will also show and summarize the findings in the way for easier to understand for reader or researcher out of the research scope.

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Chapter four: Survey and Analysis on Household Lifestyle in relation with Energy Use in Japan

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Chapter seven: Building Energy Use and Lifestyle Simulation of Various Japanese Housing Models

Chapter eight: Conclusions

第一章

序論

Chapter one: Introduction

1-1 Research background

1-2 Research purpose

1-3 Literature review

1-4 Research novelty

1-1 Research background

1-1-1 Energy consumption situation in Asian Countries

Due to the fast growth of economy, Asia-Pacific region is the world's largest energy consumer (especially South East Asia region), accounting for 39.1% of global energy consumption and 68.8% of global coal consumption [1]. Responding this issue, some development countries such as Japan, innovates with environmentally hi-technologies, such as wind power, solar panel, and nuclear power plant.

Japan, is dependent on imports for 91.3% of its energy supply. Since experiencing the two oil crises of the 1970s, Japan has taken measures to promote energy conservation. As a result, its dependence on petroleum declined from 77.4% in fiscal 1973 to 43.7% in fiscal 2010. However, after the Great East Japan Earthquake, the percentage of fossil fuels has been increasing, as a substitute for nuclear power as fuel for power generation. The level of dependence on petroleum which had been on a declining trend in recent years increased to 47.3% in fiscal 2012 [2]. As a result, the government has been working to construct energy policies aiming to provide a stable energy supply and lower energy costs. In this process, the introduction of energy saving and renewable energy has been promoted, and reviews are being conducted in a direction toward lowering the level of dependence on nuclear energy. In the other hand, the energy consumption of the building sector has increased 2.5 times during 1973 to 2007, the highest increase compared to transportation (2.0 times) and industrial sector (1.0 times)[3]. The housing sector consumes energy more than double that of the time of the first oil crisis, while after the oil crisis, development of energy saving type home electronic appliances, gas apparatuses and so on were penetrating progressively to homes. Energy consumption has been increasing under the influence of changes in national lifestyle in the pursuit of convenience and comfort, an increase in the number of households, and the changes in the social structure such as rise in the proportion of the aged and use of larger electric appliances[4].

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[1] Annual report of household energy consumption (2002). Jyukankyo Research Institute Inc. (in Japanese).

[2] Statistical Handbook of Japan, Chapter 7, Energy, Statistics Bureau, Japan (2013) 77-82.

[3] The Agency for Natural Resources and Energy, "Comprehensive Energy Statistics".

[4] The Institute of Energy Economics, Japan, "EDMC Handbook of Energy & Economic Statistics in Japan"

Indonesia is rich in natural resources including the petroleum, natural gas, and coal. About 35% of the petroleum mining products exported to other countries. On the other hand, Indonesia's economic growth affects the increasing of domestic energy demand. However, these energy resources are limited and need hundreds of years of production. From 2000 until 2009, Indonesia's oil export decreased 48% as an impact of oil production decrease. According to the National Energy Outlook of Indonesia, in the period 2000-2009 energy consumption in Indonesia increased from 709.1 million SBM (Barrels of Oil Equivalent/BOE) to 865.4 million SBM, or increased by 2.2% per year. Until the end of 2011, the largest sector of final energy consumption is still dominated by industrial and then followed by household sector and transportation sector, each are 37%, 36%, and 21% [5]. However, with the national population booming, there is possibility for the household sector will increase significantly.

China, Energy consumption of China has been increasing rapidly due to the recent economic growth and development. This leads to serious environment problems such as air pollution and acid rains. Meanwhile the building sector accounts for large parts of energy consumption. It is almost 30% of total energy consumption in 2007 [6]. Especially in recent years, people's demand for life quality triggered drastic annual increase of energy consumption on urban areas in China. In order to estimate the future trend of residential indoor environment and energy consumption in China it's necessary to understand the actual conditions of the usage of facilities the indoors thermal conditions and quality in different zones. In China, the space heating energy consumption is about 40% in the urban area on average though there is great difference between the south region where people use individual heating equipment and the north region where district heating is generally used [7]. However, the energy consumption is comparatively large in the villages of China because firewood and crops are used as the energy source.

[5] Ministry of energy and mineral resources of republic Indonesia, http://www.esdm.go.id, 2009, Indonesia

[6] Y.D.Ni ng, Y. Tonooka, X. Zhao, e t, al. Analysis on trends of urban housing energy consumption in Shanghai, in: Proceedings of The Fifth International Conference on Building Energy and Environment Dalian, China (2008) , pp. 412-419

[7] The World Fact book. CIA. 2008. Retrieved March, 2006.

Thailand, The National statistical office of Thailand has conducted a survey of household energy consumption by 2009 and found out the comparison of the energy cost of the households across the country in 2008 and 2009 has increased from 1,568 baht (51USD) to 1,818 baht (60 USD)or increase the percentage of 15.9 per year. Particularly oil, biodiesel and renewable energy, although it is rarely used but has been increased 50%, gas was increased 33.7% and diesel increased by 25.7%. The electric consumption was found increases of 11.6 over the year 2008, which has just in 2.1%. From 2008 to 2009, the monthly energy cost of residential sector has increased 10.6% (from 83 USD to 92 USD) [8].

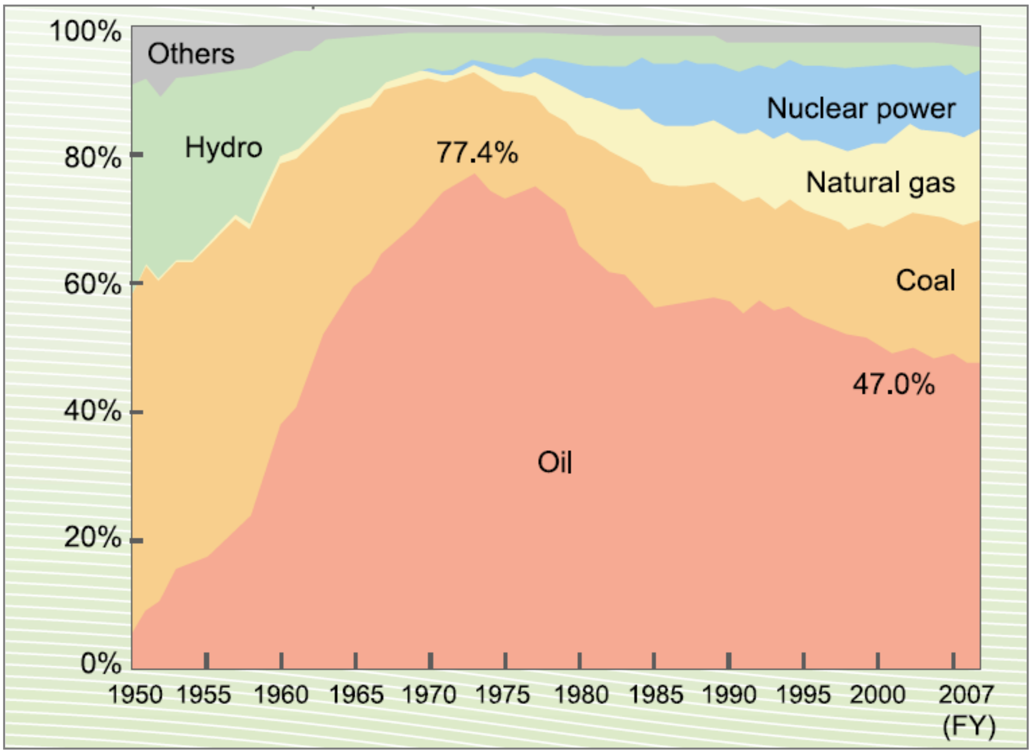

Figure 1-1 Composition of the total supply of primary energy of Japan

Figure 1-1 shows the composition of total supply energy in primary sector, it is described that oil still accounts for the largest share in Japan. Oil accounts for about 47% of the primary energy supplied to Japan. Although this percentage has been declining from 77% in the year of 1973, the share is still the largest of all energy resources [9].

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8 National statistical office, the survey of household energy consumption by 2008-2009, Thailand

9 Agency for Natural Resources and Energy, "Comprehensive Energy Statistics" The Institute of

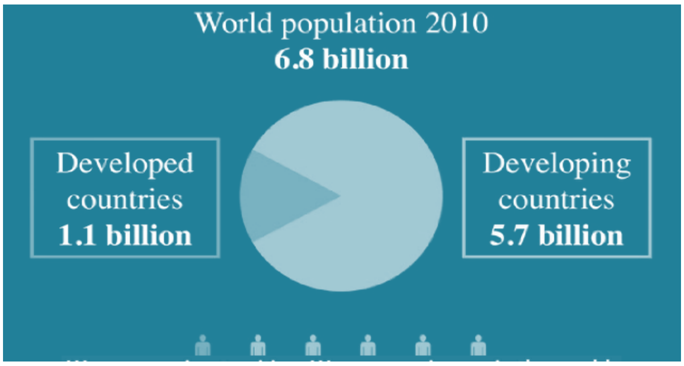

Figure 1-2 Word population composition of developing and developed countries [10]

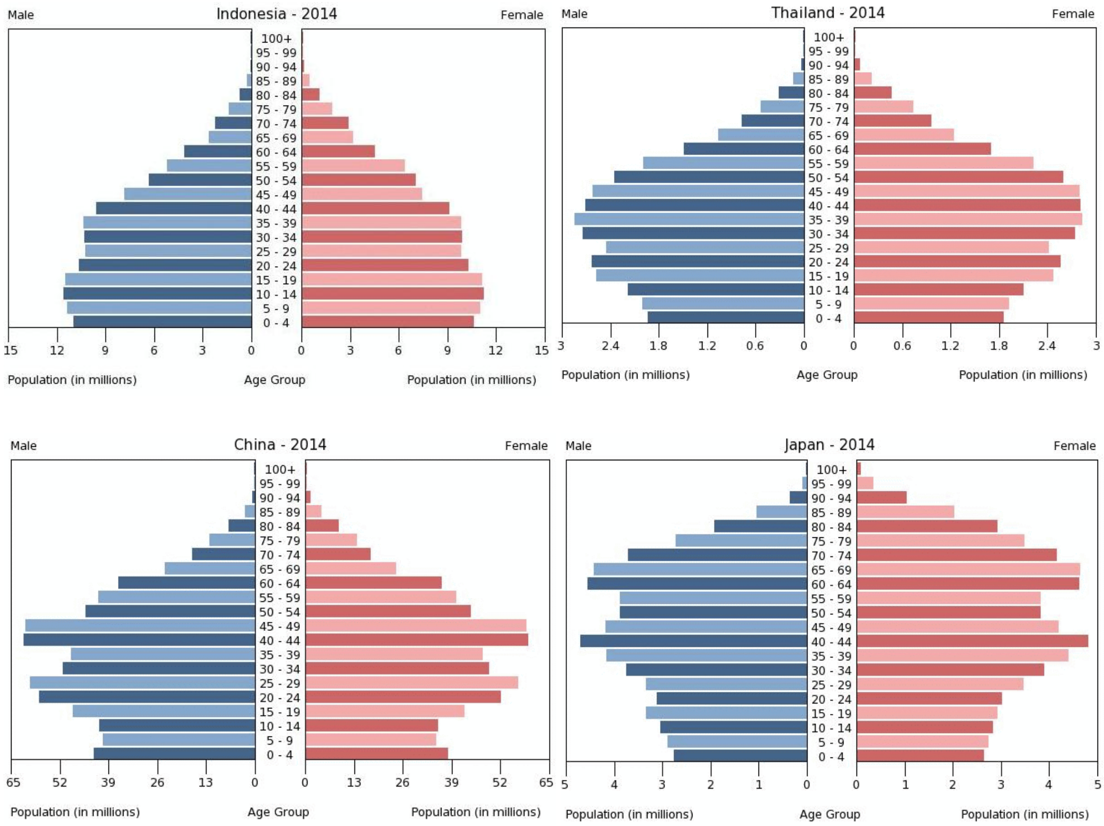

Figure 1-3 Population charts of four Asian countries [11]

Based on **Figure 1-2** and **1-3**, the reason for fast growth of Asian economy could be understood. World population is dominated by developing countries and more people will live in the city. While as a comparison, in Asia region, Japan as the developed countries has shows the population decline and will continue to the aging population. While Indonesia, Thailand, and China shows the high number of young population.

Energy Economics, Japan, "EMDC Handbook of Energy & Economic Statistics in Japan"

10 United Nations, World Population Prospects 2010

11 The World Fact book. CIA. 2008

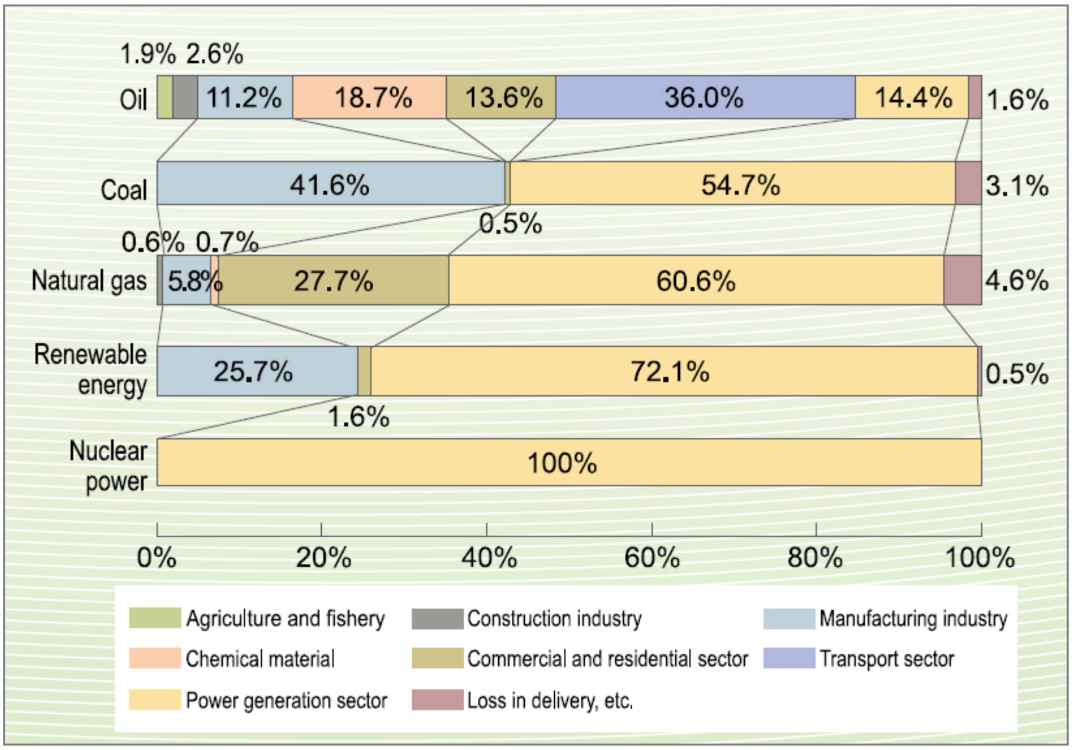

Figure 1-4 Uses of energy resources in Japan

In addition, **Figure 1-4** shows the uses of energy resources, the use of oil has penetrated to a wide range of uses in comparison with other energy resources. Fuel input for steam for industrial use is included in manufacturing industry [12]. In the power generation sector, the total power generated for business and private use is shown. On the other hand, the renewable energy stated above is included of hydrogen and biomass. When the world economy recovered after Asian economic crisis in 1998 to 1999, the price turned to follow a rising trend, marking an all time high of 134.1 USD in July 2008, although, the price changes between 80 USD from 60 USD in June 2009 [13]. Thus, the relationship of world economical situation shows high correlation to the country's energy supply.

12 Agency for Natural Resources and Energy "Comprehensive Energy Statistics 2007"
13 Agency for Natural Resources and Energy

Figure 1-5 shows the trend in energy consumption and GDP in Japan between fiscal year of 1973 to 2007. Energy consumption divided into three categories, which are the commercial and residential sector, the transport sector, and the industrial sector. Based on this figure, the amount of consumption in the industrial sector has remained roughly around the same level after the world oil crisis. Contrary, in the commercial and residential sector as well as the transport sector, the amount has significantly increased. Until 2007, the relative proportion of the industrial: commercial-residential: transport changed to 2: 1 – 4: 1[14].

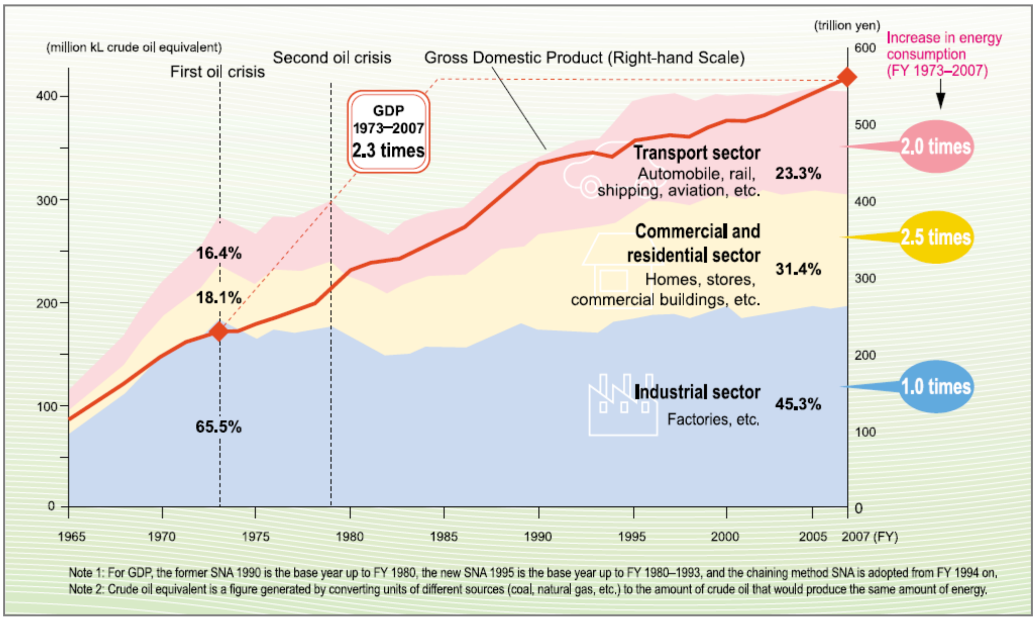

Figure 1-5 Trends in energy consumption and GDP in Japan

On the other hand, in **Figure 1-6**, the global energy consumption in 2030 is predicted to rise to 1.4 times its present level, while it is said that about half of the increase will be caused by Asian countries. It is expected that the demand for fossil fuels such as oil, coal, and natural gas will increase continuously along with the economic growth in developing countries such as China, India, and South-east Asian countries[15].

14 "Annual National Accounts Bulletin"; The Institute of Energy Economics, Japan, "EDMC Handbook of Energy & Economic Statistics in Japan"

15 IEA/World Energy Outlook 2009

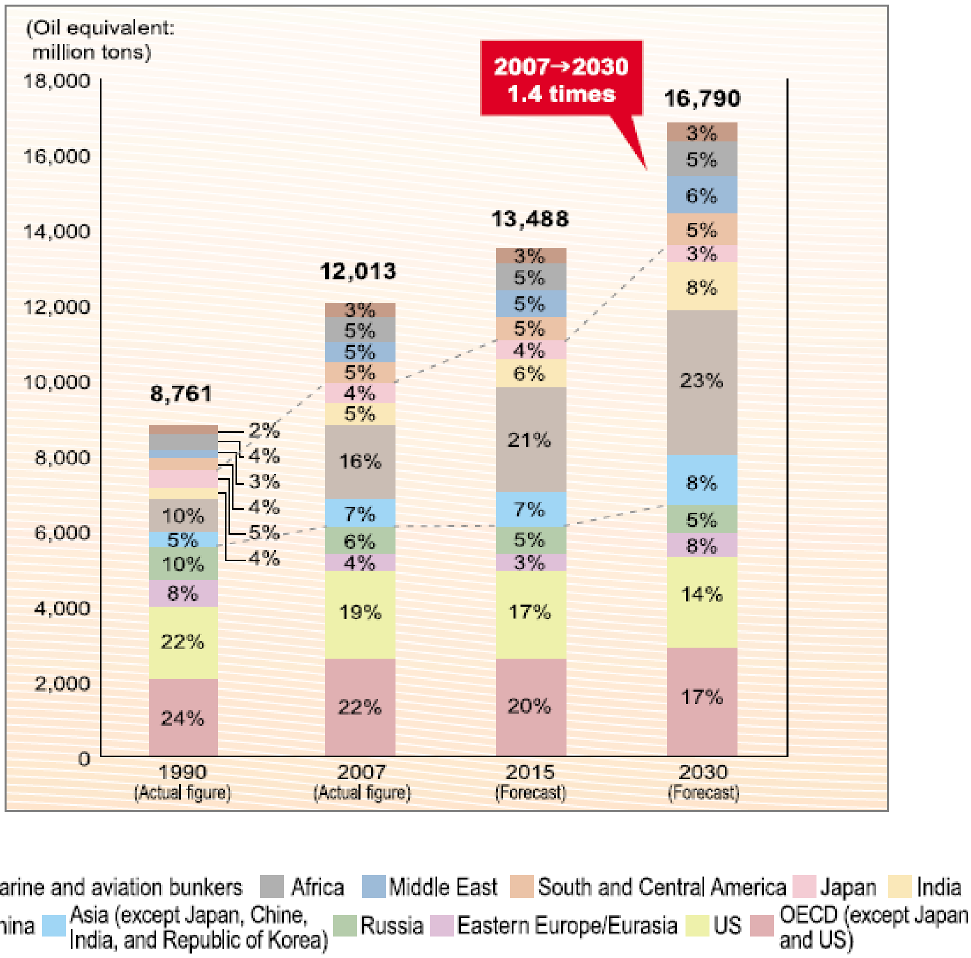

Figure 1-6 Anticipated global energy demand by region/country

1-1-2 Energy consumption and lifestyle

The housing sector consumes energy more double that of the time of the first oil crisis [16]. While after the oil crisis development of energy-saving type home-electric appliances, gas apparatuses and so forth advanced, penetrating progressively to homes, energy consumption has been increasing under the influences of changes in national lifestyle in pursuit of convenience and comfort, an increase in the number of households, and the changes in the social structure such as rise in the proportion of the aged and use of larger electric appliances, as shown in **Figure 1-7**. Thus, promoting and practicing the energy saving lifestyle in the residential housing sectors is major task for us.

[16] The Institute of Energy Economics, Japan, "EMDC Handbook of Energy &Economic Statistics in Japan"

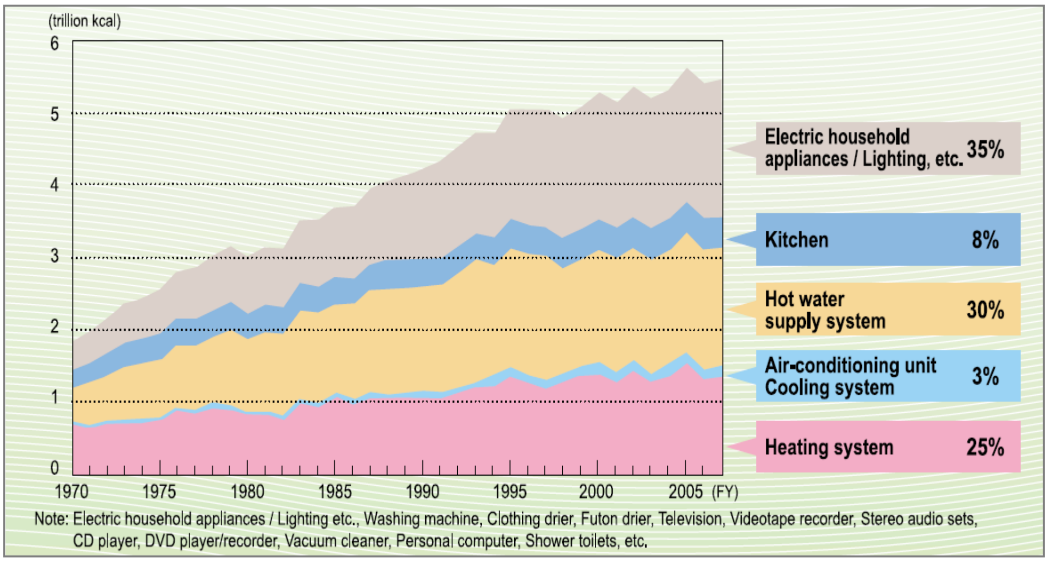

Figure 1-7 Energy consumption of the home sector by usage

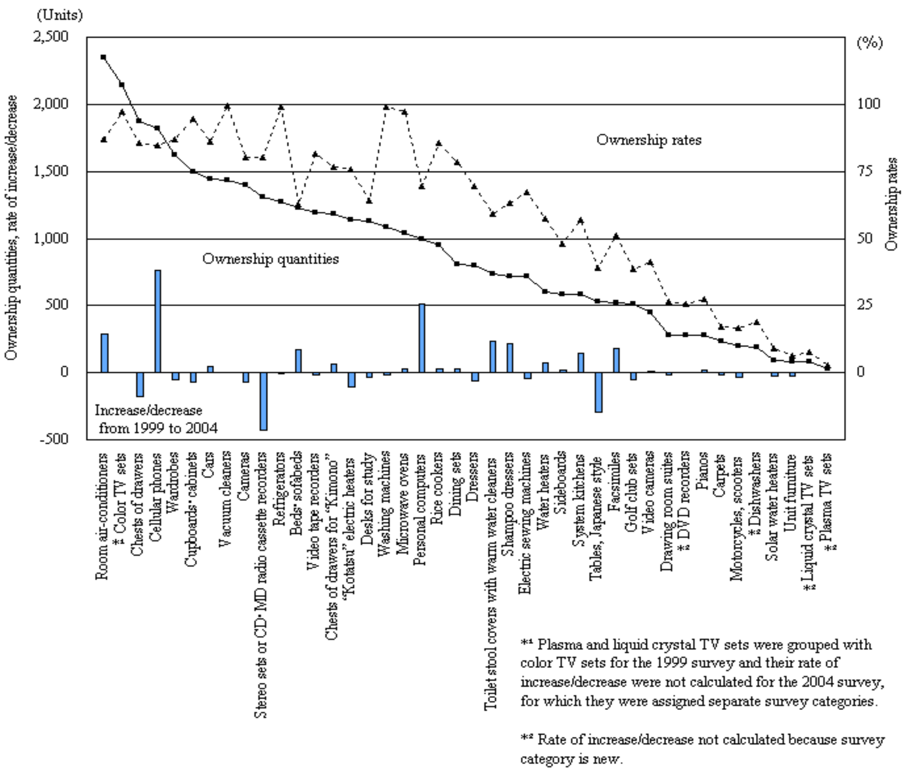

Figure 1-8 Major Durable Goods Ownership Quantities and Ownership Rates [17]

Based on **Figure 1-8**, Japan's first appliance energy efficiency standards were set in 1979 under the Energy Conservation Law. In order to plan the energy

17 The Statistics Bureau and the Director-General for Policy Planning of Japan

conservation in the residential housing, electric appliances such as air conditioning equipments would be an extremely effective measure. From the beginning, The Energy Conservation Law contained energy consumption efficiency standards for machinery and equipment to stimulate equipment energy conservation. Initially, the types of machinery equipment covered by the regulations were limited to three items: electric refrigerators, air conditioners, and passengers cars.   Electronic equipment such as air conditioners, cellular phones, personal computer, and housing appliances are increase significantly in 5 years period, predicted will continue to increase more in the future balance with people's lifestyle.

1-2 Research purpose

The main purposes of this paper are to analyze the lifestyle characteristics of household and to find out the influential factors of household energy use in some Asian countries.

Firstly, the study tried to grasp the energy use characteristics and household behavior in three countries except Japan, to understand the present situation of residential housing characteristics, family characteristics, and their living environment condition. Secondly, followed up the result of fundamental survey in Asian countries, the study area is chosen in the southern area of Japan, Kitakyushu City. Here, the questionnaire developed and distributed to more than 4,000 households. The purpose is trying to reveal the housing unit characteristics, household characteristics, ownership of domestic electrical appliances, use of indoor thermal equipment, and monthly energy use. Based on questionnaire results from households in the seven districts of Kitakyushu City, we conducted statistical analyses to estimate the impact of lifestyle related household energy demand.

In addition, this study also purposes to develop the method to evaluate the people lifestyle and its relationship with their environment, through combination of data base, statistical software, and simulation software. Finally, by the results of this study, we tried to promote and build a guide or baseline for future sustainable residential housing development to the local government, architect, urban planner, and community

1-3 Literature review

In response to the issue of increasing energy demand in the housing sector, several studies on residential energy use have been conducted by many researchers in Asian and Western countries. Some researches about trends of energy use and its relationship with households attributes in Japan were reviewed. *Nakagami et al.* [18] reported that the energy demand is expected to increase continuously as well as the increase of housing appliances ownership in Japan. They also surveyed residential energy consumption and its indicators in 18 countries, both developed and developing countries, and revealed that in the Western Countries, household energy consumption shows a trend toward saturation, but in the Asian Countries it is likely that household energy consumption will continue to rise[19]. *Kagajo et al.* [20] analyzed the household energy consumption trends based on the standard models of family pattern, aging society, and its life schedule. *Nomura et al.* [21] conducted a study on the interrelationship between household electricity consumption and family member ages. *Tsurusaki et al.* [22] found that space-heating, space-cooling, lighting and usage of electronic entertainment equipment are the major influences on household energy consumption in the cold climate area, Hokkaido, Japan. *Fong et al.* [23] pointed out the lifestyles in terms of family pattern, employment status; employment sector, gender, and age do have a significant impact on household energy consumption, later the lifestyles were categorized as indirect lifestyles.

In other Asian countries, numerous researches were also reviewed in this paper. *Yu et al.* [24] made a questionnaire and simulation in northeast, middle and east of

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[18] H. Nakagami, Annual report of household energy consumption, Jyukankyo Research Institute Inc., Japan, 2002. (in Japanese).

[19] H. Nakagami, Appliance standards in Japan, Energy and Buildings 26 (1997) 69-79.

[20] T. Kagajo, S. Nakamura, Analysis of household energy consumption trends based on the standard models of family pattern. Energy Economics (1997)11-29.

[21] N. Nomura, H. Ohya, Interrelationship of household electricity consumption and family member ages. Journal of the Japan Institute of Energy 80(8) (2000) 727-735.

[22] T. Tsurusaki, C. Murakoshi, M. Yokoo, Measurement and analysis of residential energy consumption in Hokkaido. Proceeding of the Conference on Energy, Economy and Environment (2000)417-422.

[23] W.K. Fong, H. Matsumoto, Y.F. Lun, R. Kimura, Influences of indirect lifestyle aspects and climate on household energy consumption. Journal of Asian Architecture and Building Engineering, 402 6(2) (2007) 395-402.

[24] L. Yu, T. Watanabe, H. Yoshino; W. Gao, Research on energy consumption of urban apartment buildings in China. J. Environ. Eng. 73 (2008) 183-190.

China, and generated an equation to calculate the energy used for district heating of households in Shenyang, Dalian, Beijing, and Luoyang. *Chen et al.* [25] using Quantification Theory I, investigated the influential factors on energy consumption in seven big cities of China in the summer time and presented a comparative study of the results. *Chen et al.* [26] in another paper, with the same method did the comparative study between two different districts in China and revealed the difference influential factors of two types (old and new) of residential housing. *Lam et al.* [27] also made the research on residential energy consumption with five different building types in Hong Kong, and evaluated the end use values. *Long et al.* [28] conducted an investigation on the electricity use of air conditioners in Shanghai, and got the mean monthly energy consumption values in the air conditioning seasons and transition seasons. *Tso et al.* [29] studied domestic energy structure in Hong Kong and found the breakdown of end use and the daily properties of energy loads by calculations, and finally revealed the influential factors of electricity use in summer and winter. *Yoshino et al.* [30] carried out the investigation to 240 houses during the winter from 1998 to 2000 by means of questionnaire in terms of the space heating and indoor thermal environment of residential buildings in three big cities of China. *Yoshino et al.* [31] in another study compared the apartment buildings located in three cities of China through questionnaire survey revealed the lifestyle within the residence in summer season and its correlation with air conditioners equipment. Again, *Yoshino et al.* [32] investigated

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[25] S. Chen, H. Yoshino, N. Li, Statistical analyses on summer energy consumption characteristics of residential buildings in some cities of China, Energy and Buildings 42 (2010) 136-146.

[26] S. Chen, H. Yoshino, M.D. Levine, Z. Li, Contrastive analyses on annual energy consumption characteristics and the influence mechanism between new and old residential buildings in Shanghai, China, by statistical methods, Energy and Buildings 41 (2009) 1347-1359.

[27] J.C. Lam, An analysis of residential sector energy use in Hongkong, Energy 21 (1) (1996) 1-8.

[28] W.D. Long, T. Zhong, B.H. Zhang, Situation and trends of residential building environment services in Shanghai. Proceedings of the 4th International Symposium on Heating, Ventilating and Air Conditioning, Beijing, China (2003) 493-498.

[29] G.K.F. Tso, K.K.W. Yau, A study of domestic energy use pattern in Hongkong. Energy 28 (2003) 1971-1682.

[30] H. Yoshino, H. Lou, Indoor thermal environment of residential buildings in three cities of China, Journal of Asian Architecture and Building Engineering 1(1) (2002) 129-136.

[31] H. Yoshino, S. Guan, Y.F. Lun, T. Shigeno, Y. Yoshino, Q. Zhang, Summer survey on indoor thermal environment of urban residential buildings in China, Journal of Asian Architecture and Building Engineering 1(2) (2002) 65-72.

[32] H. Yoshino, Q. Zhang, Y. Yoshino, T. Shigeno, S. Guan, et al., Summer investigation on indoor environment of Residential Buildings in Beijing and other four cities, Journal of Asian Architecture and Building Engineering 3(1) (2004) 47-54.

and characterized the physical environment of urban residential indoors, thermal comfort, and indoor air quality in Beijing, characterized the physical environment also identified the forces that would be influential in making these changes. *Yoshino et al.* [33] also analyzed the correlation of annual and daily energy consumption profiles of two typical houses to space heating and the results indicated that the characteristics of energy consumption were not only greatly influenced by regional climate but also the use of households equipment and lifestyle. *Ogawa et al.* [34] carried out research to investigate the characteristics of building energy standard of the residential building in China and classified the climate zones based on thermal environment design, specified new standard of sunlight, lighting, and ventilation. *Wei et al.* [35] analyzed the current condition of urban and rural residential energy consumption of Jilin, China by establishing a model of residential energy demand, which can predict energy demand based on demand types and environmental load until 2020. *Quyang et al.* [36] identify the changes in the occupants' behavior of residential housing in Hangzhou, China, and predicted that residential electricity use will increase continually in the near future due to improved standards of living and a greater dependency on electric appliances, also more than 10% of household electricity use can be conserved by informing occupants of energy-saving measures to improve their behavior. *Hubacek et al.* [37] examined the contribution to CO2 emissions (I) of population growth (P), affluence (A) (representing different lifestyles and consumption patterns) and CO2 intensity (T) representing technology. *Kang et al.* [38] developed energy load prediction equations which can be easily used to estimate the energy consumption of multi-residential buildings in Korea

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[33] H. Yoshino, J.C. Xie, T. Mitamura, T. Chiba, H. Sugawara, K. Hasegawa, K. Genjo, S. Murakami, A Two year measurement of energy consumption and indoor temperature of 13 houses in cold climatic region of Japan, Journal of Asian Architecture and Building Engineering 5(2) (2006) 361-368.

[34] Y. Ogawa, W. Gao, N. Zhou, T. Watanabe, H. Yoshino, T. Ojima, Investigation on the standard for energy and environmental design of residential house in China, Journal of Asian Architecture and Building Engineering 4(1) (2005) 253-258.

[35] X. Wei, J. Xuan, J. Yin, W. Gao, B. Batty, T. Matsumoto, Prediction of residential building energy consumption in Jilin Province, China, Journal of Asian Architecture and Building Engineering 5(2) (2006) 407-412.

[36] J. Quyang, L. Gao, Y. Yan, K. Hokao, J. Ge, Effects of improved consumer behavior on energy conservation in the urban residential sector of Hangzhou, China, Journal of Asian Architecture and Building Engineering 8(1) (2009) 243-249.

[37] K. Hubacek, K. Feng, B. Chen, Changing lifestyles towards a low carbon economy: an IPAT analysis for China, Energies 5 (2012) 22-31.

[38] H.J. Kang, E.K. Rhee, A development of energy load prediction equation for multi-residential buildings in Korea, Journal of Asian Architecture and Building Engineering 11(2) (2012) 383-389.

by using Orthogonal Array to carry out simulation and investigated the relative importance of each energy factor with ANOVA. *Yoo et al.* [39] identified the changes in occupants' lifestyles using national statistics survey data, and then estimations were made by connecting each occupant activities to the corresponding residential appliances.

In the Western societies, numerous researches about residential energy use and family lifestyle were also reviewed in this paper. *Wood et al.* [40] emphasized the importance of time-series electricity use analysis of each residential appliance in a particular house, in order to reflect the occupant's characteristics and how those characteristics impact electricity use in the UK. *Diamond et al.* [41] characterized the physical environment and identified the forces that would be influential in making implications for the future energy use in US buildings. *Brounen et al.*[42] analyzed the extent to which the use of gas and electricity is determined by technical specification of dwelling as compared to demographic characteristics of the resident in Dutch homes, revealed that the gas consumption is determined principally by structural characteristics, while electricity consumption varies more directly with household composition, income, and family structure. *Haas et al.* [43] investigated the impact of the thermal quality of buildings, consumer behavior, heating degree days, building type (single or multi-family dwellings) on residential energy demand for spaces heating have been investigated in Austria. *Linde´n et al.* [44] based on a survey of 600 Swedish households, revealed those behavioral patterns that are efficient and those that need to be improved for energy conservation, after that several policy instruments for change were identified in the study and they include combinations of information, economic measures, and administrative measures and more user friendly technology as well as

[39] J. H. Yoo, K. H. Kim, Development of methodology for estimating electricity use in residential sectors using national statistics survey data from South Korea, Energy and Buildings 75 (2014) 402–409.

[40] G. Wood, M. Newborough, Dynamic energy-consumption indicators for domestic appliances: environment, behavior and design, Energy and Buildings 35(8) (2003) 821–841.

[41] R. Diamond, A lifestyle-based scenario for US buildings: implications for energy use, Energy Policy 31 (2003) 1205–1211.

[42] D. Brounen, N. Kok, J. M. Quigley, Residential energy use and conservation: Economics and demographics, European Economic Review 56(2012)931–945.

[43] R. Haas, H. Auer, P. Biermayr, The impact of consumer behavior on residential energy demand for space heating, Energy and Buildings 27 (1998) 195-205.

[44] A.L. Linden, A.C. Kanyama, B. Eriksson, Efficient and inefficient aspects of residential energy behavior: What are the policy instruments for change? Energy Policy 34 (2006) 1918–1927.

equipment with sufficient esthetic quality. *Olexsak et al.* [45] compiled 274 measurements of observed changes in electricity demand caused by Earth Hour events in 10 countries, the events reduced electricity consumption by 4% on average, with a range of +2%(New Zealand) to −28% (Canada). *Leighty et al.* [46] investigated the changes in behavior and technology induced by a transient crisis which can permanently lower electricity use in Juneau, Alaska by 25% and concluded persistent electricity savings appear to be the result of reduced thermostat settings, continued CFL bulb use, keeping fewer lights on, unplugging appliances when not in use, use of power-saving settings on appliances, and showering behavior (both shorter duration and fewer).

On the other hand, a review of literature of the concept on measuring residential satisfaction has been used in numbers of disciplines such as economics, social, physiological, and engineering. *Amerigo et al.* [47] presented a theoretical and psychological approach to the study of residential satisfaction and gave a general view of relationships between people and their residential environment. *Day et al.* [48] through sequential mixed methods, conducted study to better understand the relationships between occupant behaviors, reported environmental satisfaction, and learning in high performance buildings. Survey was sent to ten high-performance buildings in the United States. It was hypothesized that participants who had received effective training for high-performance building features would be more satisfied with their environment than those who had not received training. *Tu et al.* [49] identified the internal evaluative structure with which Taipei City's residents assess the quality of their residential environment in high-density and mixed-use settings. Data from questionnaire then analyzed through Principal Component Analysis, to extract the

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[45] S. J. Olexsak, A. Meier, The electricity impacts of Earth Hour: An international comparative, Energy Research & Social Science 2 (2014) 159–182.

[46] W. Leighty, A. Meier, Accelerated electricity conservation in Juneau, Alaska: A study of household activities that reduced demand 25%, Energy Policy 39(2011)2299–2309.

[47] Amerigo M. Psychological approach to the study of residential satisfaction. J. Environ. Psycol. 2002; 17:47–57.

[48] Day JK, Gunderson DE. Understanding high performance buildings: The link between occupant knowledge of passive design systems, corresponding behaviors, occupant comfort and environmental satisfaction. Building and Environment 2014; 84:114–124.

[49] Tu K, Lin L. Evaluative structure of perceived residential environment quality in high-density and mixed-use urban settings: An exploratory study on Taipei City. Landscape and Urban Planning 2008; 87: 157–171.

major scales and factors of residents' evaluative structure.

Residential satisfaction and its correlation with neighborhood conditions is one of the most studied topics in the field of residential environment. *Smith et al.* [50] investigated the physical elements that contribute to the quality of the community and establish a framework for understanding the relationship between quality of the urban environment and its physical form or design. *Moore* [51] has proposed four-level of theoretical construction in organizing and integrating studies of the residential environment, which are conceptual orientations, frameworks, models, and theories. *Turkoglu* [52] were measuring the perceived quality of residential environments in Istanbul which facing with housing shortages issue. Six factors were studied: (i) size and physical conditions of the dwelling, (ii) accessibility to the city center, workplace, hospital, shopping and municipal services, (iii) availability and maintenance of social, recreational and educational services, (iv) social and physical environmental problems, (v) climatic control of the dwelling, and (vi) satisfaction with neighbors. *Bonaiuto et al.* [53] also identified clusters of residents who use the city in different ways and who differ in their perceptions and evaluations of neighborhood attributes. *Lee* [54] conducted a field survey of 331 Taipei residents to survey subjective resident assessments of Quality of Life (QOL) and analyzed the data through Linear Structural Relationship (LISREL) analysis to explore the causal relationships among the QOL variables. Results of this study demonstrate that district, marriage, age, education, and income influence various satisfaction domains. The model results show that the main influences on satisfaction are community status and local attachments, followed by neighborhood satisfaction. *Lovejoy et al.* [55] examined characteristics associated with higher levels of

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50 Smith T, Nelischer M, Perkins N. Quality of urban community: framework for understanding the relationship between quality and physical form. Landscape and Urban Planning 1997; 39:229–241.

51 Moore GT. Toward environment-behavior theories of middle range. In: Advances in environment, behavior, and design. Plenum Press, New York 1997; p. 1–40.

52 Turkoglu HD. Residents' satisfaction of housing environments: the case of Istanbul, Turkey. Landscape and Urban Planning 1997; 39:55–67.

53 Bonaito M, Bones M. Residential satisfaction in the urban environment within the UNESCO-MAB Rome Project. In: Residential Environment: Choice, Satisfaction, and Behavior. Bergin &Garvey, Westport, Connecticut, London 2002; pp. 101-134.

54 Lee YJ. Subjective quality of life measurement in Taipei. Building and Environment 2008; 43: 1205–1215.

55 Lovejoy K, Handy S, Mokhtarian P. Neighborhood satisfaction in suburban versus traditional environments: An evaluation of contributing characteristics in eight California neighborhoods. Landscape and Urban Planning 2010; 97: 37–48.

neighborhood satisfaction among residents of traditional versus suburban neighborhoods, using an ordered logic model in eight California neighborhoods, found that neighborhood satisfaction is higher among the traditional neighborhood residents, even after controlling for socio-demographics and other characteristics.

Various researchers were also found the significant influences of people's satisfaction of indoor and building physical characteristics to the comprehensive living environment satisfaction. *Ibem et al.*[56] assessed the performance of residential buildings in public housing estates in urban areas of Ogun State Southwest Nigeria, based on 452 households. Results indicated the respondents were generally satisfied with the performance of the different components of the buildings. Satisfaction levels were generally higher with privacy and sizes of living and sleeping areas than the availability of water and electricity in the buildings. The type, location, and aesthetic appearance, as well as size of main activity areas were the most predominant factors that determined satisfaction and indeed the performance of the buildings in meeting users' needs and expectations. *Kim et al.* [57] proposed the development and application of housing performances evaluation model for multi-residential buildings in Korea, forty-one objectives, and feasible housing performance indicators are classified into a series of categories and analyzed by analytical hierarchy process. They also suggested the evaluation program based on statutory performance value or the one frequently met in practice. *Lee et al.* [58] conducted comparative study based on questionnaire in Dongtan District, Korea, for comprehensive satisfaction level of green apartment residents, suggest improvements and further direction for the Korean Green Building Certification Criteria (KGBCC) by comparison with resident satisfaction levels, the comparison results of both apartment and the improvement direction of KGBCC were verified. *Zalejska-Jonsson et al.* [59] studied the impact of perceived indoor environment quality on overall satisfaction in Swedish dwellings, showed that general satisfaction

[56] Ibem E, Opoko AP, Adeboye AB. Performance evaluation of residential buildings in public housing estates in Ogun State, Nigeria: Users' satisfaction perspective. Frontiers of Architectural Research 2012; 2: 178–190.

[57] Kim S, Yang I, Yeo M, Kim K. Development of a housing performance evaluation model for multi-family residential buildings in Korea. Building and Environment 2004; 40:1103–1116.

[58] Lee K, Yeom D. Comparative study for satisfaction level of green apartment residents. Building and Environment 2011; 46:1765-1773.

[59] Zalejska-Jonsson A, Wilhelmsson M. Impact of perceived indoor environment quality on overall satisfaction in Swedish dwellings. Building and Environment 2013; 63:134–144.

with air quality has the highest impact on occupants' overall satisfaction includes of outdoor environment qualities. The occurrence of problems with indoor environment quality, particularly draught, dust and too low indoor temperature may affect occupants' overall satisfaction.

Environment satisfaction is also used to evaluate the living condition post occupancy and natural disasters such as earthquakes and floods. *Liu* [60] presented a study of the physical and social factors, which influence residential satisfaction of residential area in Hong Kong. They made a comparison of the perceived factors of dissatisfaction amongst the public and private housing occupants, suggested a wider systematic coverage of the subject through investigative and diagnostic Post-Occupancy Evaluation (POE) in Hong Kong. *Tas et al.*[61] presented qualitative evaluation on permanent housings in Turkey in terms of user satisfaction after the earthquake disaster in 1999. A Geographical Information System (GIS)-based method proposed by *Etzion et al.*[62], which simplifies recording and analysis of post-occupancy changes in residential buildings in Israel with the intention of (i) highlighting modifications related to the climatic performance of buildings and (ii) developing a set of recommendations aimed at improving the design of new residential buildings. In this study, post-occupancy changes were made primarily in ground-level apartments and in outdoor private spaces. *Joseph et al.* [63] conducted study on GIS-based assessment of Urban Environmental Quality (UEQ) in Haiti, results showed that the UEQ is affected by several built-environment factors that are unique to the experience of local residents such as proximity to water body (including coastal) pollution, open market, cemetery and slum. The study area is also prone to many natural disasters such as flooding, landslide and coastal surge.

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60 Liu AMM. Residential satisfaction in housing estates: a Hong Kong perspective. Automation in Construction 1999; 8:511–524.

61 Tas N, Cosgun N, Tas M. A qualitative evaluation of the after earthquake permanent housings in Turkey in terms of user satisfaction: Kocaeli, Gundogdu Permanent Housing model. Building and Environment 2007; 42: 3418–3431.

62 Etzion Y, Portnov BA, Erell E, Meir I, Pearlmutter D. An open GIS framework for recording and analyzing post-occupancy changes in residential buildings: a climate-related case study. Building and Environment 2000; 36: 1075–1090.

63 Joseph M, Wang F, Wang L. GIS-based assessment of urban environmental quality in Port-au-Prince, Haiti. Habitat International 2014; 41: 33–40.

In Japanese society, there are also various researchers in the field of environment satisfaction based on questionnaire surveys. *Morita et al.* [64] developed environmental indices according to the urban resident's evaluation based on qualitative questionnaire and quantitative data of different aspects of the environment in some areas of local city in Japan. *Savasdisara* [65] conducted a study to identify the physical and socio-environmental components of a neighborhood that affect resident's satisfaction to more than 329 randomly selected occupants in Tokyo in 1986. Findings the influential factors included noise and ground vibration caused by traffic, amount of sunlight and duration of sunshine inside dwelling units, roads and roadside walkways, open space, car and bicycle parking, ground drainage and sewage systems. *Ge et al.* [66] used questionnaire survey of two Japanese cities to evaluate the satisfaction and classified various pattern of residential preferences. They then analyzed the characteristics of residential preferential patterns, residential choice factors and residential satisfaction, also its interrelationships.

64 Morita T, Noda K, Horiuchi Y. A computation of environment indices according to evaluation by residents: for environmental management in Kitakyushu City. City Planning Review, Annual Conference of the City Planning Institute of Japan 1985; 20: 133–147.

65 Savasdisara T. Residents' satisfaction and neighborhood characteristics in Japanese urban communities. Landscape and Urban Planning 1988; 15: 201–210.

66 Ge J, Hokao K. Research on residential lifestyle in Japanese cities from viewpoints of residential preferences, residential choice and residential satisfaction. Landscape and Urban Planning 2006; 78(3):165–178.

1-4 Research novelty

Several studies have obtained the major influential factors on household's energy use and proposed some strategies to change the behavior of occupants, but the sample mostly were randomly taken, especially in terms of household's types and only a few discuss about the people lifestyles. Before this study, we conducted rudimentary surveys in other Asian big cities such as Shanghai (China) and Jakarta (Indonesia) to more than a thousand respondents in order to grasp the house energy situation in developing countries. In this paper, we selected a local city of Kitakyushu in Japan (Kitakyushu City was chosen by the national government as a model for developing environment based community) and targeted the younger nuclear families aging between 20's to 40's (married couples with children, or single parent with children) as representative for future energy demand. The large number of feedback and unique database are new contribution to this research field, since it is very difficult for researcher to conduct such kinds of questionnaire surveys in Japan due to privacy issues and strict rule of local government. This study also adds a new method on grouping the households based on daily behavior and physical attributes by analyzing the similarities and dissimilarities. Furthermore, we also contribute to the discussion on energy use pattern by types of houses and energy sources. Also, despite an increasing number of studies and many researchers have been performed to evaluate residential environment, and some evaluation models and index systems have been presented on the evaluation of residential areas, only a few have paid attention to the identification of the components that influence the degree of residential satisfaction and the literature on residential lifestyles is not rich, especially in Asian societies.

第二章

住宅ライフスタイルの理論と研究方法

Chapter two: Theory and Research Method of Residential Lifestyle and Energy

2-1 Background

2-2 Questionnaire survey

2-3 Field measurement and experiment

2-4 Building energy simulation

2-5 Geographical Information System application

2-6 Summary

2-1 Background

With the diversification of personal senses of value as well as the abundance of lifestyles, people's preferences, demands, and perceptions of their housing and living environment are also becoming more and more diversified so it is hard to grasp. The residential environment quality and comfort are main factors for quality of life, as well as the main support for the economic activities, culture and society. On the other hand, world population is estimated at 6.9 billion as of 2010, with an annual growth rate of about 1.1%, adding about 77 million per year. Long-range population projections suggest that the world's population could ultimately stabilize at about 9 billion people. While all regions of the world show declining fertility, almost all the projected growth will take place in developing countries. The major population challenge is to meet the human needs of 2.1 billion more people, house and employ 4 billion new urban residents, while limiting the environmentally damaging impacts of such growth and urbanization. At the same time, the continued global fertility decline leads to an increasing ageing of the population. A growing population need is to care for ageing populations in industrialized and newly industrializing countries and to absorb the migrants those societies will require [1]. Human sustainability interfaces with economics through the voluntary trade consequences of economic activity. Moving towards sustainability is also a social challenge that entails, among other factors, international and national law, urban planning and transport, local and individual lifestyles and ethical consumerism. Thus, ways of living more sustainably is become one solution for many environment problem recent years, but it can take many forms from controlling living conditions (e.g., eco-villages, eco-municipalities and sustainable cities), to reappraising work practices (e.g., using perma-culture, green building, sustainable agriculture), or developing new technologies that reduce the consumption of resources. Considering the positive relationship between residence and lifestyle, this research tried to elucidate the concept of residential lifestyles, especially from the perspective of its interrelation between residential energy use, residential choice, residential preference, and residential satisfaction.

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1 UNESCO. (2002). Universal Declaration on Cultural Diversity issued on International Mother Language Day, February 21, 2002 U.N. Economic and Social Council, Commission on Population and Development. (2009). World Demographic Trends: Report of the Secretary-General. 1-22. New York: United Nations E/CN.9/2009/6.

Universally, "*lifestyle*" or "*a way of life*" typically reflects an individual's attitudes, values or worldview. Therefore, a lifestyle is a means of forging a sense of self and to create cultural symbols that resonate with personal identity. Not all aspects of a lifestyle are voluntary. Surrounding social and technical systems can constrain the lifestyle choices available to the individual and the symbols she/he is able to project to others and the self [2].

The "lifestyle/exposure theory" was developed by *Hindelang, Gottfredson,* and *Garofalo* [3]. Lifestyles are patterned, regular, recurrent, prevalent, or "routine activities". Lifestyles consist of the activities that people engage in on a daily basis, including both obligatory and discretionary activities. *Kennedy and Forde*[4] summarized the lifestyle/exposure model as "lifestyle, encompassing differences in age, sex, marital status, family income, and race, influences daily routines and vulnerability to criminal victimization, resulting in the fact that "Victimization is not evenly distributed randomly across space and time -- there are high-risk locations and high-risk time periods", *Garofalo* [5].

The lines between personal identity and the everyday doings that signal a particular lifestyle become blurred in modern society [6]. For example, "green lifestyle" means holding beliefs and engaging in activities that consume fewer resources and produce less harmful waste (a smaller carbon footprint), and deriving a sense of self from holding these beliefs and engaging in these activities. Some researches argue that, in modernity, the cornerstone of lifestyle construction is consumption behavior, which offers the possibility to create and further individualize the self with different products or services that signal different ways of life [7]. Lifestyle may include views on politics, religion, health, intimacy, and more. All of these aspects play a role in shaping

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2 Spaargaren, G., and B. VanVliet. (2000). 'Lifestyle, Consumption and the Environment: The Ecological Modernisation of Domestic Consumption.' Environmental Politics. 9(1): 50-75.

3 Hindelang, Michael, Gottfredson, Michael & Garofalo, James. (1978). Victims of personal crime: An empirical foundation for a theory of personal victimization. Cambridge, Mass.: Ballinger.

4 Kennedy, Leslie & Forde, David. (1990). "Risky lifestyles and dangerous results: Routine activities and exposure to crime." Sociology and Social Research: An International Journal 74(4), 208-211.

5 Garofalo, James. (1987). Reassessing the lifestyle model of criminal victimization. In Michael Gottfredson & Travis Hirschi (Eds.), Positive criminology. Newbury Park, Calif.: Sage.

6 Giddens, A. (1991). Modernity and self-identity: self and society in the late modern age. Cambridge: Polity Press.

7 Ropke, I. (1999). 'The Dynamics of Willingness to Consume. Ecological Economics. 28: 399-420.

someone's lifestyle and its physical context of housing and landscape.

How people act in their physical living environment, and how much it has an impact to their environment condition are the focus of this study. Environmental behavior is an interdisciplinary field. It focuses on the interplay between humans and their surroundings. The field defines the term environment broadly, encompassing natural environments, social settings, built environments, learning environments and informational environments. Since its conception, the field has been committed to the development of a discipline that is both value oriented and problem oriented, prioritizing research aiming at solving complex environmental problems in the pursuit of individual well-being within a larger society [8]. The environmental behavior explores such dissimilar issues as place-attachment and place-identity [9], common property resource management, way-finding in complex settings [10], the effect of environmental stress on human performance, the characteristics of restorative environments [11], human information processing, and the promotion of durable conservation behavior. This multidisciplinary paradigm has been the catalyst in attracting other schools of knowledge in its pursuit as well aside from research. Recent years, the designers (urban planners, architects and interior designers), as well as geographers, economists, policy-makers, sociologists, anthropologists, educators, and product developers all have discovered and now participate in this research field.

Although environmental behavior is arguably the best-known and most comprehensive description of the field, it is also known as human factors science, cognitive ergonomics, environmental social sciences, architectural psychology, socio-architecture, ecological psychology, eco-psychology, behavioral geography, environment-behavior studies, person-environment studies, environmental sociology, social ecology, and environmental design research.

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[8] Ittelson, W. H., Proshansky, H., Rivlin, L., & Winkel, G. (1974). An Introduction to Environmental Psychology. New York: Holt, Rinehart and Winston.

[9] Proshansky, H. M. (1987). "The field of environmental psychology: securing its future." In D. Stokols and I. Altman. 'Handbook of environmental psychology. New York: John Wiley & Sons. pp. 1467–1488. ISBN 0-471-63017-9.

[10] Passini, R. (1992) Wayfinding in Architecture, Van Nostran Reinhold.

[11] Hartig, T. (2007) three steps to understanding restorative environments as health resources. In C. Ward Thompson & P. Travlou (Eds.), Open space: People space (pp. 163-179).

The term ‘quality of life’ is used to evaluate the general well-being of individuals and societies. The term is used in a wide range of contexts, including the fields of international development, healthcare, and politics. Quality of life should not be confused with the concept of standard of living, which is based primarily on income or financial level. Instead, standard indicators of the quality of life include not only wealth and employment, but also the built environment, physical and mental health, education, recreation and leisure time, and social belonging [12]. An individual well-being is defined as sufficiency in all aspects of his/her life satisfactory human relationship, meaningful occupation, opportunities for contact with natural and man-made environments, social networks, creative expression, and making a positive contribution to society (WHO, 1946). Researchers have begun in recent times to distinguish two aspects of personal well-being: Emotional well-being, in which respondents are asked about the quality of their everyday emotional experiences— the frequency and intensity of their experiences of, for example, joy, stress, sadness, anger, and affection— and life evaluation, in which respondents are asked to think about their life in general and evaluate it against a scale [13]. Organizations such as the World Bank (2006), for example, declare a goal of "working for a world free of poverty", with poverty defined as a lack of basic human needs, such as food, water, shelter, and freedom, access to education, healthcare, or employment. In other words, poverty is defined as a low quality of life. Using this definition, the World Bank works towards improving quality of life through neoliberal means, with the stated goal of lowering poverty and helping people afford a better quality of life.

In order to reach a better quality of life, sometimes, direct or indirectly people have to sacrifice the nature. Urbanization, deforestation, city economic growth, GDP growth, and comfort living, were become hard to control. For that reason, in this study, the first and smallest society, a family, become the main object of the research. We conducted the hearing, questionnaire survey, experimental study, in order to know and understand their behavior. In this section, the method to assess the household lifestyle and behavior in residential housing from many research fields will be reviewed and

[12] Derek, G. et al., ed. (June 2009). "Quality of Life". Dictionary of Human Geography (5th Ed.). Oxford: Wiley-Blackwell. ISBN 978-1-4051-3287-9.

[13] Kahneman, D.; Deaton, A. (2010). "High income improves evaluation of life but not emotional well-being". Proceedings of the National Academy of Sciences 107 (38): 16489–16493.

discussed. This study mainly adopted some theories which have been used in many social sciences research field to find the influential factors in extent to one dependent variable. Meanwhile, the four concepts from WHO of satisfaction regarding the environment quality measurement were also adopted in order to find its correlation with people behavior and energy use in housing. In addition, the conceptual framework and integration between statistical data and Geographical Information System will be discussed in detail.

2-2 Questionnaire Survey

2-2-1 Method and data processing

A survey is a data gathering method that is utilized to collect, analyze and interpret the views of a group of people from a target population. Surveys have been used in various fields of research, such as sociology, marketing research, politics and psychology. The survey methodology is guided by principles of statistics from the moment of creating a sample, or a group of people to represent a population, up to the time of the survey results' analysis and interpretation. From simple polls regarding political beliefs, to opinions regarding a new product versus another, the survey method is proven to be an effective technique to gather necessary information for the advancement of science and technology[14].

Figure 2-1 Questionnaire form distribution

In this study the questionnaire survey was carried out from the beginning of 2012 among more than 4,000 households targeted the younger families and selected in the high density of local residential areas of some Asian cities. All of the questionnaires in this study targeted young families (aging between 20 to 40 years old of householders) to know what they are thinking about future and give direction to the local government on facing the energy crisis and environmental issues.

In order to obtain representative samples, the sampling method was designed

[14] Sarah Mae Sincero (Jul 10, 2012). Surveys and Questionnaires - Guide. Retrieved Dec 20, 2012 from Explorable.com: https://explorable.com/surveys-and-questionnaires

in three stages. In the first stage, the seven wards/districts in Kitakyushu City were decided then we classified each based on the district characteristics. In the second stage, we selected the most populous residential area of each district to get a high number of respondents. In the third stage, by using GIS (*Geographical Information System*) we selected the nearest elementary school in each selected residential area. Through the elementary school, the questionnaires were distributed randomly from first-grade to sixth-grade students and let the householders fill in the answers.

In addition, internet based survey (*google form*)[15] was also conducted. However, the feedback from internet survey was not as much as the paper sheet questionnaire.

2-2-2 Quantification Theory on analyzing the data base from questionnaire

In 1950s, Dr. Chikio Hayashi, the ex-director of the *Japan National Institute of Statistical Mathematics*, pioneered a new analyzing method called "Quantification Theory", more than 10 years before the *Correspondence Analysis* by a French researcher. (The Correspondence Analysis is theoretically similar to *Hayashi's Quantification Theory Type 3*. Hayashi's Type 1 is the qualitative Multiple Regression analysis. Type 2 is the qualitative Discriminant Analysis. Type 4 is the qualitative Multi Dimensional Scaling). His theory was proposed, in a sense, too early to become popular in psychology or other social sciences. However, the research trend started changing in 1980s in psychology and other social sciences, and the qualitative research once again revived long after the curse of behaviorism. The software for Hayashi's Quantification Theory has been developed: Add-in software for *SPSS* and *Microsoft EXCEL* are available. In Japan, Hayashi's methods of quantification are well known and widely used in various fields, such as social and marketing surveys, psychological research, and medical research, where information is obtained mainly in the form of qualitative categories.

There are four methods of quantification theory, as shown in **Table 2-1.** It is divided into two main classes. One contains the methods for the case where an external criterion is present and is used to predict the external criterion or to analyze the effects of factors. The other contains the methods for the case where no external criterion is

[15] https://apps.google.com/intx/en_sg/products/forms/

present, and is used to construct a spatial configuration so as to grasp the mutual relationships of the data. The "external criterion", which is also called "outside variable", means something to be predicted or explained.

In this study, the qualitative and quantitative variables of summer energy consumption are analyzed based on *Quantification Theory I*. Qualitative variables cannot be analyzed in traditional statistical theories, while by Quantification Theory, qualitative variables can be introduced into models and be analyzed together with quantitative variables [16]. The analysis of influence factors is a very important realm for the application of Quantification Theory. It is mainly used in metric sociology at the very beginning, and then extended to these fields of forestry, mining industry and clinic medicine, and achieved a successful application [17]. In recent years, few researchers begin to apply it for building energy use analysis in Japan, and it gets nice results too [18].

Table 2-1 *Hayashi* based four methods of quantification [19]

Situation	Observation	Method
Case with an external criterion (for prediction or analyzing the effects of factors)	The external criterion is observed quantitatively	First method (to maximize the correlation coefficient)
	The external criterion is observed qualitatively	Second method (to maximize the correlation ratio)
Case with no external criterion (for classification or constructing a spatial configuration)	Response patterns of subjects on some attributes are given	Third method (to maximize the correlation coefficient between subjects and categories)
	Similarities between pairs of subjects are observed quantitatively	Fourth method (to maximize the objective function)

[16] W.Q. Dong, G.Y. Zhou, L.X. Xia, Quantification Theory and its Application, Jilin People's Press, Changchun, 1979.
[17] X.L. Zhang, Study on comprehensive criteria for regional prediction of coal and gas outburst, Journal of China Coal Society 28 (3) (2003) 251–255.
[18] J.C. Xie, Long-term detail measurement of residential energy consumption and the research on energy conservation potential based on the simulation, PhD Thesis, Department of Architecture and Building Science, Tohoku University, 2006.
[19] Tanaka, Y., and Asano, C. A generalized method of optimal scaling for partially ordered categories. Proceedings of the Third Symposium on Computational Statistics, Leiden, the Netherlands, Aug. 21-25, 1978.

The first method of quantification is a method to predict the quantitative external criterion or criterion variable on the basis of the information concerning the qualitative attributes of each subject and to analyze the influence of each attribute to the criterion variable. The data for this method are usually given in the form of **Table 2-2**.

Table 2-2 Data for the first method of quantification (quantification theory type I) [20]

External criterion	Item 1				Item 2				...	Item I			
	1	2	...	c_1	1	2	...	c_2	...	1	2	...	c_I
Y_1	√					√						-	√
Y_2		√			√					√			
.													
.													
.													
Y_n				√				√			√		

Let Y be the quantitative external criterion, and let us suppose that every subject under study can be classified into one and only one of *ci* categories of the *i*-th attribute item for $i = 1, 2, ..., I$. *Dummy* variables are introduced such that:

$$x_\alpha(ij) = \begin{cases} 1, \text{if subject } \alpha \text{ belongs to category } j \text{ of the} \\ \quad i\text{-th attribute item, } i = 1, 2, \ldots, I \\ 0, \text{otherwise,} \end{cases} \qquad (1)$$

for subject a, *a = 1, 2, . . ., n*. In order to analyze the relationships between the external criterion and the qualitative attributes we shall assign a quantity or numerical score su to category j of the *i*-th item, and as a result assign a score.

$$W_\alpha(i) = \sum_{j=1}^{c_i} s_{ij} x_\alpha(ij) \qquad i = 1, 2, \ldots, I \qquad (2)$$

[20] Tanaka, Y., and Asano, C. A generalized method of optimal scaling for partially ordered categories. Proceedings of the Third Symposium on Computational Statistics, Leiden, the Netherlands, Aug. 21-25, 1978.

to attribute i of subject a and a score

$$Y_{(c)\alpha} = W_\alpha(1) + w_\alpha(2) + \ldots + W_\alpha(I) = \sum_{i=1}^{I} \sum_{j=1}^{c(i)} s_{ij} x_\alpha(ij)$$

Where,

$$c_j \equiv c(j) \qquad (3)$$

to subject a. The principle for quantification is to maximize the sample correlation coefficient between {Y} and {Y(C, *i.e.*,

$$\rho^2 = r^2(Y, Y_{(c)}) = \frac{\{\Sigma_\alpha (Y_\alpha - \bar{Y})(Y_{(c)} - \bar{Y}_{(c)}\}^2}{\Sigma_\alpha (Y_\alpha - \bar{Y})^2 \, \Sigma_\alpha (Y_{(c)\alpha} - \bar{Y}_{(c)})^2} \rightarrow \max. \qquad (4)$$

The partial correlation coefficient in Quantification Theory I is used as an important index to weigh contribution extents of independent variables to the dependent variable. The significance test is taken to judge that how large the partial correlation coefficient is, the factor will have effect on residential energy consumption. The bigger the significance probability is, the less the partial correlation coefficient is, the less the factor affects residential energy consumption. In this model, it is assumed that if the significance probability is smaller than 0.05, the factor has effect on energy consumption [21]. The score of each variable is used to weigh the influence of all the categories of qualitative variables and quantitative variables on the dependent variable. The larger the score is, the more the energy is consumed. The qualitative and quantitative independent variables used in this analytic model refer to housing unit characteristics, household characteristics, energy consuming equipment and indoor thermal environment. The summer energy consumption amount of each family sample is taken as the dependent variable. The software of Statistical Program for Social Sciences (SPSS) is used for the model calculation [22].

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[21] Y. Jiang, Current building energy consumption in China and effective energy efficiency measures, HV&AC 35 (5) (2005) 30–40.
[22] X.Y. Liu, C.Y. Yuan, B.F. Duan, The Statistics Software of SPSS10.0 and its Application, National Defense Industry Press, Beijing, 2002.

2-3 Field Measurement and Experiment

In this study, field measurement is conducted in the targeted residential building in **Chapter 6.** Since the current building is to be functioned as exhibition, education, and a tourist purpose, therefore, there is no real family or residences live in the house. The basic home appliances such us rice cooker, washing machine, refrigerator, etc., were attached and installed by the research team in the existing house for about one year. The home appliances selection was based on the questionnaire results which collected to Kitakyushu City households (**Chapter 4**).

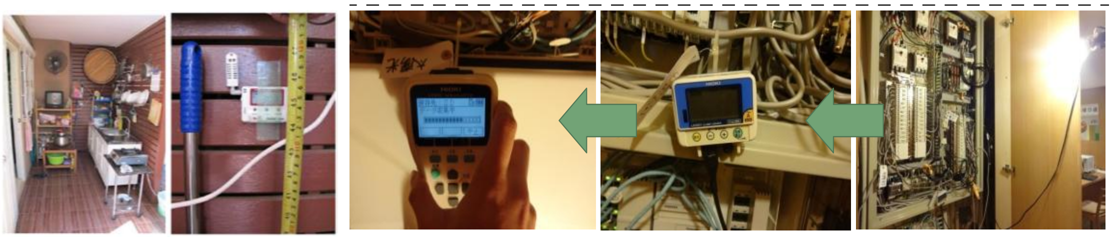

Figure 2-2 Picture during field measurement

Measurement is the assignment of a number to a characteristic of an object or event, which can be compared with other objects or events [23]. The scope and application of a measurement is dependent on the context and discipline. In the natural sciences and engineering, measurements do not apply to nominal properties of objects or events, which is consistent with the guidelines of the International vocabulary of metrology published by the International Bureau of Weights and Measures[24]. However, in other fields such as statistics as well as the social and behavioral sciences, measurements can have multiple levels, which would include nominal, ordinal, interval, and ratio scales [25]. Measurement is a cornerstone of trade, science, technology, and quantitative research in many disciplines. Historically, many measurement systems existed for the varied fields of human existence to facilitate comparisons in these fields. Often these were achieved by local agreements between trading partners or collaborators. Since the 18th century, developments progressed towards unifying,

23 Pedhazur, Elazar J.; Schmelkin, Liora Pedhazur (1991). Measurement, Design, and Analysis: An Integrated Approach (1st ed.). Hillsdale, NJ: Lawrence Erlbaum Associates. pp. 15–29.
24 International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM) (3rd ed.). International Bureau of Weights and Measures. 2008. pp. 16.
25 Kirch, Wilhelm, ed. (2008). "Level of measurement". Encyclopedia of Public Health 2. Springer. p. 81. ISBN 0-321-02106-1.

widely accepted standards that resulted in the modern International System of Units (SI). This system reduces all physical measurements to a mathematical combination of seven base units. The science of measurement is pursued in the field of metrology.

2-4 Building Energy Simulation

The building energy simulation, also called building energy modeling (or energy modeling in context), is used in this study to predict the energy use of targeted residential buildings. A typical energy model will have inputs for climate; envelope; internal gains from lighting, equipment, and occupants; heating, cooling, and ventilation systems; schedules of occupants, equipment, and lighting [26]. Energy models will output building energy use predictions in typical end-use categories: heating, cooling, lighting, fan, plug, process. In addition to energy units, most software includes utility rates input, and can predict energy costs. Energy-savings measures can be calculated using simple spreadsheets and a wide variety of bespoke software applications are available.

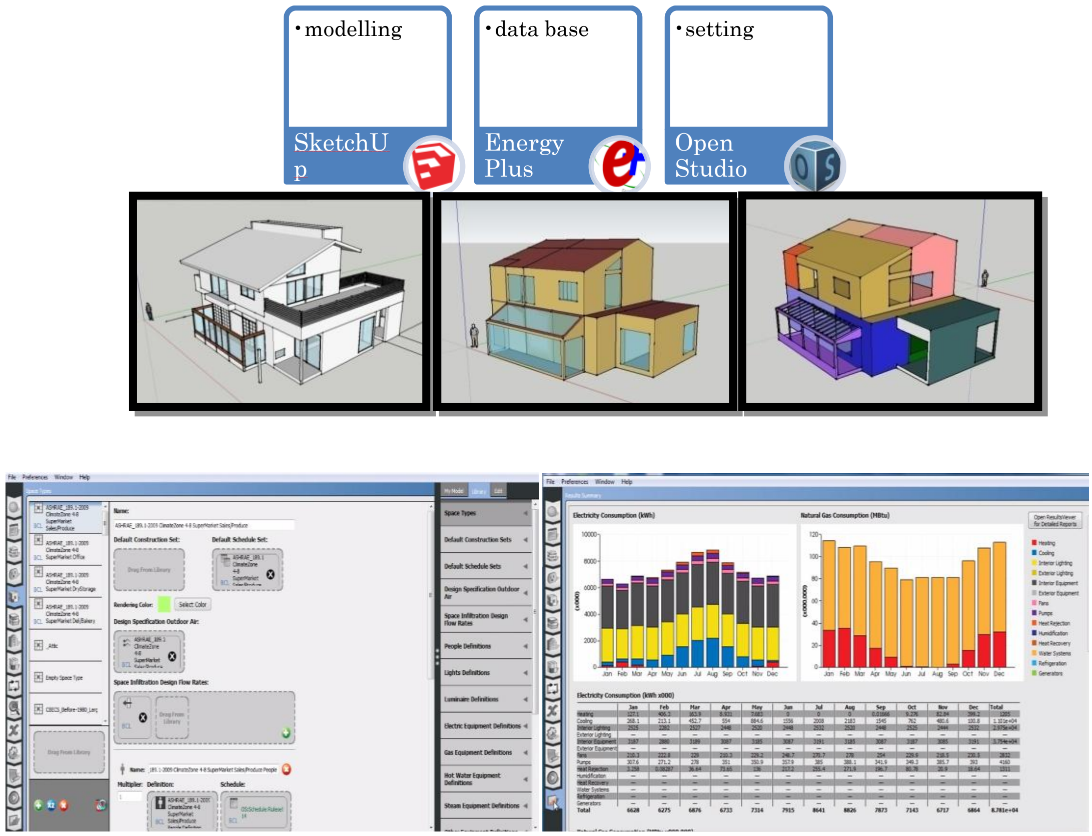

Figure 2-3 Display in sketch-up with energy-plus and open studio software

In this study, the EnergyPlus software was used as the main (engine) software.

[26] Rosenbaum, Marc (2003). "Understanding the Energy Modeling Process: Simulation Literacy 101". http://www.buildinggreen.com/. BuildingGreen.com. Retrieved 2014-06-15.

EnergyPlus is a whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption—for heating, cooling, ventilation, lighting, and plug and process loads—and water use in buildings. Its development is funded by the U.S. Department of Energy Building Technologies Office[27]. Some of the notable features and capabilities of EnergyPlus include: Integrated, simultaneous solution of thermal zone conditions and HVAC system response that does not assume that the HVAC system can meet zone loads and can simulate unconditioned and under-conditioned spaces; Heat balance-based solution of radiant and convective effects that produce surface temperatures, thermal comfort, and condensation calculations; Sub-hourly, user-definable time steps for interaction between thermal zones and the environment, with automatically varied time steps for interactions between thermal zones and HVAC systems. These allow EnergyPlus to model systems with fast dynamics while also trading off simulation speed for precision; Combined heat and mass transfer model that accounts for air movement between zones; Advanced fenestration models including controllable window blinds, electro chromic glazing, and layer-by-layer heat balances that calculate solar energy absorbed by window panes; Illuminance and glare calculations for reporting visual comfort and driving lighting controls; Component-based HVAC that supports both standard and novel system configurations; A large number of built-in HVAC and lighting control strategies and an extensible runtime scripting system for user-defined control; Functional Mockup Interface import and export for co-simulation with other engines; Standard summary and detailed output reports as well as user definable reports with selectable time-resolution from annual to sub-hourly, all with energy source multipliers.

Weather data in a format that can be read by EnergyPlus is available on the EnergyPlus website. EnergyPlus is a console-based program that reads input and writes output to text files. Several comprehensive graphical interfaces for EnergyPlus are also available. DOE does most of its work with EnergyPlus using the OpenStudio software development kit and suite of applications.

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[27] US department of energy. Energy Efficiency and Renewable Energy. http://apps1.eere.energy.gov/buildings/energyplus/

As for the interface software, Open studio [28] and DesignBuilder were used. OpenStudio is a cross-platform collection of software tools to support whole building energy modeling using EnergyPlus and advanced daylight analysis using Radiance. OpenStudio is an open source (LGPL) project to facilitate community development, extension, and private sector adoption. The graphical applications include the OpenStudio SketchUp Plug-in, OpenStudio Application, ResultsViewer and the Parametric Analysis Tool. The OpenStudio SketchUp Plug-in is an extension to Trimble's popular SketchUp 3D modeling tool that allows users to quickly create geometry needed for EnergyPlus. Additionally, The OpenStudio Application is a fully featured graphical interface to OpenStudio models including envelope, loads, schedules, and HVAC. ResultsViewer enables browsing, plotting, and comparing simulation output data, especially time series. The Parametric Analysis Tool enables studying the impact of applying multiple combinations of OpenStudio Measures to a base model as well as export of the analysis results for EDAPT submission. In addition to the graphical interface, OpenStudio allows building researchers and software developers to quickly get started through its multiple entry levels, including access through C++, Ruby, and C#. Users can leverage the Ruby interface to create OpenStudio Measures that can be easily shared and applied to OpenStudio Models.

Just like OpenStudio, DesignBuilder provides advanced modelling tools in an easy-to-use interface. This enables the whole design team to use the same software to develop comfortable and energy-efficient building designs from concept through to completion [29]. Both, OpenStudio or DesignBuilder were used in this study.

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[28] National Laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. https://www.openstudio.net/

[29] DesignBuilder Software Ltd 2005-2015 http://www.designbuilder.co.uk/

2-5 Geographical Information System to analyze the living environment condition

A geographic information system (GIS), or geographical information system, captures, stores, analyzes, manages, and presents data that is linked to location. Technically, GIS is geographic information systems which includes mapping software and its application with remote sensing, land surveying, aerial photography, mathematics, geography, and tools that can be implemented with GIS software. Still, many refer to "geographic information system" as GIS even though it doesn't cover all tools connected to topology [30].

In the other words, the term describes any information system that integrates stores, edits, analyzes, shares, and displays geographic information. In a more generic sense, GIS applications are tools that allow users to create interactive queries (user created searches), analyze spatial information, edit data, maps, and present the results of all these operations. Geographic Information Science is the science underlying the geographic concepts, applications and systems, taught in degree and GIS Certificate programs at many universities.

A geographic information system is a digital computer application designed for the input, storage, manipulation, and output of geographic information; geographic information is defined as information referenced to specific locations on the surface of the Earth [31]. Thus geographic databases represent the variation of phenomena over the Earth's surface. While there are potentially many ways to do this, in practice only a few are supported by the designers of GIS software, who tend to be driven by the needs of their users. Given the context of this paper, three broad classes of GIS representations are identified [32]: 1) Schemes that represent continuous variation over the surface, one parameter at a time; these are termed field models. The best-known example of a field model in GIS is a representation of the elevation of the land surface;

[30] D. Stevens, S. Dragicevic, K. Rothley, 2007. iCity: A GIS-CA modelling tool for urban planning and decision making, Environmental Modelling & Software, 22, 761-773.

[31] Simone Leao, Ian Bishop, David Evans, Resources, 2001. Assessing the demand of solid waste disposal in urban region by urban dynamics modelling in a GIS environment, Conservation and Recycling, 33,289-313.

[32] Lubos, M.,, Pavel, E.,, Zbynek,J., 2006.A GIS-based approach to spatio-temporal analysis of environmental pollution in urban areas: A case study of Prague's environment extended by LIDAR data. Ecological Modelling, 199, 261-277.

other similarly single-valued functions of geographic coordinates include surface temperature, or land ownership. 2) Schemes that represent collections of discrete point, line, or area features, and their associated properties; these are termed discrete entity models. This conceptualization is consistent with a view of the landscape as populated by discrete, potentially overlapping features such as lakes, houses, roads, contours, mountain peaks, or survey benchmarks. 3) Schemes that represent variation over a linear network embedded in the surface; these are termed network models. Such models are commonly used to represent transportation networks, and networks formed by surface hydrologic features. The three schemes are not entirely mutually exclusive. A network (3) can be regarded sometimes as a collection of discrete linear entities (2). A single discrete entity (2) such as an area can be represented through the spatial variation in a binary parameter which has the value of 1 inside the area and zero elsewhere, and collections of such entities can be treated similarly.

In practice, currently available GIS software offers six forms of field models [33]. A field can be represented by storing its average value in each of a regular array of rectangular cells; its value at the center of each of a rectangular array of sample points (both of these options are included in the loose term raster); its value at each of a collection of irregularly spaced sample points; its average value in each of a set of non-overlapping, irregular areas; its value at the corner points of an irregular mesh of triangles; or by storing the locations of iso-lines (these last four are instances of structures loosely termed vector). However, not all GIS offer all six, but all are represented by commonly available data sets [34]. While the field models are dominant in many GIS applications, notably in environmental science, where fields are used to represent the spatial variation of parameters such as topographic elevation, vegetation class, or mean annual temperature, they are clearly of less interest in transportation modeling. Attempts to model urban three systems as fields of continuously varying parameters have been described by Angel and Hyman and many others, but are comparatively obscure. Numerous efforts have been made to model spatial interactions

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[33] Yates, P. and I.D. Bishop. 1998. "The integration of existing gis and modelling systems: with urban applications" Comput., Environ. and Urban Systems, 22(1), 71-80.

[34] Zhang, B., 2008. A study of GIS-SD based temporal-spatial modeling of water quality in water pollution accidents. The international archives of the photogrammetry, Remote Sensing and spatial information sciences, Vol. XXXVII, Part B2. 155-160.

using continuous fields rather than discrete entities, but they have not met widespread acceptance. Network models are clearly important, and many models of urban behavior are based on discrete entities. Thus the emphasis in this paper will be on the latter two schemes: models of discrete entities, and networks.

The choice between alternative representations is driven by many factors. In science, a representation may be chosen because it is more accurate; and generally, greater accuracy is achieved by representations that capture greater detail, and thus occupy more storage space. A representation may also be preferred because it is closer to human conceptualization; for example, people may find it easier to understand a weather forecast expressed in terms of discrete entities (fronts, highs, lows) than continuous pressure fields, despite the fact that the models underlying such forecasts are predominantly field-based. This tension between scientific accuracy and intuitive understanding will be increasingly important in areas such as discrete transportation modeling, where human users must interact directly with scientific models and database structures in a range of environments. This point will be revisited several times in the discussion.

2-6 Summary

In this chapter, the conclusion can be drawn as follows:

1. Questionnaire survey could grasp more information of lifestyle pattern but low in accuracy. Based on this paper, questionnaire survey by paper sheet were still showing high feedback rather than by internet survey. Although, due to different privacy level of each countries, some of the results become hard to compare.
2. Field measurement could collect detailed data of energy use which are needed to perform a validation from questionnaire result. Field measurement conducted in this study has shown and collected real-time data of energy use which then can be used to build a data base. Even so, the object building is house model and not intended to be lived by family which make the number of measurement is not many. However, by building simulation software this small number of measurement can be resolved.
3. Data logging period has become limitations of field measurement. However, by combining with the building simulation software this small number of measurement still can be useful input.
4. GIS (geographical information system) were also combined with statistical data in order to provide map/spatial analysis which easier to understand. The geographical method analysis using GIS were also combined with statistical data in order to find the influential factors on household satisfaction, characterizing and categorizing the urban residential.

第三章

アジアにおけるライフスタイルと住宅エネルギー消費量に関する基礎調査

Chapter three: Fundamental Survey on Lifestyle and Household Energy Use in Asian Countries

3-1 Background

3-2 Survey method

3-3 Investigation on household energy use and environmental behavior in China

3-4 Investigation on household energy use and thermal environment in Thailand

3-5 Investigation on residential lifestyle and household energy use in Indonesia

3-6 Discussion

3-7 Summary

3-1 Background

This study tried to investigate the Asian people's lifestyle in term of household energy consumption. Due to the fast growth of economy, Asia-Pacific region is the world's largest energy consumer. This study focuses to the investigation on residential building characteristics and its people's lifestyle in terms of energy consumption. The research began with collecting data by questionnaires which were sent to some cities of some countries in Asia. In this paper, we conducted the review and comparison of residential housing situation and energy behavior between three different countries, Indonesia, Thailand, and China. These three countries were chosen because of their different characteristics on geographical, cultural, and economical situation. The result of this study will be used to indicate the energy use and develop an idea for energy conservation in Southeast Asian countries, which are predicted its energy use will highly increase near the future. Some basic situations on energy use situation of each country were briefly explained in the following paragraph.

According to the *National Energy Outlook* of Indonesia, in the period 2000-2009 energy consumption in Indonesia increased from 709.1 million SBM (Barrels of Oil Equivalent/BOE) to 865.4 million SBM, or increased by 2.2% per year. Until the end of 2011, the largest sector of final energy consumption is still dominated by industrial and then followed by household sector and transportation sector, each are 37%, 36%, and 21%[1]. Even so, with the national population booming, there is possibility for the household sector will increase significantly. The same situation also happens in Thailand, the industrial sector still consumes most of the energy consumption in Thailand. Industrial sector reach 34%, followed by transportation sector 33%, and household sector 15%, and the actual figure increases every year [2]. Since the fast growth of economy in China, people's living standard has been obviously improved too. Residential energy consumption is the second largest energy use category, reach about 10% in China even there is big difference with the industrial sector and urban

[1] Ministry of energy and mineral resources of republic Indonesia, http://www.esdm.go.id, 2010, Indonesia

[2] National statistical office, the survey of household energy consumption by 2008-2009, Thailand

residents account for 63% of the residential energy consumption [3].

Based on these facts, this study was carried out by the research teams which were based in Japan conducted fundamental research in order to grasp the different living situation and their way of life in Asian societies.

3-2 Survey method

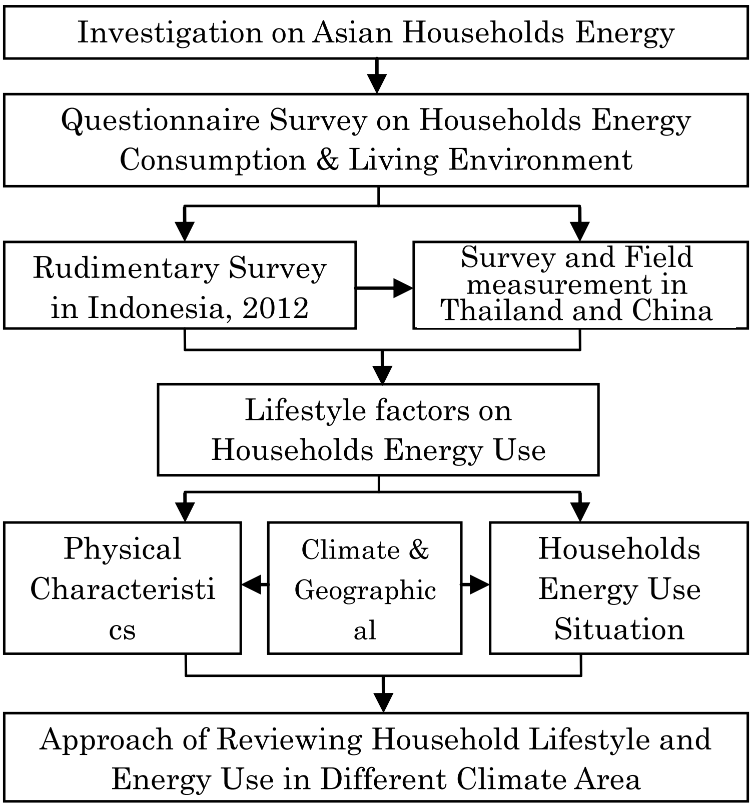

Figure 3-1 Study framework

The research framework can be seen in **Figure 3-1**. The great differences of the climate and architecture characteristics among three countries lead to residential indoor environment and energy usage structures in different countries having their own characteristics. The rudimentary/fundamental surveys were conducted in three big cities of Indonesia, and then in the same year, the survey in residential urban area of

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[3] Y.D.Ni ng, Y. Tonooka, X. Zhao. Analysis on trends of urban housing energy consumption in Shanghai, in: Proceedings of The Fifth International Conference on Building Energy and Environment Dalian, China (2008), pp. 412-419

Thailand and China were conducted.

The surveys were carried out for these three countries from August 2011 to December 2012 among more than 1,000 households in a total (400 households in Indonesia, 300 households in Thailand, and 300 households in China). Questionnaire distribution and collection were done through local cooperative school with their teacher's assistance. Despite of random sample, the targets of respondent were selected based on the family structure. Since the research focusing a study on the household behavior, the nuclear family is become the main target of the questionnaire survey. The questionnaire has seven parts: building characteristics, family income, and outcome, building appliances, family characteristics, lifestyle, interior air quality condition, and effort on energy consumption reduction. The investigated contents are shown in **Table 3-2**.

Table 3-2 Questionnaire survey contents

Item	Content
Building characteristics	Housing area, housing type, housing status, housing structure, housing construction year;
Family income and consumption	Annual income, electricity bill consumption, water bill consumption, gas bill consumption;
Building appliances	Heating and cooling system type, kitchen equipment, entertainment equipment, cleaning & showering equipment, lighting type, transportation type, etc.;
Family characteristics	Number of occupants, work type, family structure, age;
Life style	Heating & cooling period, heating & cooling time, number of staying persons, method on circulating the air, use of appliances, use of electrical lighting;
Interior air quality condition	Sense of thermal comfort, satisfaction of environment, environmental conditioning method;
Effort on energy consumption reduction	Environmental problem, waste management, passive technology usage, etc.

The types of buildings involved in the survey range from low-rise to high-rise building, the monthly energy consumption data of gas & electricity and field measurement data of humidity & temperature in a year were obtained also.

In Indonesia, the survey was conducted from September 2011 to October 2011 among 400 households in the transition time between rainy season and dry season respectively, which were selected in an urban area. Almost of the data were collected from three big cities in Java Island, are Jakarta, Bandung, and Semarang City.

In China, the survey was conducted from September 2011 to December 2011, between summer and autumn, which were selected in Shanghai commuter cities, among more than 300 households.

In Thailand, the survey data was collected from Bangkok City in the same period with Indonesia survey. The participants were about 300 households in urban area.

In response to the issue of increasing energy demand in the housing sector, several studies on residential energy use have been conducted by many researchers in Asian and Western countries. Some literatures studies have obtained the major influential lifestyle factors on household's energy use and proposed some strategies to change the behavior of occupants, but the sample mostly were randomly taken, especially in terms of household's types. In this study, we conducted surveys in Asian big cities: Shanghai (China), Jakarta (Indonesia), and Bangkok (Thailand) to more than a thousand respondents in order to grasp the house energy situation in developing and developed countries. In this paper, we selected some local cities of three countries and targeted the younger nuclear families aging between 20's to 40's (married couples with children, or the single parent with children) as a representative for future energy demand. The large number of feedback and unique database are a new contribution to this research field since it is very difficult for a researcher to conduct such kinds of questionnaire surveys in different countries due to some privacy issues and strict rule of local government.

Table 3-3 shows the total GDP and GDP per capita of some countries in Asia. As the total GDP, China lead the Northeast Asia statistic and Indonesia in the top position of Southeast Asia. Even China and Indonesia not in the highest list on GDP per capita, based on the population and economic growth of those countries, it is predicted that in the future GDP per capita will increase rapidly compared to development countries (Japan, South Korea, etc.).

Table 3-3 GDP (PPP) of some Asian countries (World Bank)

Country	GDP (2012)	Per capita (2012)
China	$12,164.940	$12,880
Japan	$4,507.970	$37,390
South Korea	$1,616.790	$35,277
Indonesia	$1,208.542	$10,651
Thailand	$643.266	$14,354
Malaysia	$491.967	$24,654

3-3 Investigation on household energy use and environmental behavior in China

3-3-1 Area of study

The questionnaire survey about living environment condition and household energy use in China was conducted in sub-urban of Haining City. Haining City is belonging to Zhejiang Province of China (third biggest province of China). It is 125 kilometers west of Shanghai, and 61.5 kilometers east of Hangzhou, the capital of the province. Based on local government data (2010 census), Haining is the small city with area of 700.5 km^2 and lived by 806,966 population but physically the house unit was more than the family's population and it was hard to grasp due to limited information. Meanwhile, Haining City has developed as a city well known for its industrial area and factories. The environmental problem such as factory waste pollution has been a serious problem in 2011[4].Haining's climate is similar with Hangzhou City humid subtropical (*Köppen Cfa*) with four distinctive seasons, characterized by long, very hot, humid summers and chilly, cloudy and drier winters (with occasional snow). The mean annual temperature is 17.0 °C (62.6 °F), with monthly daily averages ranging from 4.6 °C

[4] "Protest over factory pollution in E China enters third day". China Daily. Xinhua. 18 September 2011. Retrieved 19 September 2011. Hangzhou - Hundreds of villagers in East China's Zhejiang; Province protested for the third day on Saturday at a solar panel manufacturer, whose parent is a New York-listed firm, over concerns of its harmful wastes.

(40.3 °F) in January to 28.9 °C (84.0 °F) in July. The city receives an average annual rainfall of 1,438.0 mm (56.6 in) and is affected by the plum rains of the Asian monsoon in June. In late summer (August to September), Hangzhou suffers typhoon storms, but typhoons seldom strike it directly. Generally they make landfall along the southern coast of Zhejiang, and affect the area with strong winds and stormy rains. Extremes since 1951 have ranged from −9.6 °C (15 °F) on 6 February 1969 (unofficial record of −10.5 °C (13 °F) was set on 29 December 1912 and 24 January 1916) to 41.6 °C (107 °F) on 9 August 2013 (unofficial record of 42.1 °C (108 °F) was set on 10 August 1930). With monthly percent possible sunshine ranging from 30% in March to 51% in August, the city receives 1,709.4 hours of sunshine annually [5].

Figure 3-2 shows the area which the survey was conducted. From total distributed questionnaire to 800 households, data from 300 households were collected. The less answer of total number question made the number of valid feedback from the respondents is low. On the other hand, **Table 3-4** shows the basic information of distributed questionnaire feedback.

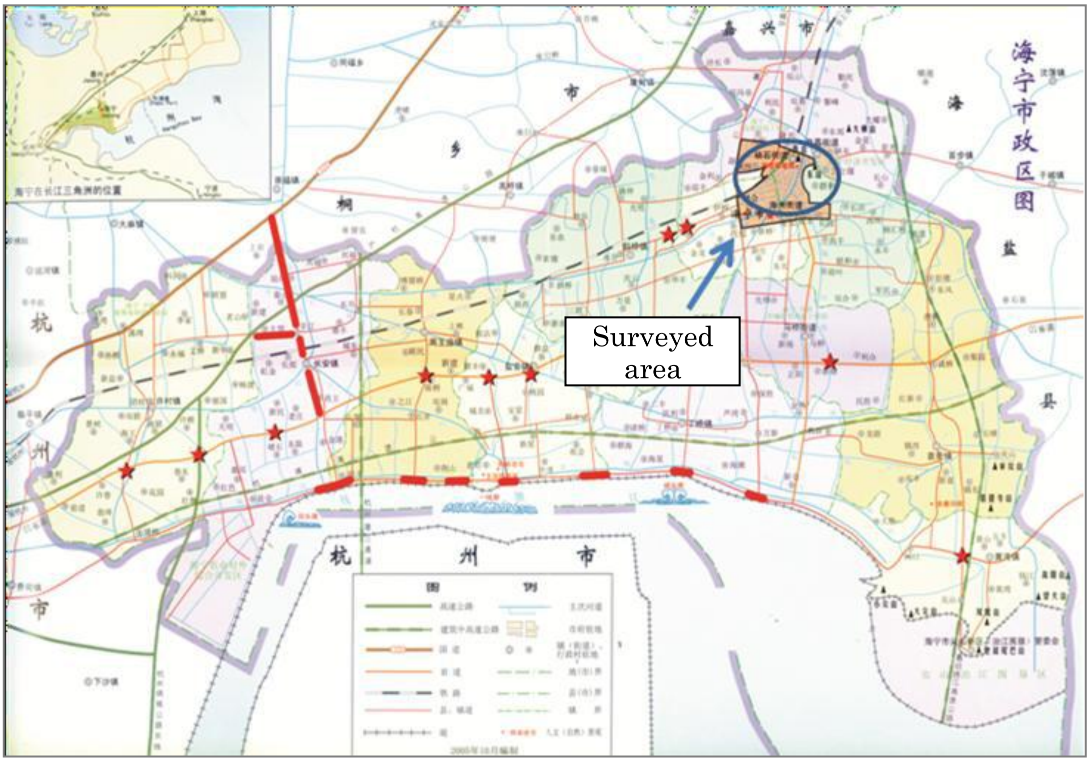


Figure 3-2 Surveyed Area of Haining City

5 "Extreme Temperatures Around the World". http://www.mherrera.org/temp.htm. Retrieved 2013-02-21.

Table 3-4 Questionnaire Survey Basic Information

Total participants	Number of respondents	Valid feedback	Survey period
800 households	360 households	300 households	2011 9/6～9/16
100%	45%		

3-3-2 Questionnaire Outline

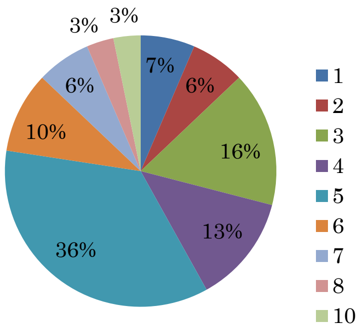
The questionnaire was not given to householders directly but the research team was divided into 6 different areas then the teams which consist of students from China and Japan Universities did the onsite interview to collect the data from the respondents. In the end of the day the feedback sheets were gathered and confirmed with some geographical data.

Table 3-5 Questionnaire survey contents in China

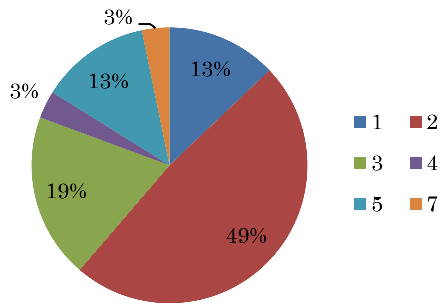
Categories	Contents
Family Characteristics	Family member, family structure, age, gender
	Person stay at home, residence year
	Yearly income, occupation,
Housing Characteristics	Built year, house status, building orientation
	Floor area, floor number, land area
	Main structure, envelope, construction cost,
	Wall, windows, and doors material,
Housing Appliances and Equipments	Heating-cooling system, hot water supply
	Electronic appliances ownership
Lifestyle Characteristics	Heating and cooling method,
	Sleep time, cook time, bath time, daily activity,
	Energy saving efforts,
Energy Consumption Characteristics	Electricity, gas, and water consumption
	Fuel type and consumption cost
Living Environment Satisfaction	Satisfaction on Amenity and its factors,
	Satisfaction on Safety and it factors,
	Satisfaction on Health and its factors,
	Satisfaction on Convenience and its factors

In detail, the questionnaire sheets divided into six categories, which are the question about the family, housing, appliances, lifestyle (in terms of energy use in house), energy consumption, and living environment satisfaction. The last category purposes to evaluate the satisfaction level of householders living in the village. The classification of *Amenity, Safety, Health,* and *Convenience* are referring to the WHO [6]. Each category explained in **Table 3-5**.

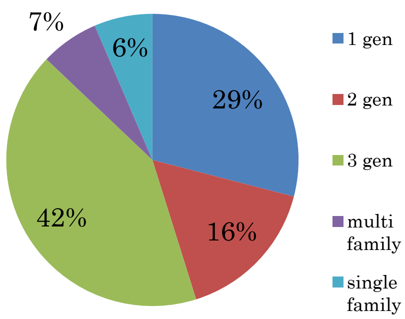
3-3-3 Questionnaire Results



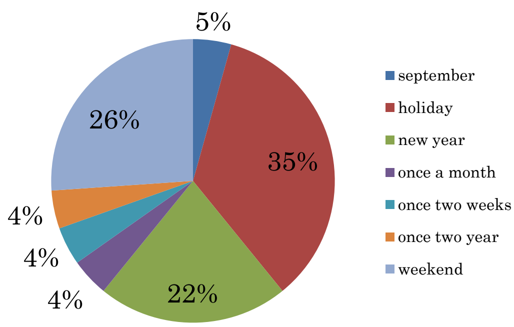
(a) Family size



(b) Family member stay



(c) Family structure



(d) Periodically family member

Figure 3-6 (a-d) Family characteristics

Figure 3-6 show the family characteristics result from questionnaires. Mostly the family's members are five persons which is 36% from total respondents. While 16% is three persons and 13% is 4 persons. By the average the family member are 4.58 persons per family and more than half of the respondents (58%) are families with member more than four persons. In the modern society, some of family members,

[6] Bonaito M, Bones M. Residential satisfaction in the urban environment within the UNESCO-MAB Rome Project. In: Residential Environment: Choice, Satisfaction, and Behavior. Bergin &Garvey, Westport, Connecticut, London 2002; pp. 101-134.

especially the younger prefer to live closely to the working place in urban area. More than half (52%) of the total surveyed houses only lived by not more than two people. **Figure 3-6 (d)** shows the comeback time period of family member which stayed in central urban area. Mostly, about 35% were back to the village in public holiday and 22% were back in Chinese New Year which is one times a year. There are 26% were back every weekend to the village.

Three generation of family were dominating the family structure about 42% from the whole respondents, followed by 1 generation and 2 generation of family which are 29% and 16% respectively. Even so there is significant number of single family (means only 1 person stay in the house) which is 6% from the total respondents. The detailed composition of each family structure can be seen in **Figure 3-6 (e)** below.

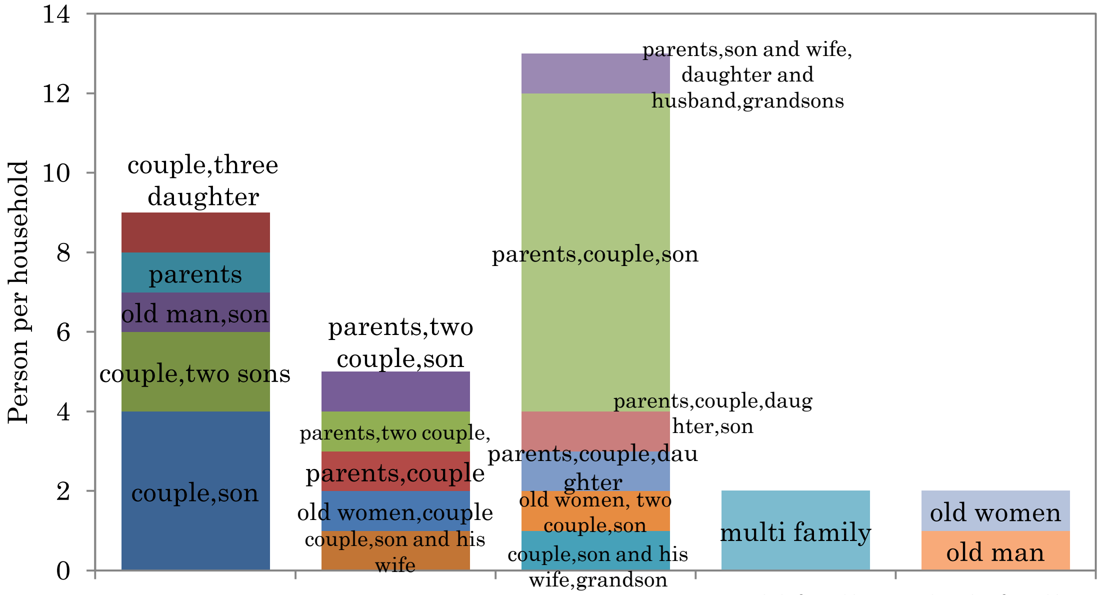
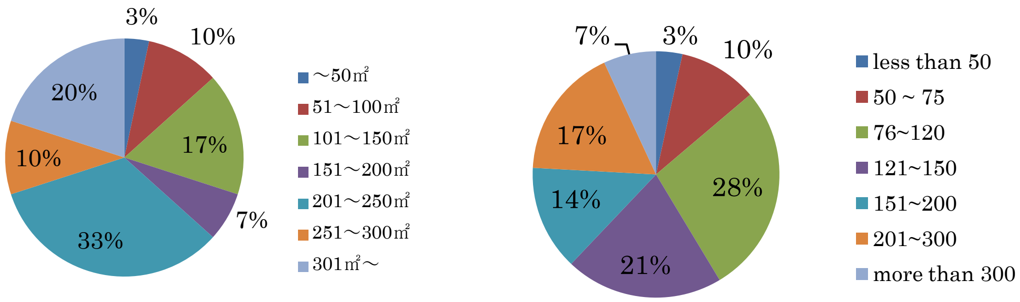


Figure 3-6 (e) Family composition

**generation*



(f) Floor area (g) Land size

Figure 3-6 (f-g) House characteristics

Figure 3-6 (f and g) shows the floor area of residential house and total land size respectively. The floor area were varies from less than 50m^2 until bigger than 300m^2. There is only 3% households have floor area less than 50m^2, while 33% of households were between 201m2 to 250m^2 and about 20% were living in more than 300m^2. In terms of land area, about 28% of total surveyed houses stand in 76 to 120 m^2 of land size, followed by 21% in 121 to 150m^2 and even quite high percentage of houses stand in more than 150m^2 of land size. Only 16% from the whole surveyed houses were built 1 floor houses, while 77% were consisted of 2 floors which is the highest percentage. And there is significant percentage of houses which consisted of three floors and more.

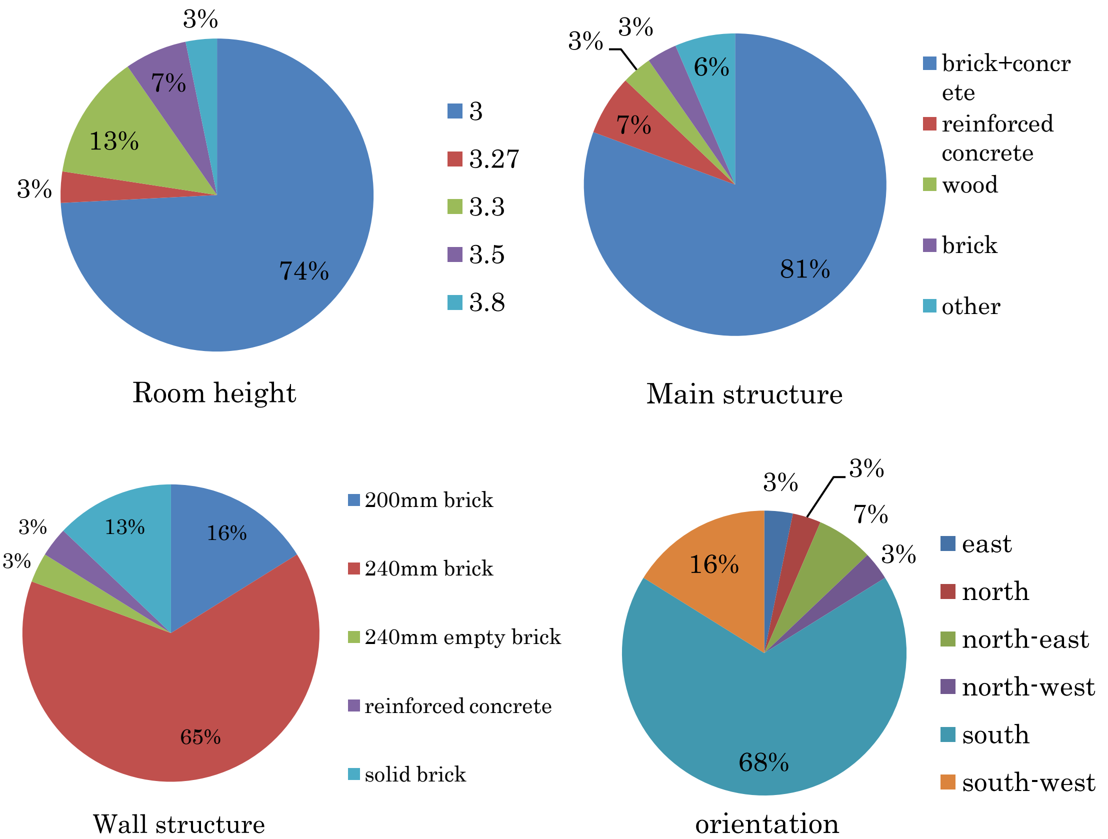


Figure 3-6 (h-k) House characteristics

Figure 3-6 (h-k) show the residential housing characteristics. The room height were also questioned to the householders, from the results, almost 100% of the houses which surveyed have at least 3 meters height of spaces. 74% houses were 3 meters height, 3% houses were 3.27 meters, 13% were 3.3 meters, 7% were 3.5 meters and 3% were 3.8 meters height. Main structure of the housing was also being attention in this survey, in order to understand how the local characteristics contributed the building structure and material. As the results, 81% of total surveyed houses were mainly constructed with combination of brick and concrete, while 7% used the reinforced concrete and only 3% used wood to build their houses.

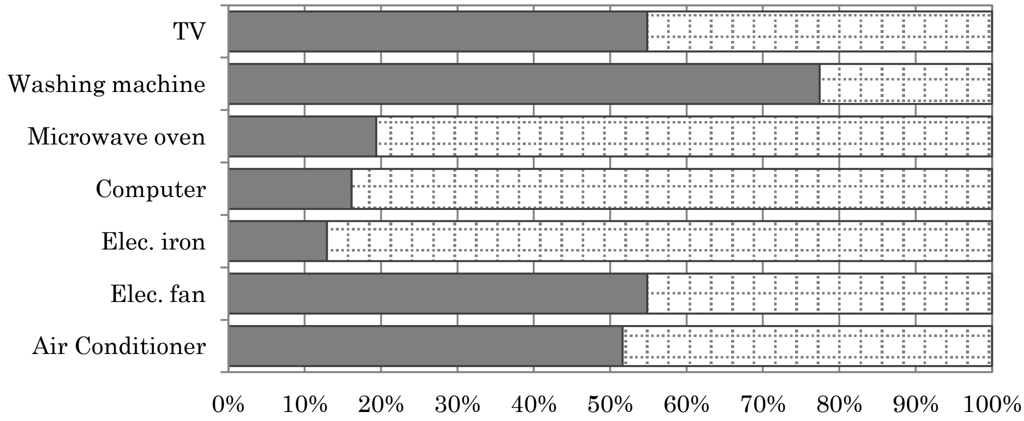
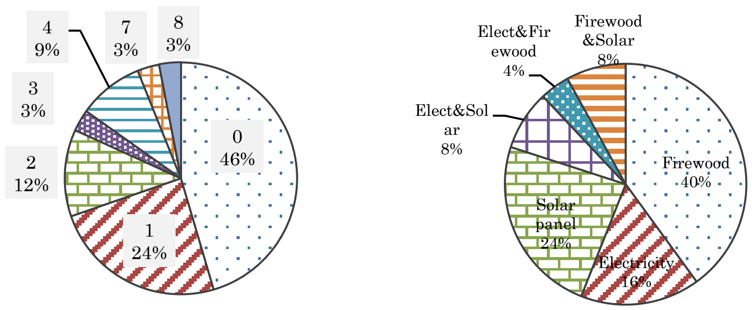


Figure 3-6 (j) Electronic appliance ownership



(k) AC ownership (unit) (l) Water heating method

Figure 3-6 (k-l) Air-conditioning and hot water system

The possession of household appliances is shown in **Figure 3-6 (j)**. While **Figure 3-6 (k)** shows the electric Air-conditioner (AC) ownership number. The percentage of AC ownership is more than half of households are using electric AC but the most popular appliances were a washing machine, it is 77% of ownership. Commonly, the people in suburban did not use washing machine are doing the laundry in manually by hand. In the other hand, households who do not own electric AC are using the electric fan for cooling and firewood or charcoal in the winter season. Based on these result, when the annual income increased, the increased of possession on space heating-cooling equipment was also increased significantly. **Figure 3-6 (l)** shows the percentage of water heating equipment possession. About 40% of households are using traditional way to get the hot water by firewood. But in the other hand, the number of solar water heater also shows high percentages which about 24% of surveyed households are installing the solar water heater.

On the other hand, all energy units from the survey of each household, including electricity and gas, were converted into calorific value (Joules) so the energy consumption per year in the demand side can be presented. The energy conversion values used are shown in **Table 3-6**.

As a result, the annual energy consumption of each house is shown in **Figure 3-7**. The total energy consumption by households shows very high amount, reached almost 12 GJ/year. But in the other hand, the result shows very high differences between the highest and the lowest energy consumption, which is only less than 1 GJ /year, there are nearly ten times difference, even in the same village area. However, in case of the energy consumption per capita, the difference shrinks to about six times smaller between the highest and the lowest energy consumption. Since some of the houses were only lived by small number of occupants, the energy used for bigger houses seem too high and wasted. In other hand, the consumption of water is very hard to grasp due to almost 100% of villagers are using the water from the river.

Table 3-6 Energy conversion value

Item	Calorific value
Electricity	3.6 [MJ/kWh]
Charcoal	28.9 [MJ/kg]
Firewood	16.0 [MJ/kg]
LPG	42.3 [MJ/kg]

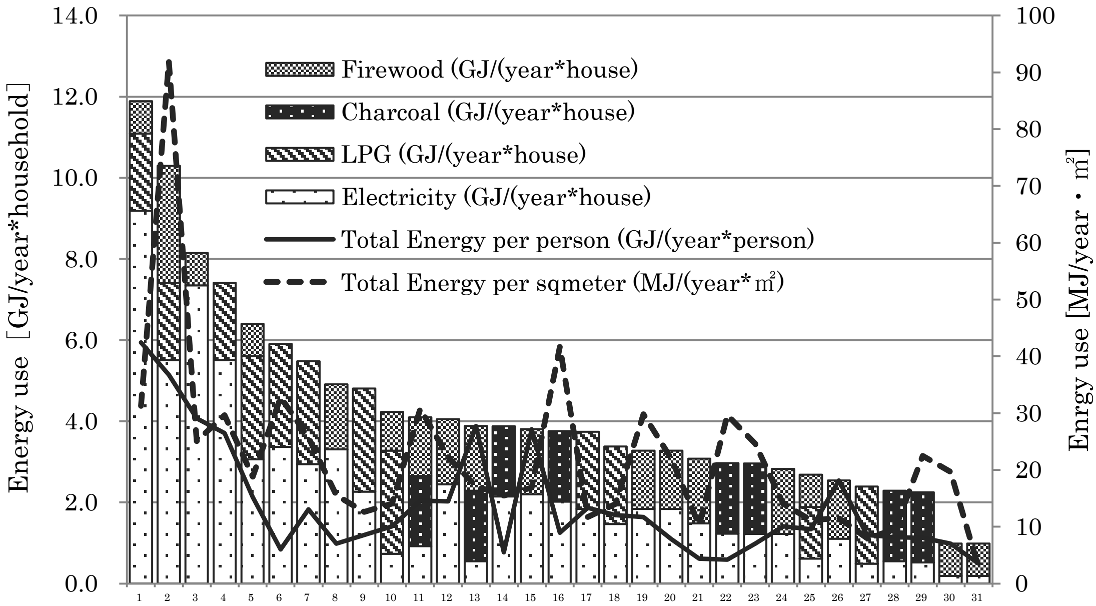


Figure 3-7 Annual energy consumption by household

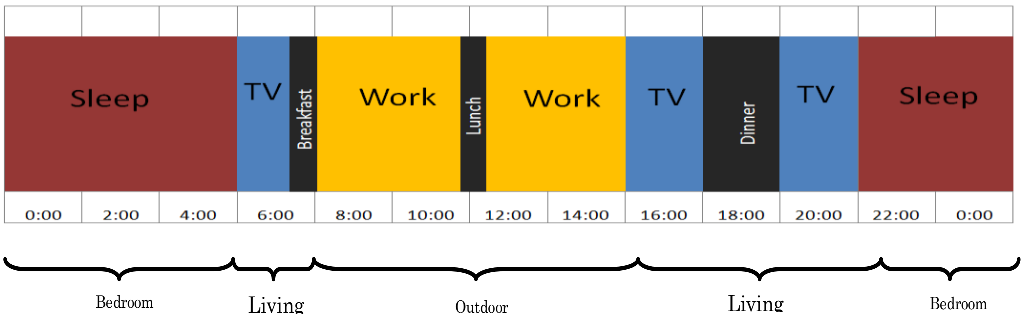


Figure 3-8 Lifestyle pattern in average

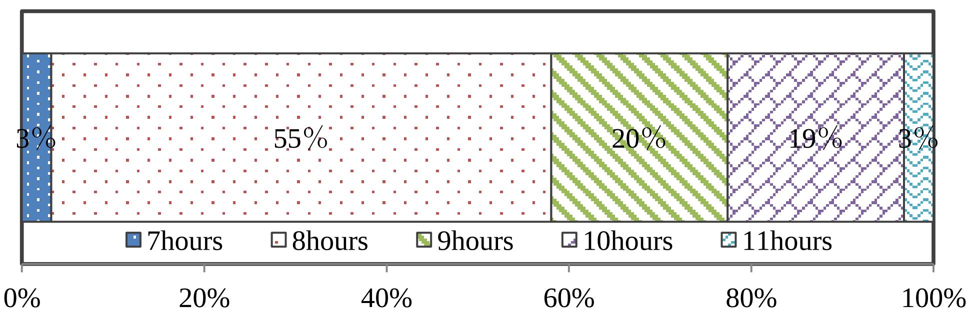
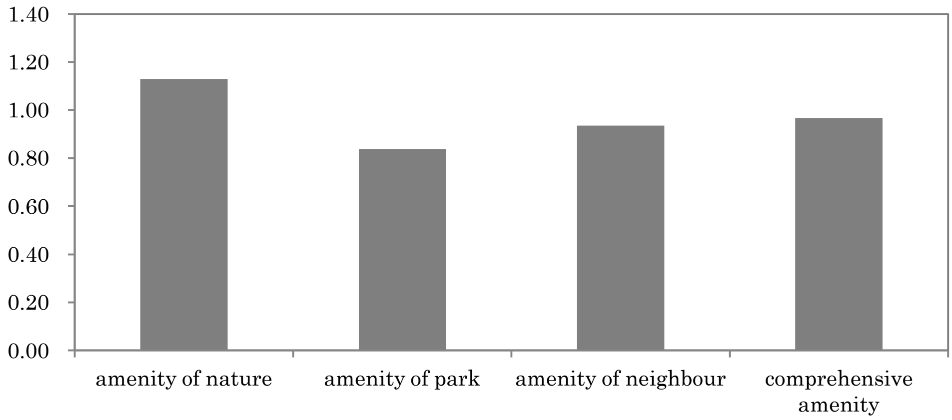


Figure 3-9 Average sleeping hours

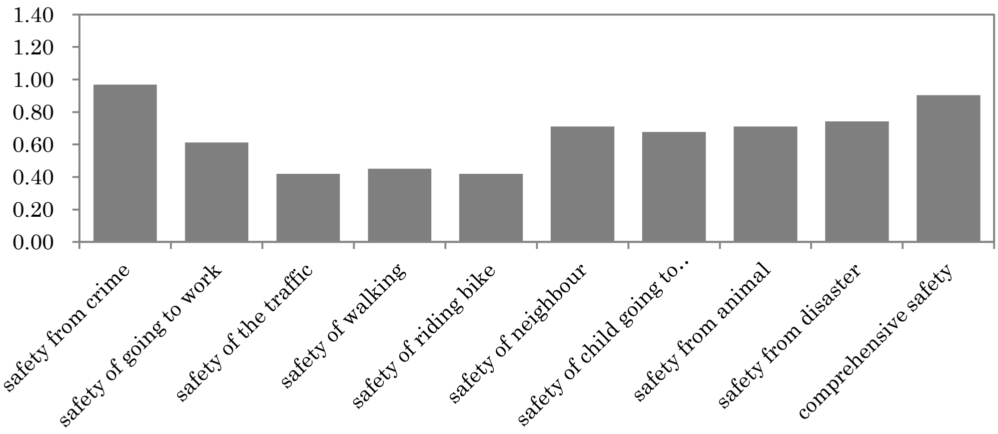
In the questionnaire, the research team included all aspect of daily behavior which may have influence on household energy use. Sleep length, sleeping hours, meal time, the start time and the end time of work and also family time such as watching TV or other entertainment activities were investigated. Then by average (the average method were used due to there is no significance different between each house), the household lifestyle can be summarized in **Figure 3-8** and **Figure 3-9**. Most of the householders return home at 17:00, then go to sleep at 22:00. Living room which designated directly in the front of the main door was being the central of family activities.

In order to understand the quality of the living environment, the question concerning to their satisfaction on present living environment were carried out. As the results, **Figure 3-11 (a-d)** show the household satisfaction score level based on WHO concept, Amenity, Safety, Health and Convenience. The scores are the average of numerical scale (-2=very un-satisfied, -1=un-satisfied, 0=mid, 1: satisfied, 2= very satisfied). Averagely, the household satisfaction is very high since there is no negative score in the result. As for the Amenity, the people satisfaction is very high on amenity related with nature. As for the Safety, even there is no negative score, the lowest satisfaction score is the safety related with traffic, since the road is narrow and many big vehicles used for transporting the product. Unlike the satisfaction on Health which is almost in the same score between each factors, the satisfaction on Convenience is varying, there is low score of satisfaction related to the convenience of medical facility, since the households have to go quit far from the residential area to near city central.

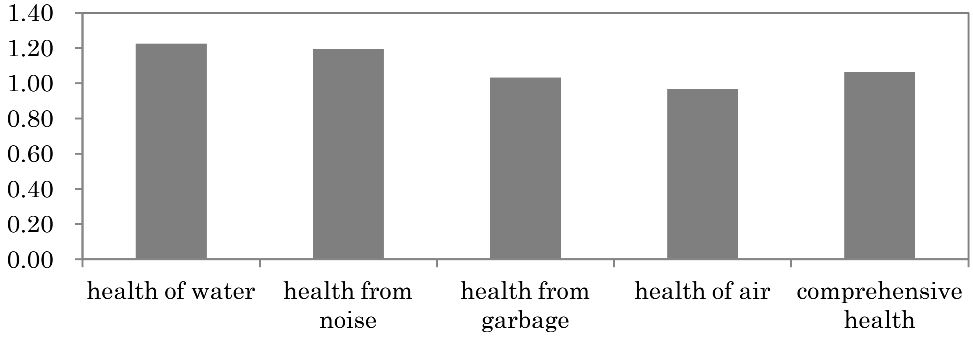


(a) Amenity

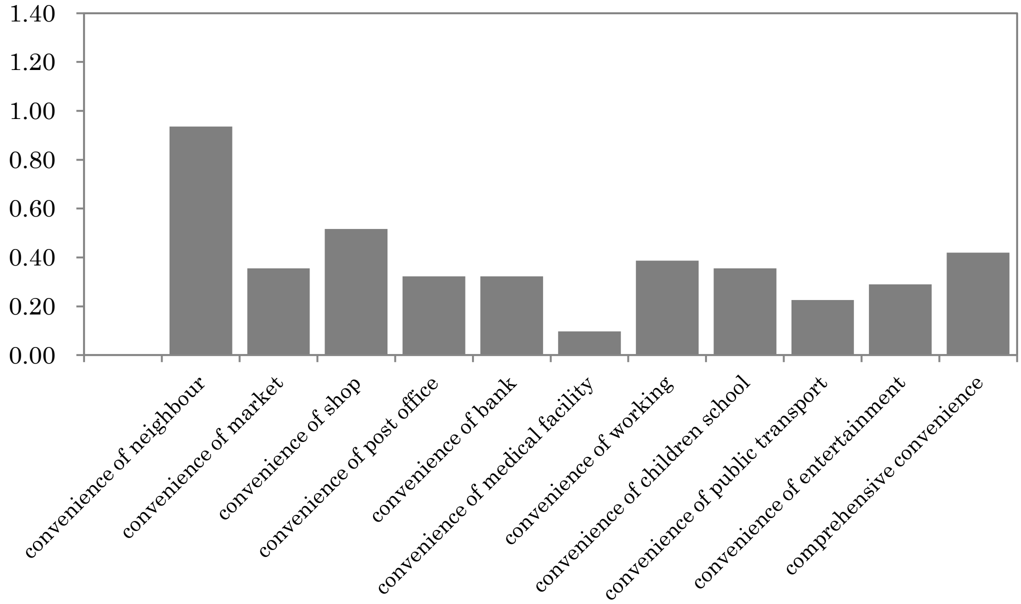
Figure 3-11 (a) Satisfaction evaluation on living environment



(b) Safety



(c) Health



(d) Convenience

Figure 3-11 (b-d) Satisfaction evaluation on living environment

3-3-4 Influential factors on residential energy use in China

All the energy use results data from the questionnaire survey were converted into Mega-Joules. To clarify the housing energy sources, to perform correlation analysis on residential unit attributes 18 items and energy consumption by using a *SPSS 16*. To be able to compare the effect on residential energy consumption of each item was classified factors into five grades. The classification criteria it is shown in **Table 3-12**. It was subjected to correlation analysis using the five grades. As a result it is shown in **Figure 3-13**. As a guideline of how to read the correlation coefficient, ± 0.0 ~ 0.2 if uncorrelated, ± 0.2 ~ 0.4 if somewhat weak correlation, ± 0.4 ~ 0.6 if somewhat strong correlation, ± 0.6 ~ 0.8 if fairly strong correlation, ± If 0.8-1.0 was to be a very strong correlation. In order correlation is strong, family size, income, land area, rank, sleep time, became the total floor area.

Table 3-12 Grade analysis

Factor	Five phases of classifications				
	1	2	3	4	5
The family number of people	˜2	3˜4	5	6˜7	8˜
The residence number of people	˜2	3˜4	5	6˜7	8˜
total floor area[㎡]	0˜100	101˜200	201˜250	251˜300	301˜
site area[㎡]	0˜101	101˜201	201˜251	251˜301	302˜
Number of floors	1	2	3		
The height of the room[m]	˜3	3.2	3.3	3.5	3.5˜
structure	concrete structure	reinforced concrete structure	wooden construction	Brick wall structure	
The building year	˜1985	1986˜1990	1991˜1999	2000˜2005	2006˜
Building Direction	south	southwest	northwest	northeast	north
Income[Yuan]	˜10000	10001˜35000	35001˜45000	45001˜100000	100000˜
Heating system	electric power	coal	firewood	electric power+firewood	electric power+coal
Cooling system	electric fan	air conditioner			
Possession number of the air-conditioner	0	1	2	3	4˜
Water heating system	firewood	electric power+firewood,solar heat	firewood+solar heat	solar heat	electric power
Possession of TV	No	Yes			
Possession of the washing machine	No	Yes			
Power saving awareness	Yes	No			
sleep time	˜7	8	9	10	11˜

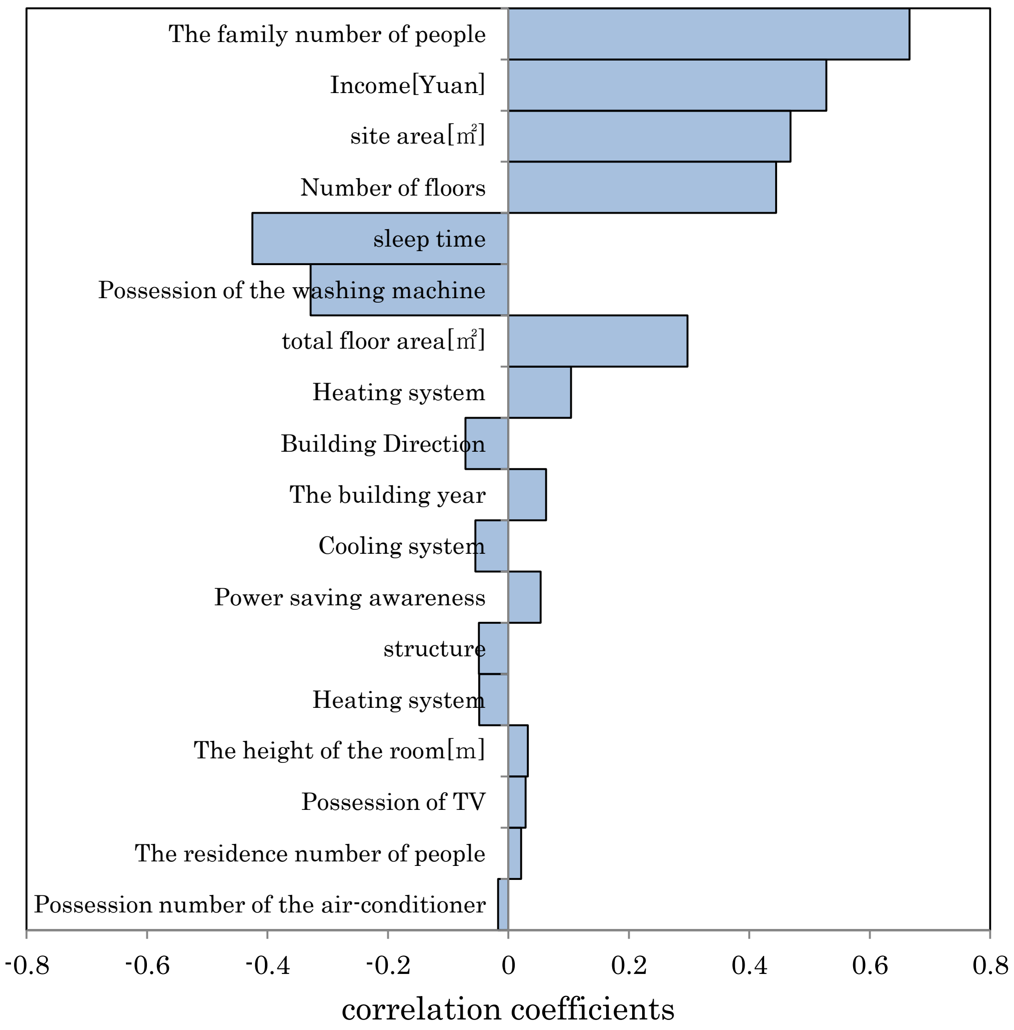


Figure 3-13 Correlation coefficients weight

In order to find the influential factors on housing energy consumption, the multiple regression analysis were conducted using SPSS ver. 20. The housings annual energy consumption was stand as the dependent variable and the 18 factors was the independent variable. In this paper, if the factors have the Partial Correlation Coefficient (PCC) between ± 0.0 ~ 0.2 it means the factors are uncorrelated, if PCC ± 0.2 ~ 0.4 means the factors have weak correlation, if PCC ± 0.4 ~ 0.6 is strong correlation, if PCC ± 0.6 ~ 0.8 means the factors have strong correlation, and if ± 0.8-1.0 means the factors have very strong correlation.

Family member, yearly income, land size, floor number, sleep length, floor number and washing machine ownership has strong influence on increasing the energy consumption. The regression analysis conducted once again using the seven highest factors in **Figure 3-13**. Then, in **Figure 3-14**, the correlation result between surveyed results and prediction result of yearly energy consumption were shown. The R^2 shows 0.754, it may also be noted that the model fitness (R^2) is quite high, which is indicating that the seven factors included in the regression can offer a promising and valuable theoretical framework for modeling residential energy consumption. From this result, the prediction equation can be presented as follow:

$$y = 739x1 + 359x10 + 985x4 + 880x5 + 1266x18 - 513x16 - 513x3 - 820 \qquad \textbf{(eq.1)}$$

where,

y: dependent variable (annual energy use)
x(n): quantitative independent variables

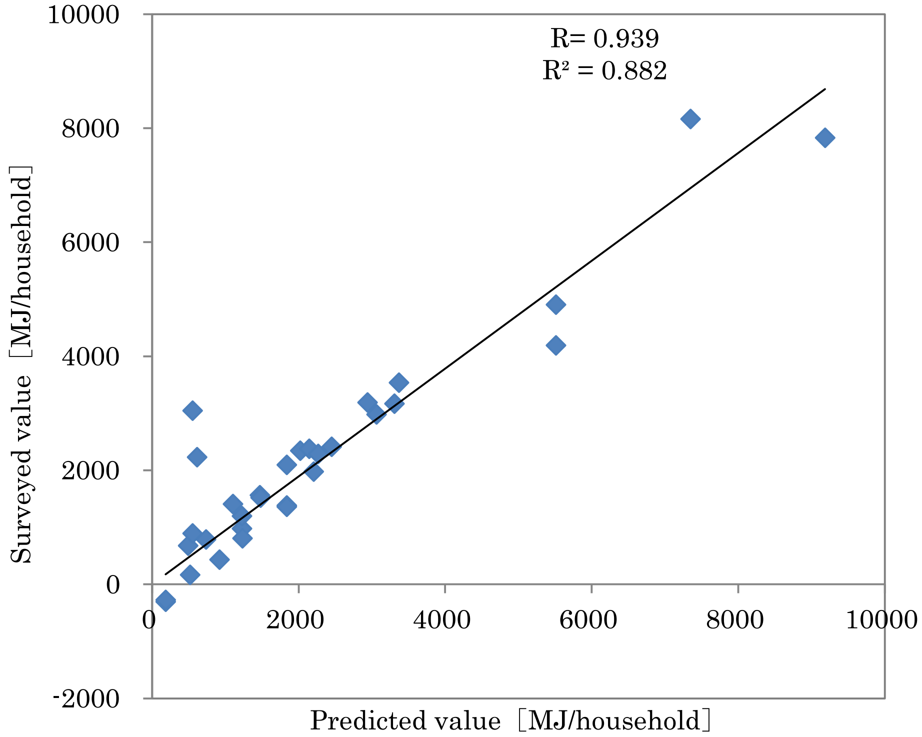


Figure 3-14 Correlation between predicted value and survey data

3-3-5 Summary of questionnaire survey in China

The summary of China studies on household behavior are described as below:

1) The two person family member in households accounted for about 50% from total feedback, and it was be-come common in the village. Means the spaces they built were not follows the need but more than investment in housing, if this phenomenon continues the environment damage will increase faster.

2) The houses which age for 5 years or less, shows very big number on total floor area, but in the other hand only few people lived there.

3) Households that do not own the AC were about 50% even the area is still comfortable to be lived, but due to the increase of living standard the ownership of AC is going to increase continuously.

4) The energy consumption vary highly, there are nearly 10 times difference between the highest and the lowest. It is shows that the economic condition of some householders is under the living standard but in the same area also there are householders lived above the living standard.

5) The annual energy use of people in the village are highly influenced by family number, yearly income, land size, floor number, sleep length, floor number and washing machine ownership. AC use influence is low maybe because the ownership of AC is very low, only half from the total respondents are using AC.

3-4 Investigation on household energy use and thermal environment in Thailand

3-4-1 Area of study

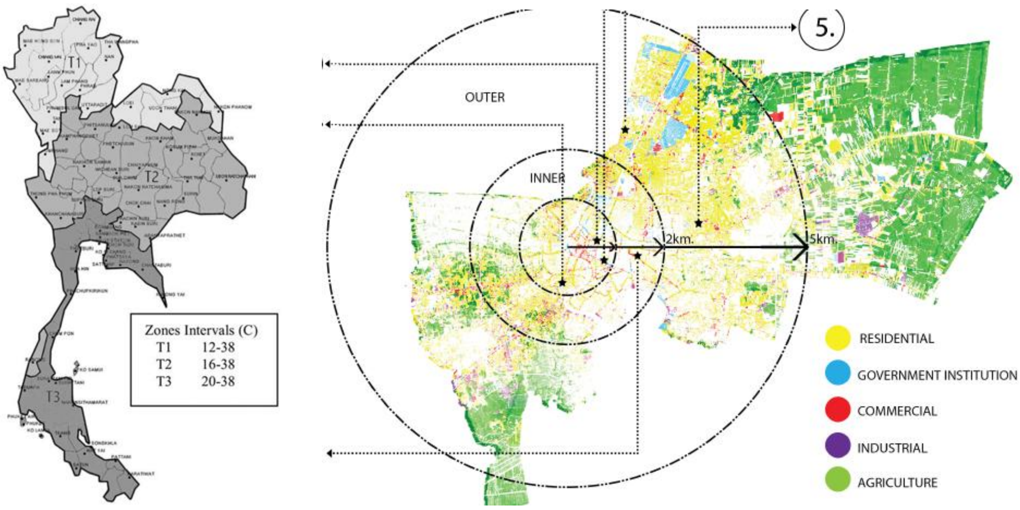


Figure 3-15 location of study area in Bangkok

The area of study was chosen in the urban and sub-urban area of Bangkok City, as shown in **Figure 3-15**. Bangkok is the capital of Thailand and is among the larger cities in Asia, with an estimated population well in excess of 10 million people in its 1,576 km^2 area. Bangkok Metropolitan Administration has divided the city into three zones, inner, middle, and outer zone, in accordance with the population density. The southern part of Thailand area belongs to tropical climate zone, while the northern have some similarity of subtropical climate. The hot season (hot and humid climate) is from March to June. At this time, temperatures in Bangkok average around 34℃ and April is the peak of the hot season.

On the other hand, Bangkok's population is continually increasing due to the urbanization. This rapid rise in population, capital investment, factories and employees in Bangkok city have caused the household numbers to increase leading to the development of road networks, real estate developments, land value and advanced technologies which had resulted in expansion of the city to the surrounding areas. This rapid urbanization has led to several environmental problems such as air pollution, water pollution [7]. Furthermore, as cities continue to grow in population and physical

[7] Office of the National Economic and Social Development, Thailand.

size, the energy use in household sector also increased gradually. The annual electric energy consumption has been raised 200% in 1988 to 2009. During the same period, the growth rate of residential sector electricity consumption was 240%. The annual energy consumption pattern shows a tendency that varies by season. Electricity demand in Bangkok continuously increases from March and reached its peak in April (hot season) and then started to fall in July until December (cool season). **Figure 3-16** shows the monthly average of temperature.

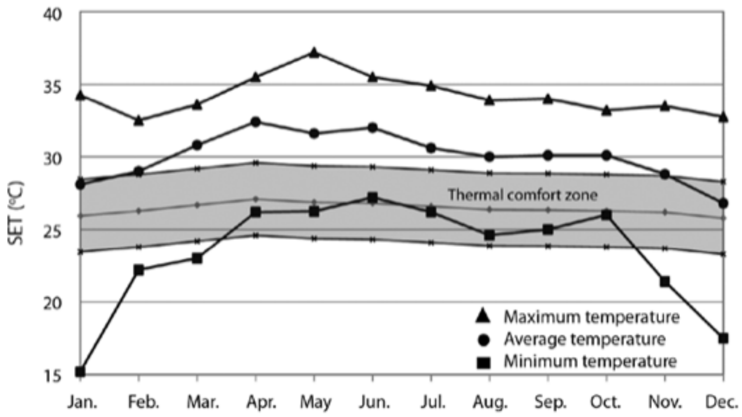


Figure 3-16 Monthly average temperature of Bangkok City

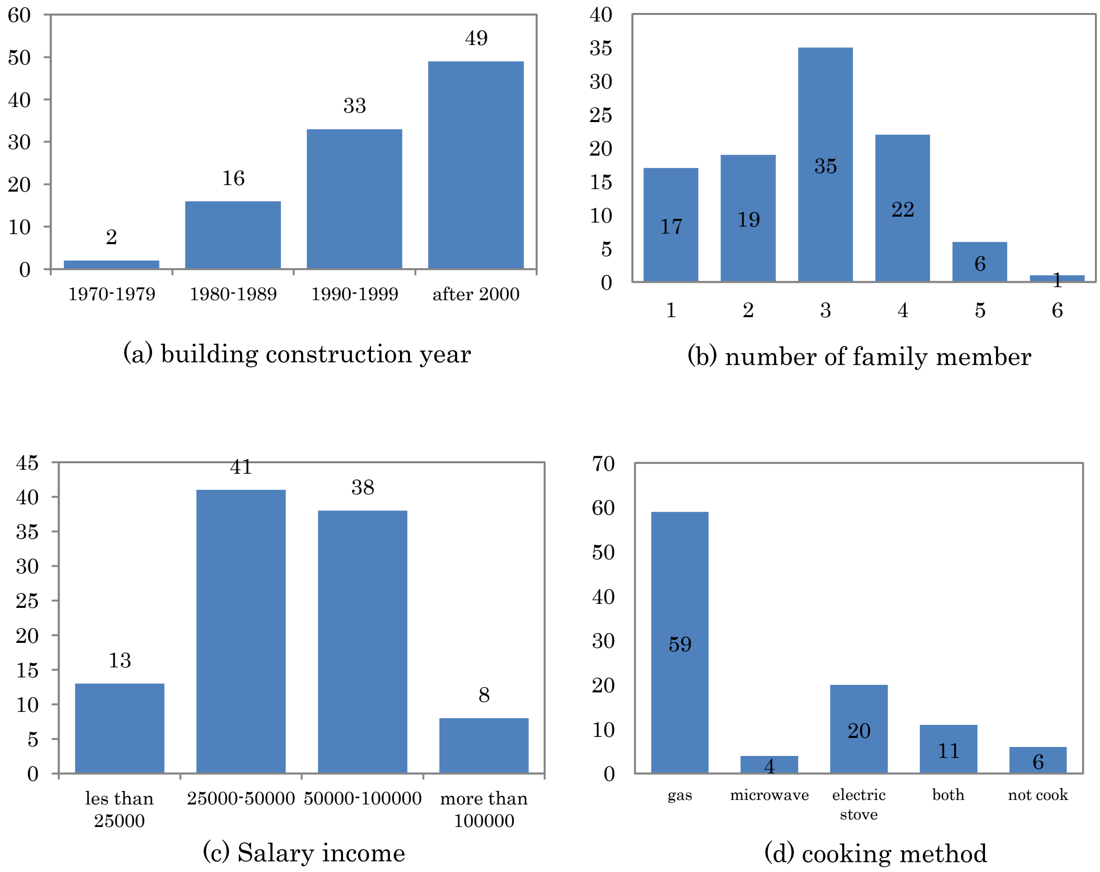
3-4-2 Questionnaire outline

Table 3-13 Questionnaire content of survey in Bangkok

Item	Content
Family Characteristic	Number of residents, Income, Electricity consumption information, Water consumption information
Building Characteristic	Living house total area, Construction year, Structure, Architecture area, Type of building, Renovation
Housing Equipment	Air condition control and ventilation
Lifestyle relate with electricity	Time open window, Time open air condition, Bath and Cooking activity
Effect for energy saving & environment	Concerned about environmental program, Manage about waste and garbage, using the advance technology and how to reduce the energy

3-4-3 Questionnaire result

Based on the number of housing unit type which was constructed in Bangkok during 1998-2008, there are 36.84% of low-rise housing and 18.84% of high-rise housings in Bangkok. For perimeters of Bangkok, there are 39.62% of low-rise housing and 4.7% of high-rise building. The 300 questionnaire sets could be divided by 75 sets for low-rise housing and 25 sets for high-rise building. The distribution of data collection is determined on the basis of statistical value of the distribution of the number of housing type in Bangkok metropolitan region. When considering the construction year of residential building, two building were constructed during 1970-1979 (2%), fifteen during 1980-1989 (16%), thirty-one during 1990-1999 (33%), forty-seven after 2000 (49%) which can be illustrated in **Figure 3-17 (a)**. It can be seen that most of the residential building was major constructed after the year of 2000.



(a) building construction year

(b) number of family member

(c) Salary income

(d) cooking method

Figure 3-17 (a-d) Questionnaire results of survey in Thailand (%)

Figure 3-17 (b) shows the trend of the family characteristics from the survey, with the average number of people per household is 2.84. **Figure 3-17 (c)** shows the average income of the people in Bangkok, which is a range between 25,000-75,000 baht (1 baht= 0.028 USD). This major group of respondent is about 79% of the sampling in this survey. The average income of the sampling is about 33,000 baht/month. In **Figure 3-17 (d)**, 59% families use gas for cooking, 4 families use microwave, 20% families use electric stove, 11% families use both of equipment such as stove and traditional stove that use coal for cooking energy. Result on **Figure3-18**, in the morning 53% of household change the ventilation of their housing by closing all of windows, 33% just open some windows. In afternoon, it shows 52% of household change the housing air flow by closing all of window and 37% open some window for ventilation. And evening, there are 92% of household use method of turning on air conditioner and 87% select to close the window and 14% open some window. **Figure 3-19** shows the reason of not open the window to circulate the air. There are 36% of household stated that pollution reason from outdoor. Other 24% household selected closing the window because of safety and the security reason. While, 18 families select not to open the window due to the external noise.

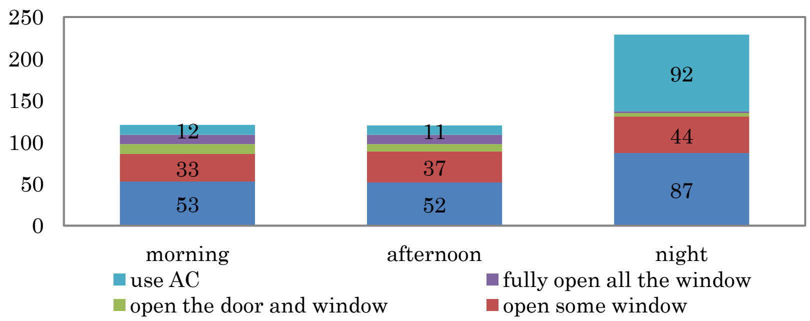


Figure 3-18 Indoor air changing method (%)

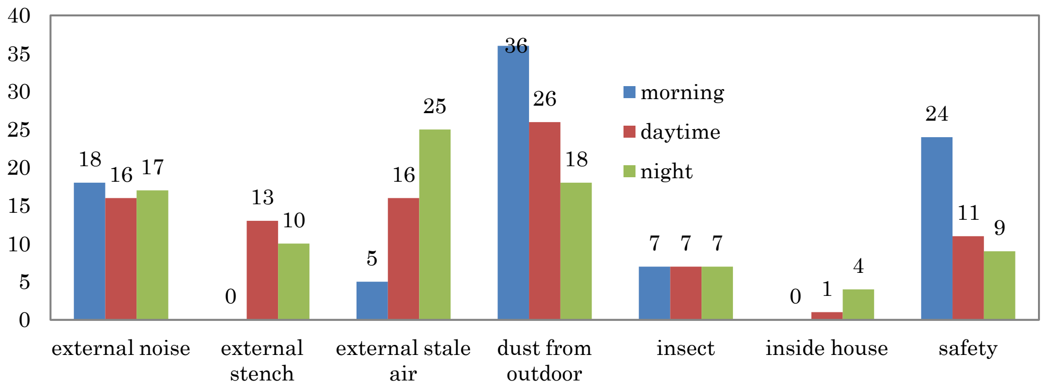


Figure 3-19 Reason cant open the window (%)

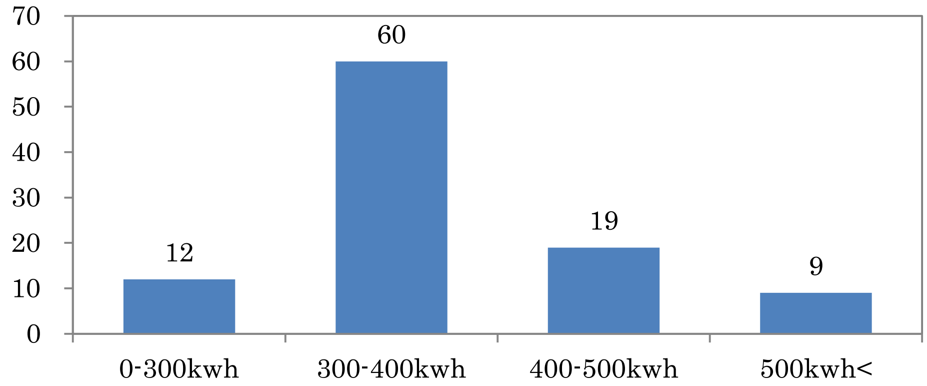


Figure 3-20 Questionnaire result of monthly electricity consumption (%)

Monthly residential electricity use in Bangkok is not showing significant different each month, **Figure 3-20** shows the variation of electricity use in household based on the questionnaire result. About 60% of household consumed between 300 to 400 kWh/ month, which is the highest percentage. As for the average, the electricity use of the surveyed household accounted 396.3 kWh/ month.

3-4-4 Conclusion and recommendation for further study

The review of questionnaire survey result was explained in this section. The analysis on the correlation between physical characteristic to the household energy use are extremely important in the face of rising energy use in household. However, available data are not adequate to carry out analysis of the likely effects of the household behavior to the energy use due to low number of the valid feedback in Thailand. Also interesting is to analyze the effects of growing prices of modern fuels, for example, the possible movement of households down the energy ladder. This requires significant resources and efforts to gather necessary household level data as the first step. The effects of different measures to improve energy saving action both at the household and national levels would require statistical analysis and energy system modeling. These tasks could be undertaken in a further study on the energy saving lifestyle.

3-5 Investigation on residential lifestyle and household energy use in Indonesia

3-5-1 Background

Indonesia is experiencing with high economic growth in line with rapid urbanization and therefore sees large increase of energy use in urban area. The real GDP increased stably by approximately 6-7% over the last few decades, whereas the nationwide final energy demand rose by 14 times from 1970s to the present [8]. Energy-saving strategies are, therefore, essential to be introduced further to make the cities more sustainable. At present, Indonesia has a population of 240 million and the percentage of people living in urban areas reached approximately 50% as of 2010. It has been reported that approximately 60% of the total population are distributed in the relatively small island, Java, which accounts for only 6% of the total national land [9]. As a consequence, major cities in the Java Island are densely populated, such as Jakarta, Bandung, Surabaya, Semarang, etc.

This study focuses on the research of housing building characteristic and household lifestyle in term of energy use. The whole research has conducting continuous study in order to change the Asian people lifestyle moving toward the sustainable development. In this section the first biggest developing country in Asia is chosen as study object, Indonesia. Indonesia has been choose due to its climate can be parameter in some country in the equatorial area, the population also shows a significant growth every year means that the people living standard will also continuously growth in the future. Indonesia is the world's fourth most populous country and the largest country in South East Asia. Lying along the equator, Indonesia has a tropical climate, with two distinct monsoonal wet and dry seasons. These vary of the climate and city development indicates the people lifestyle is moving to the enhancement of the country's energy consumption.

The research took three different cities in Indonesia that have different economic growth as a parameter of people lifestyle. First city is Jakarta City, the capital

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[8] Dewi, R.G., Kobashi, T., Matsuoka, Y., Gomi, K., Ehara, T., Kainuma, M., Fujino, J. 2010. Low carbon society scenario toward 2050: Indonesia, Energy sector, The Asia Pacific Integrated Model (AIM) Workshop, Bandung

[9] Indonesia. 2011. Handbook of Energy and Economic Statistics of Indonesia: Ministry of Energy and Mineral Resources of Indonesia, Jakarta.

city of Indonesia which has the highest standard of living in Indonesia (highest GDP). Second is Bandung City, located 140 km from Jakarta, has the predicate of the second largest metropolitan city in Indonesia. The last is Semarang City, which still has traditional/local culture and moving forward to the developed city.

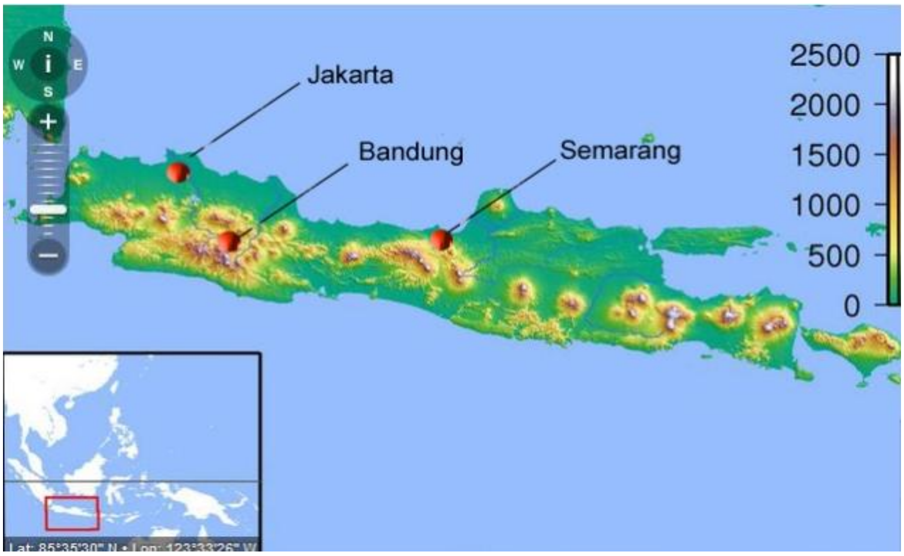


Figure 3-21 Study area of questionnaire survey in Indonesia

Table 3-14 Monthly highest-lowest temperature of three cities

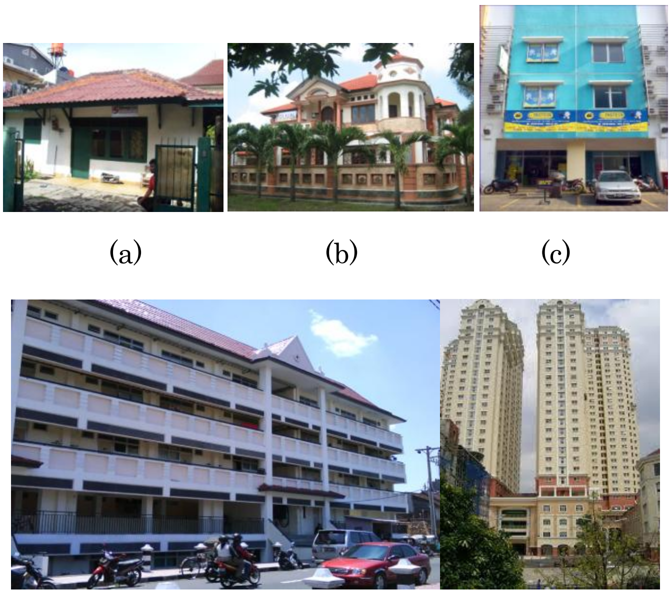
Temperature Data for Jakarta												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average high ℃	31.5	32.3	32.5	33.5	33.5	34.4	33.3	33.0	32.0	31.7	31.3	32.2
Average low ℃	24.2	24.3	25.2	25.1	25.4	24.8	25.1	24.9	25.5	25.5	24.9	24.9
Temperature Data for Bandung												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average high ℃	27	27	27	28	28	28	28	28	29	29	28	27
Average low ℃	19	19	19	19	19	18	17	17	18	18	19	19
Temperature Data for Semarang												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average high ℃	29	29	30	31	32	32	32	32	32	32	31	30
Average low ℃	25	25	25	26	26	25	24	24	25	26	26	25

Figure 3-21 shows that Jakarta, Bandung and Semarang have different topography. Near the sea makes Jakarta and Semarang have a similarity in average temperature. Bandung position which is in the middle of mountains make the temperature is lower than two other cities, but Bandung has a similar topography with Semarang (mountains area). Based on the feedback of these three cities, the different lifestyle can be identified, from the people lifestyle in developed city to the people lifestyle in developing city which move forward to developed city, and the last is from the lowest people lifestyle (low income). **Table 3-14** shows the monthly temperature data of three cities, as we can see, Bandung has cooler average temperature compare to other two cities. The outline of questionnaire was mostly the same as the questionnaire in China and Thailand (two sections before)

3-5-2 Housing Characteristics in Indonesia

Based from the feedback which has collected from questionnaires survey, housing type in Indonesia can divide into (**Figure 3-22**):

1. Single Detached House (a, b.)
2. Shop House (c)
3. Subsidized flat /low-income apartment (d)
4. Apartment (e)



(a) (b) (c)

(d) (e)

Figure 3-22 Physical appearance of house type in urban area

By this different type of housing, 300 questioners have been distributed to the household and divide into 3 different cities (100 for each city). Firstly, the question is about how big is the housing area in square meter, the result can be seen in figure 8, and then the house type can be shown in **Figure 3-23**. From the **Figure 3-24** shows the composition of house type. Detached house accounts large percentage of house type in all cities. The deeper research and more attention on promoting vertical development rather than horizontal development are importantly need consider to the increase of household population and sustainable development. **Figure 3-25** shows the housing level trend are increasing from 1 floor to 3 floors and more because people need more space in their house but the price of the land is getting higher too. **Figure 3-26** shows the concrete structure domination almost in all cities, although there are some families still using wood and bamboo as the main structure in Semarang City. When the people have enough money they will move to build concrete structure which they think a lot stronger than wood and bamboo structure.

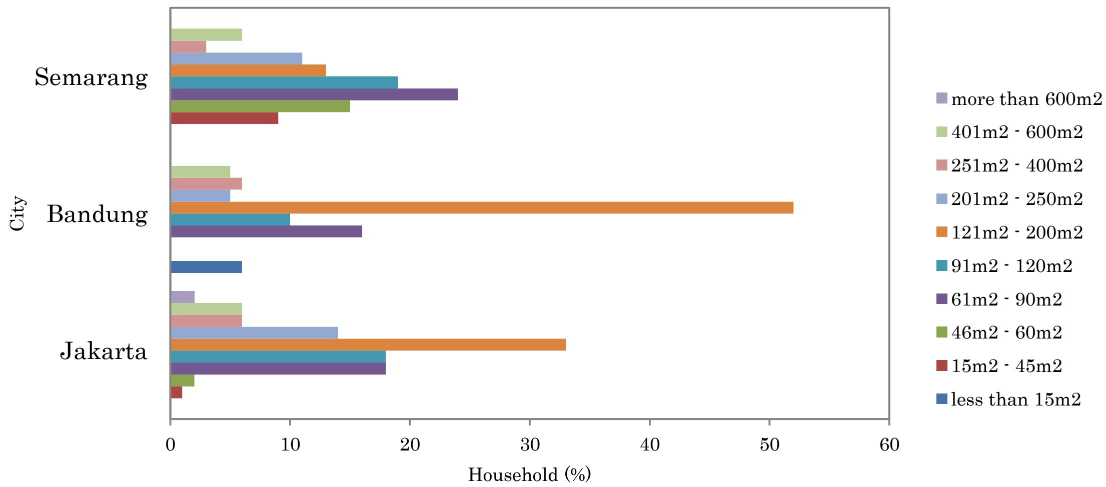


Figure 3-23 House area

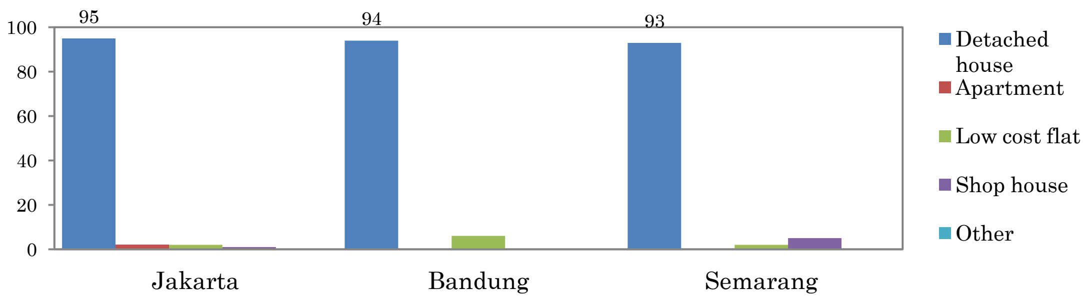


Figure 3-24 House type

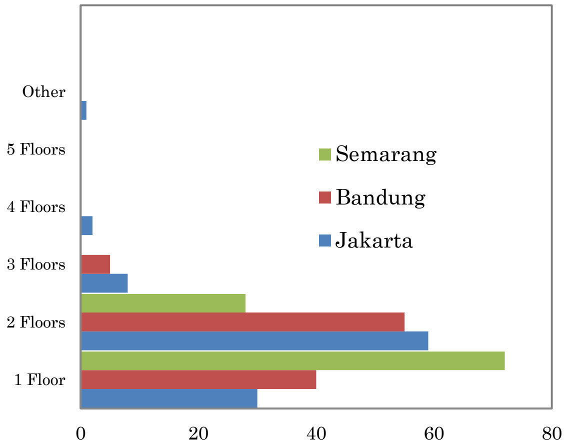


Figure 3-25 House floor

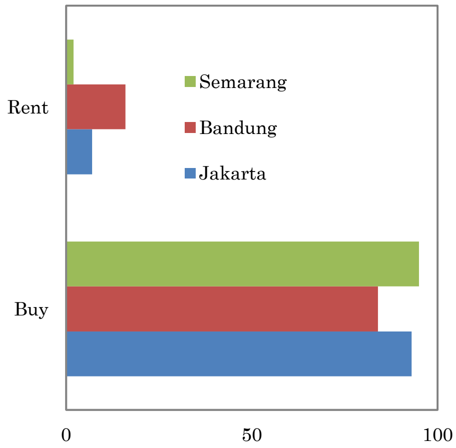


Figure 3-26 House statues

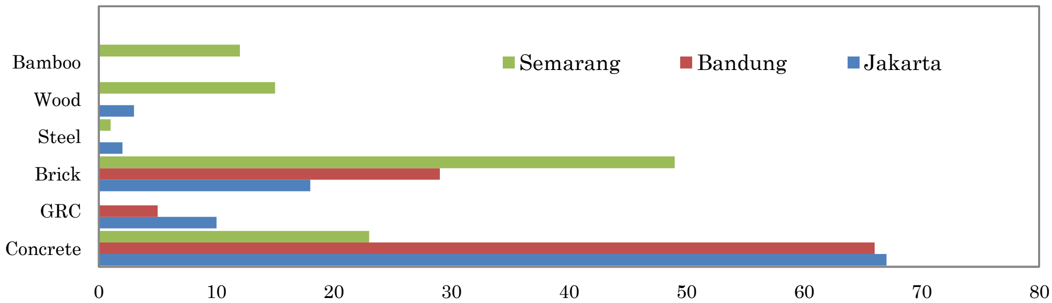


Figure 3-26 House main structure

Figure 3-27 shows Jakarta City dominates the salary income above 4,000,000 IDR, (1USD = 10,000 IDR). And then **Figure 3-28** shows the people main job, private company employers dominate the main job in the 3 cities, means the city economic is growing due to infestation in private sector.

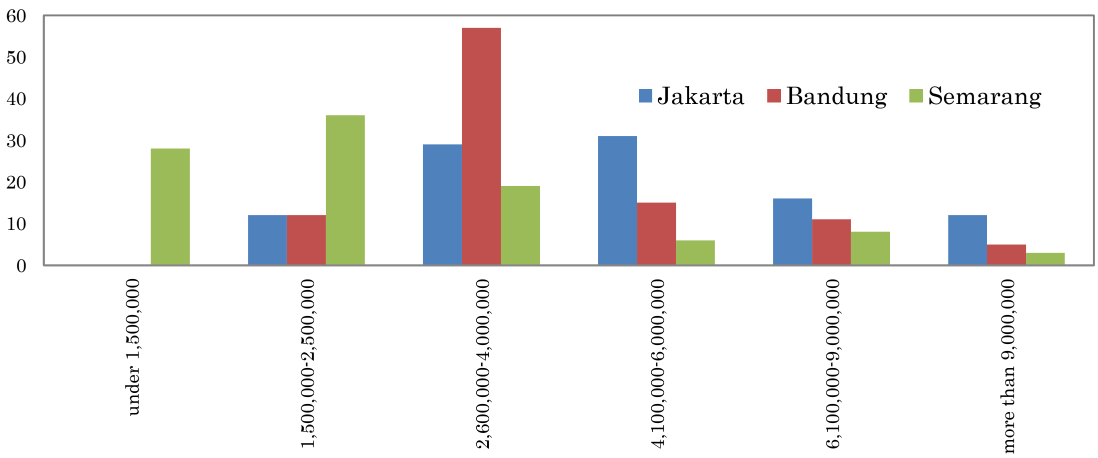


Figure 3-27 Salary Income

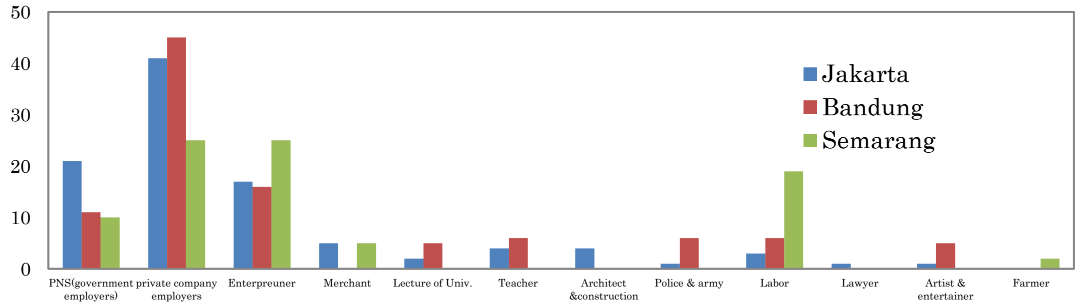


Figure 3-28 Occupation

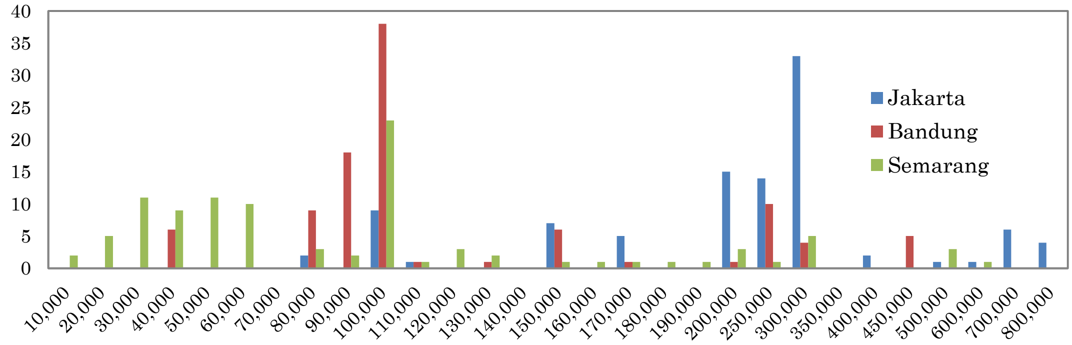


Figure 3-29 Electricity bill

Figure 3-29 shows the electricity consumption bill per month, here we can see that Jakarta have biggest consumption of the electricity. The survey use currency as parameter for easier way for people to fill the data (the tariff for every city are same). The research actually shows more result about the house equipment, but in this paper only the basic need of people can be shown. As for the air conditioning (AC) appliance, even Semarang City has similar temperature with Jakarta City, Semarang people still comfortable with the hot temperature. On the other hand, Bandung City which has low temperature there is trend on starting to use the AC in their room.

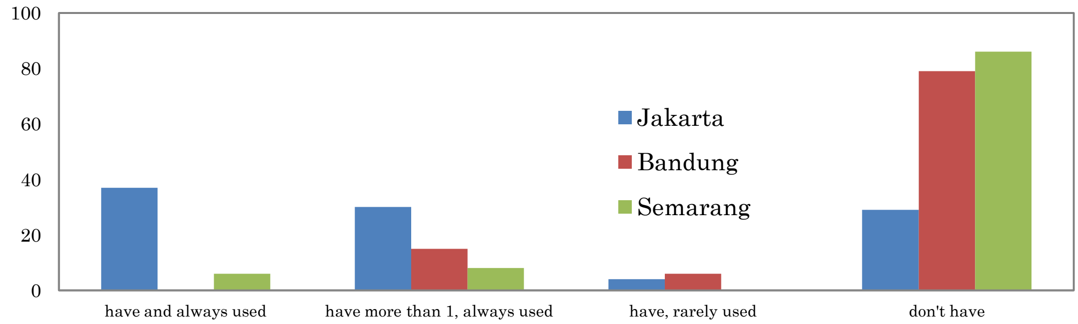


Figure 3-30 Air conditioner user

Figure 3-31 `Do you need to turn on your toilet lamp even in day time?`

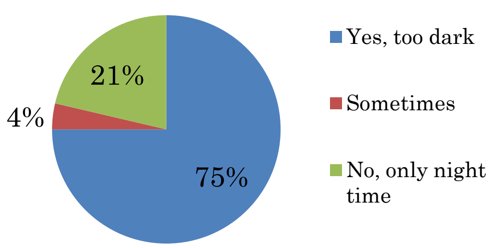


Figure 3-32 `Do you need to turn on your kitchen lamp even in day time?`

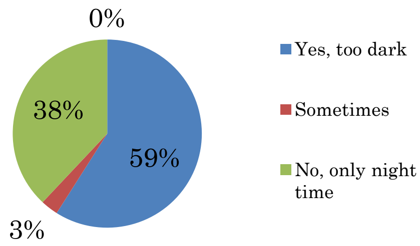


Figure 3-31 and **3-32** shows almost the people in each city turn on the lamp in their kitchen and bathroom even in day time means that the building design can't maximize the natural light use which can reduce the electricity consumption. Figure 23 also shows the quality of outdoor air is not good, because the less of greenery and air pollution by traffic. Then the result also shows there is a will of the people to change their lifestyle in energy consumption even by small thing like turn off the electricity when they don't use it. Finally, these survey result can be use to indicate the future people lifestyle in terms of energy consumption. After that, the researcher is trying to find a method to change the people lifestyle by the architecture design start from their living environment.

3-5-3 Analysis on the influential factor of energy use in Indonesia

Based on the valid feedback we conducted multiple regression analysis with Quantification Theory Type I, so the influential factor of household energy (electricity consumption) can be revealed. By including about 40 factors concerning to the household attribute and lifestyle, investigation on factors influencing the energy use of household in each cities can be explained.

Three cities with different cultural backgrounds were selected for this study, namely Jakarta, Bandung and Semarang. The factors driving electricity consumption are investigated using a field survey and classified according to how the electricity is used and the social and economic characteristics. The relationships between electricity use and its influential factors were evaluated using multivariate data analysis. The results show that in Jakarta and Bandung, family size, home occupancy schedule, education level, electric appliances ownership and lighting had a significant effect on the monthly electricity use. On the other hand, in Semarang, education level and time spent at home had a negative impact on the monthly electricity use. Based on these results, an energy conservation policy may not be generalize but will have to be specified based on local characteristics to ensure that the policy is broadly adopted by society.

3-6 Discussion

The basic building characteristics of cities in three countries were listed in **Table 3-15** rather than make a comparison, this study tried to grasp the present condition of household in Asian countries.

Table 3-15 Building characteristic

Building characteristic		Indonesia	Thailand	China
Architecture area (m^2)	<15	2		
	15- 45	3.3	7	
	46- 60	5.7	9	3.1
	61- 90	19.3	11	16.6
	91- 120	15.7	17	38.8
	121- 200	32.7	34	25.8
	201- 250	10	12	8.9
House type	Detached	94	75	25.8
	Hi-rise	0.7	25	72.2
	Low-cost	3.3		
	Shop house	2		2
House floor level	1 F	47.3	27	7.2
	2 F	47	73	16.5
	3 F or more	5.7		76.3
Construct. year (year)	< 5	9		36.6
	5 - 10	30.3	49	35.1
	11 – 20	39	33	19.5
	21 – 30	10.7	16	5.2
	31 – 40	5.7	2	3.4
	41 – 50	2.3		0
	51 – 60	2.7		0.3
	60 >	0.3		
Structure type	Concrete	43.3	90	29.1
	GRC	4.2		66.1
	Brick	26.7	10	3.3
	Steel	0.8		1.2
	Wood	21.7		0
	Bamboo	3.3		0.3
House Status	Buy	91	84	29
	Rent	9	16	71

All the energy use converted to calorific value in Mega-Joules. The gas consumption is difficult to track and make the comparison because householder in the country like Indonesia and Thailand consume gas from the LPG tube which they bought every three weeks or 1 month depend on their need. But in the China, some area already consumes gas from the pipe. From the Figure 2, the comparison between Thailand and Indonesia has slightly different in electricity price, but it has similar shape in the respondent number as shown in black parabolic line. Although, there is growth of consumption in Indonesia from point 2,000 MJ/year, means there are some household using the electricity bigger than the average. On the other hand, China has different consumption graphic pattern, it has wider variation of user's lifestyle makes the average energy consumption is bigger than the other two countries.

In order to find an idea of future energy conservation method, the influence factors of residential energy consumption has to be analyzed, also the reasons which result in the differences of energy consumption quantities between high and low energy use family group need a further analysis. Housing appliances user comparison between Indonesia, Thailand, and China can be shown from Figure 3 to Figure 9. The research investigate al-most all of the electric equipment in residential housing, but in this paper the only the housing appliances that consume high energy to be described, such as refrigerator, microwave oven, television, computer, and type of stove.

Figure 3-33 shows that more than 94% China families and about 60% Thailand families have more than 1 unit refrigerator in their house. As **Figure 3-34**, the microwave oven not really popular in Indonesia and Thailand, but more than 87% families in China have and always use the microwave. **Figure 3-35** shows the similarity of the television composition user, until nowadays, televisions are being the primary need of families. Like television, computer and laptop have been modern people lifestyle, shown in **Figure 3-36**, almost all countries have more than one unit computer in the families. **Figure 3-37** shows the gas stove user composition, Thailand is higher at non-user families in gas stove, probably because the Thai people prefer to buy food rather than cook the food by them-selves, different with Indonesian and Chinese who still like to cook for the family.

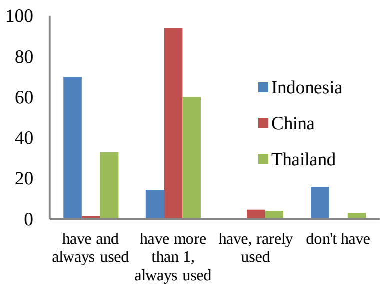


Figure 3-33 Refrigerator

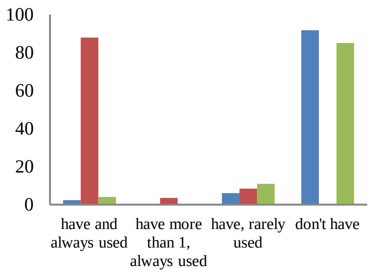


Figure 3-34 Microwave

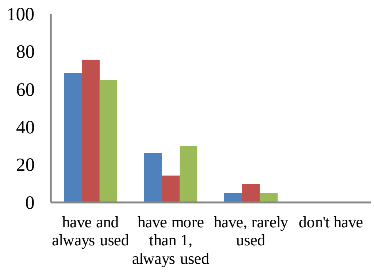


Figure 3-35 Television

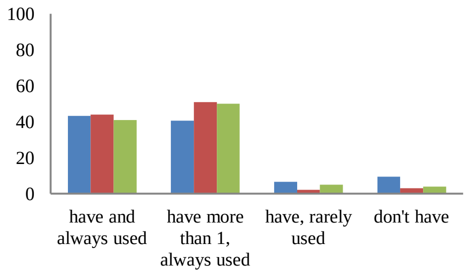


Figure 3-36 Computer

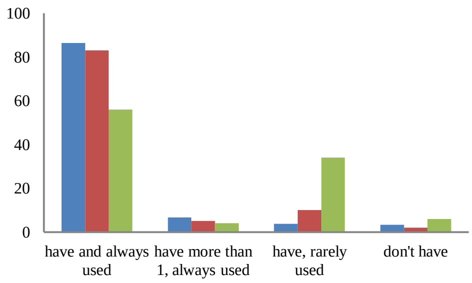


Figure 3-37 Gas Stove

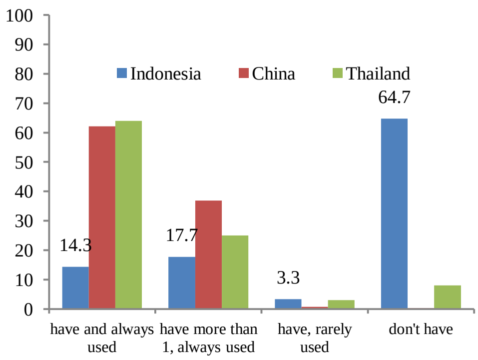


Figure 3-38 Air conditioner

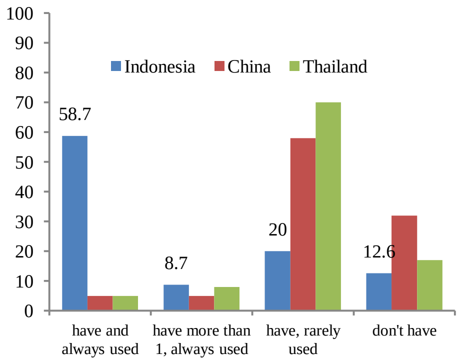


Figure 3-39 Electric fan

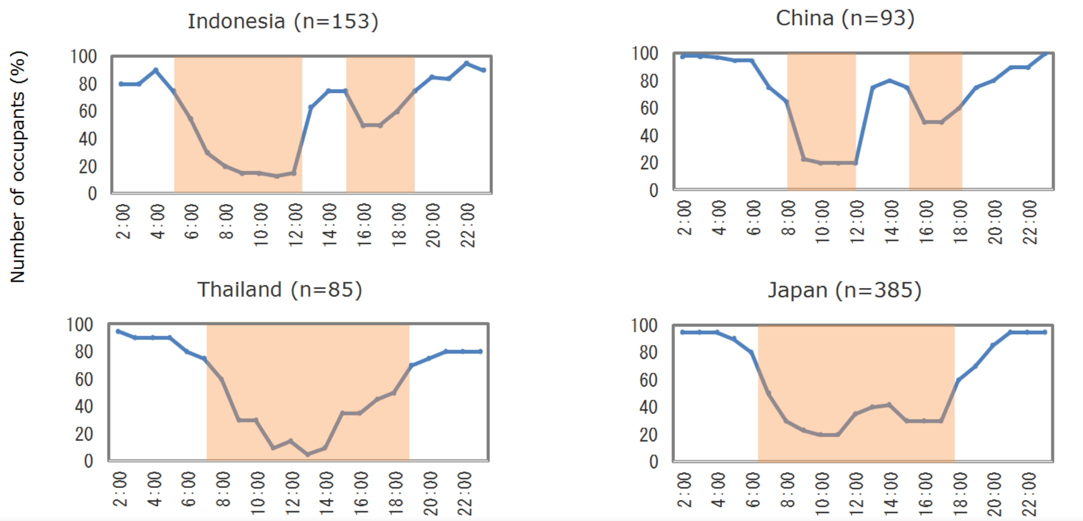


Figure 3-40 occupancy rates of weekday activities in residential building

Indonesia and south part of Thailand are still in the tropical climate zone, mean it only have two main seasons, dry season and rainy season. Even so, the average temperature in Thailand is higher than Indonesia, the result shows there are more than 60% families who have and always used the air conditioner in their houses. Different with those two countries, China has been divided five architecture thermal zones, the very cold zone, the cold zone, the moderate zone, the hot summer & cold winter zone and the hot summer & warm winter zone, its make the insulation and air conditioning system in China are the important thing to reach the thermal comfort. In the other hand, there are more than 64% of families who did not install the air conditioning system and still comfortable with the use of electric fan. Although, there is growth of air conditioner user in the Jakarta area, it is not only because the Jakarta temperature but also because of the people's lifestyle growth.

Multiple Regression Analysis (MRA) with Quantification Theory I was used to weigh the contribution of in-dependent variables (lifestyle types) to the dependent variable (total energy use per households). In this method, the qualitative and quantitative variables of yearly energy use can be introduced into models and be analyzed together. Firstly, the correlation analyses conducted to more than 40 variables and only the factors that have positive correlation were taken for the next stage of analyses. The significant test was taken to judge that to what extent the Partial Correlation Coefficient (PCC) was large enough, the factors will have effect to the energy use. The bigger Significance Probability (SP) has the less PCC. It means the factor has a bigger influence on the housing energy use. In order to get valid results, the regression analysis was conducted on all predicted factors. As a result, 24 factors were revealed with a high correlation score. In this case, there were 24 variables used as independent variables. They were:

1. House size, 2. Family size, 3. Household age, 4. House type, 5. Residential year, 6. Electricity current, 7. Daily stay hours in home, 8. Wakeup/sleep schedule, 9. Sleeping hours per day, 10. Toilet and kitchen lighting, 11. Electric light pattern, 12. Bath method, 13. Bath length per person,14. Cooking schedule, 15. House energy type, 16. TV ownership, 17. Solar PV ownership 18. Computer ownership 19. LED lamp ownership, 20. Electric fan ownership, 21. AC ownership, 22. Oil heater ownership, 23. Elec. heater ownership, 24. Gas *heater ownership.*

Then the regression was conducted once again to include 24 factors above with the filtering method correlation score up to 95%. It means if SP less than 0.05, the factor has big influence on energy use. The score of each variable was used to analyze the influence extent of all the categories of qualitative variables (e.g. housing characteristic, family characteristic, and lifestyle characteristic), and quantitative variables (e.g. appliances ownership) on the dependent variable (yearly energy use).

On the other hand, the data filtering was conducted once again on 600 households. Only data with 100% validity was selected. According to the assumption that significance probability was smaller than 0.05 (or in other words has correlation score bigger than 95%), the factor had a big influence on energy use. As a result, the influence extent of the factors on energy use can be established in the following order in **Table 3-16**:

Table 3-16 Influential factors on energy use by countries

Countries	Empirical equation	R^2
Indonesia	y = 8.06[AC use] + 3.03[family member] + 3.24[refrigerator ownership] - 2.88[fan use] + 5.07[cooking period]+2.63[TV] -9.29	0.612
China	y=7.39[family member] + 3.59[annual income] + 9.85[AC use] - 8.80[floor number] – 12.66[sleep length] + 5.13[washing machine]+ 513[floor area]-8.2	0.734
Thailand	y = 3.82[floor area] + 3.47[AC] + 2.13[residence period] + 1.98[TV] + 1.44[electric current] + 1.28[cooking period] – 16.5	0.821

Based on the survey results in Indonesia and through the application of Quantification Theory I, households energy use in Indonesia are strongly influenced by the ownership of AC, number of people stay (family member), the ownership of refrigerator, the ownership of electric fan, and the ownership of electric stove, and the ownership of gas stove.

In China, the family member, the yearly income, the land size, the housing floor number, the sleep length of the householder, the ownership of washing machine, and the housing floor size are the major factors influencing the household's energy use. While in Thailand, the floor area, residence period of stay, TV ownership, the electricity current contract choices, and daily cooking period have biggest influence on energy use in households.

Figure 3-41 shows the correlation between surveyed results and predicted energy use from regression models of three countries. The coefficient determination (R^2) was 0.612, 0.734, and 0.791, indicating that the regression model is reasonably well fitted with investigated values. Therefore, the empirical regression equation was found to have a considerable predictive power.

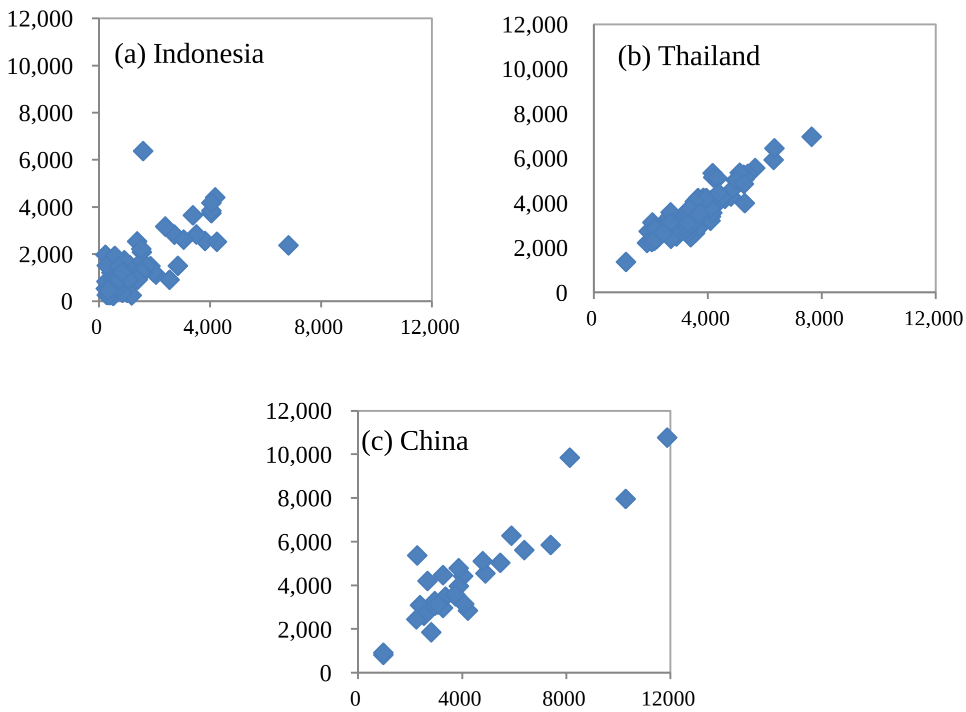


Figure 3-40 (a-c) Correlation between x-axis-surveyed value energy use (MJ/household) and y-axis-predicted value (MJ/household)

3-7 Summary

The following conclusions can be made through this survey and comparison to the survey conducted from September 2011 to December 2011 among three countries:

1) Indonesian and Thai residential building has a lot of similarity in the physical architecture style and in occupant's behavior, probably because the similarity in the climate condition and economic situation. The slightly different between these two countries is the air conditioner use, 89% of houses installed and always use air conditioner in their houses, while Indonesia only 32% households always use the air conditioner in their house. Compare with Thailand and China, energy consumption cost in Indonesia is lower, it could be the electricity and water tariff also lower in exchange rate. Although there are some families group consume bigger than the average.

2) By demographical and climatically, those three cities is different but occupancy rate in tropical (Indonesia, Thailand) is shown a similarity and it is lower than subtropical (China, Japan) this may explain the difference in yearly energy use pattern.

3) Beside the climate situation, in this study the housing appliances are very important influential factors on energy consumption in these three countries. There is a big possibility of family who doesn't has such kind of appliances now will follow the richer family's life standard. Not only families in one country, but also there is also possibility of country's life standard change follow the developed country. If Indonesian follow the Chinese and Thai lifestyle it would be have bigger energy consumption average because of the human population.

4) The architecture design of the housing building is also be an important factor in energy conservation. From the result data, in Thailand and Indonesia, energy consumption increases with the popularity of air conditioners. To prevent the increase of energy consumption, it is necessary to design open spaces between rooms for effective ventilation, to use window openings for night time ventilation, to construct roof insulation and air tightening in rooms with air conditioner. Also, the appropriate structure material choice, building orientation, and space configuration will impact to the occupant's behavior lifestyle to consume less energy. The housing design which can maximize the natural lighting and ventilation or insulation system will reach the indoor thermal comfort without consume much energy.

第四章

日本における住宅エネルギー消費量に関連した
ライフスタイルに関する調査

Chapter four: Survey and Analysis on Household Lifestyle in relation with Energy Use in Japan

4-1 Background

4-2 Survey outline

4-3 Result of questionnaire survey on household lifestyle and energy use in Kitakyushu

4-4 Sensitivity analysis on correlation of household lifestyle and residential energy use

4-5 Summary

4-1 Background

After the Great East Japan Earthquake, the percentage of fossil fuels has been increasing in Japan, as a substitute for nuclear power as fuel for power generation. The level of dependence on petroleum which had been on a declining trend in recent years increased to 47.3% in fiscal 2012 [1]. As a result, the government has been working to construct energy policies aiming to provide a stable energy supply and lower energy costs. In this process, the introduction of energy saving and renewable energy has been promoted, and reviews are being conducted in a direction toward lowering the level of dependence on nuclear energy. In the other hand, the energy consumption of the building sector has increased 2.5 times (household sector is 1.3 times) during 1973 to 2007, the highest increase compared to transportation (2.0 times) and industrial sector (1.0 times)[2].

The housing sector consumes energy more than double that of the time of the first oil crisis, while after the oil crisis, development of energy saving type home electronic appliances, gas apparatuses and so on were penetrating progressively to homes. In 2011 the annual energy consumption of housing sector reached 38.4 GJ/household, where 34.7% are shared from appliances and lighting followed by hot water supply (28.3%) and heating load (26.7%) [3]. Energy consumption has been increasing under the influence of changes in national lifestyle in the pursuit of convenience and comfort, an increase in the number of households, and the changes in the social structure such as rise in the proportion of the aged and use of larger electric appliances. For that reasons, it is important to understand the current condition of energy use and daily lifestyle of households in Japanese society.

Several studies have obtained the major influential lifestyle factors on household's energy use and proposed some strategies to change the behavior of occupants, but the sample mostly were randomly taken, especially in terms of household's types. Before this study, we conducted rudimentary surveys in other Asian

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[1] Statistical Handbook of Japan, Chapter 7, Energy, Statistics Bureau, Japan (2013) 77-82.

[2] The Agency for Natural Resources and Energy, "Comprehensive Energy Statistics".

[3] The Institute of Energy Economics, Japan, "EDMC Handbook of Energy & Economic Statistics in Japan".

big cities such as Shanghai (China) and Jakarta (Indonesia) to more than a thousand respondents in order to grasp the house energy situation in developing countries. In this paper, we selected a local city of Kitakyushu in Japan (Kitakyushu City was chosen by the national government as a model for developing environment based community[4]) and targeted the younger nuclear families aging between 20's to 40's (married couples with children, or single parent with children) as representative for future energy demand. The large number of feedback and unique database are new contribution to this research field, since it is very difficult for researcher to conduct such kinds of questionnaire surveys in Japan due to privacy issues and strict rule of local government. This study also adds a new method on grouping the households based on daily behavior and physical attributes by analyzing the similarities and dissimilarities. Furthermore, we also contribute to the discussion on energy use pattern by types of houses and energy sources.

4-2 Survey outline

The questionnaire survey was carried out at the beginning of 2012 among more than 4,000 households targeted the younger families and selected in the high density of local residential areas. The questionnaires targeted young families (aging between 20 to 40 years old of householders) to know what they are thinking about future and give direction to the local government on facing the energy crisis and environmental issues.

In order to obtain representative samples, the sampling method was designed in three stages. In the first stage, the seven wards/districts in Kitakyushu City were decided then we classified each based on the district characteristics. In the second stage, we selected the most populous residential area of each district to get a high number of respondents. In the third stage, by using GIS (Geographical Information System) we selected the nearest elementary school in each selected residential area. Through the elementary school, the questionnaires were distributed randomly from first-grade to sixth-grade students and let the householders fill in the answers. **Figure 4-1** shows the location of the surveyed areas in seven districts of Kitakyushu City. The basic information and feedback number of each district are presented in **Table 4-2**.

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[4] Kitakyushu City Homepage: http://www.city.kitakyushu.lg.jp/

Figure 4-1. Location of distributed questionnaire survey

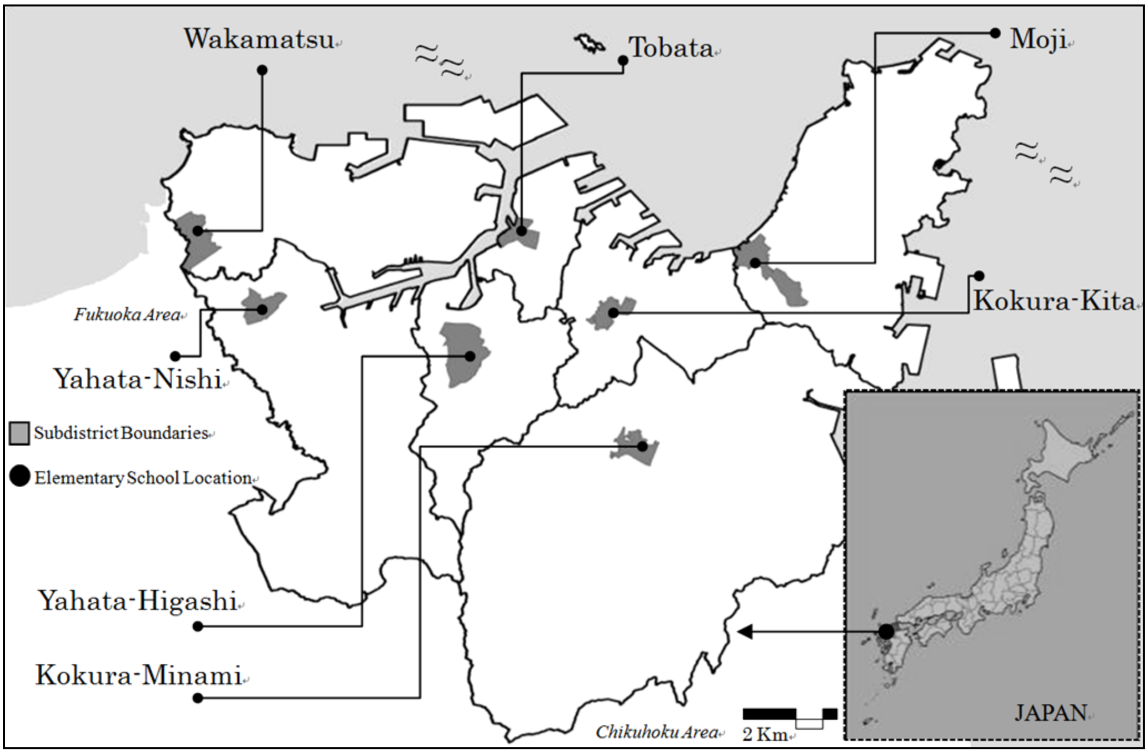


Table 4-2. District basic information

District (label)		Characteristic	Area (km^2)	Households number	Distributed	Valid feedback
1	Moji (MJ)	Port & tourist area(slope)	73.3	50,825	550	150
2	Kokura-Kita (KK)	Commercial & business (plain)	39.2	98,044	450	48
3	Kokura-Minami (KM)	Nature & commuter (slope)	170.2	99,321	650	227
4	Wakamatsu (WM)	Nature & residential (slope)	67.8	39,699	450	179
5	Yahata-Higashi (YH)	Leisure & tourist (slope)	36.3	35,711	600	37
6	Yahata-Nishi (YN)	Residential (plain)	83.04	121,656	1,150	237
7	Tobata (TB)	Industrial (plain)	16.6	29,885	600	150
Total			486,4	475,141	4,450	1,028

Table 4-3 shows the questionnaire survey contents, divided into four categories including the questions concerning building characteristics, family characteristics, daily lifestyle, and energy use. The energy use data were collected from householder's monthly bill for one year from January 2012 to December 2012. Several difficulties were encountered such as privacy on yearly income and householder's occupation, for that reason this paper did not include such variables into the analyses.

Table 4-3 Questionnaire contents

Categories	Contents
Basic Information	1) District name, 2) Address, 3) Respondent position in family;
Household Characteristic	1) Family number, 2) Family structure and age, etc;
Building Characteristic	1) House type, 2) Energy type, 3) Electric current, 4) Architectural area, 5) Construction year, etc;
Daily Lifestyle	1) Lighting, 2) Bathing, 3) Cooking activity, 4) Appliances use and ownership, 5) Heating-cooling method, etc;
Environment Condition	1) Satisfaction of indoor condition 2) Satisfaction rating of public facilities, 3) Transportation, 4) Amenity, Health, Convenience, Security, etc;
Energy Use	Monthly consumption and cost of electricity, water, and gas;
Future Improvement	Residence needs and future facilities.

4-3 Result of questionnaire survey on household lifestyle and energy use in Kitakyushu

4-3-1 Data processing and features of the sample

The households are taken as the respondents and all the questions are taken as variables. In the process of data filtering, we deleted the feedback with no answers for the whole questionnaire. We also partially deleted the feedback in the cases where a household just filled in a very small part of the questionnaires so that the feedbacks are useless for the one variable analysis, but still valid for other variables. As a result, 1,028 valid feedbacks from all districts were selected, the basic information of the samples are explained in **Table 4-4** .

Table 4-4. Basic features of samples

Item	Categories
Family number	Nuclear family more than 2 people (parent and children)
Floor area	30 to 380 m^2
House type	Multi-dwelling and single detached
Householder age	20s to 50s

4-3-2 Household attribute and energy use

The questionnaire feedback contains very detailed information referred to housing unit characteristics, daily pattern, and possession of equipment from seven different areas which are very random. In order to grasp basic data and trends regarding household's behavior, in this paper, the interval size were determined based on population size, standard deviation and 95% confidence level which is the most appropriate method to obtain representative results. The implications of determination were shown as average values of annual energy use in **Table 4-5**.

The results showed 61.3% of housings were a multi-dwelling unit type such as apartment, mansion, and municipal housing while 38.2% were single detached houses. Concerning floor area, most of the investigated buildings were between 50~100m^2, accounted for 40.5% in total. As the building energy source type, 80.8% were using combined electricity and gas, while 19.2% were using electric-only. Regarding the residential year period, most stayed from 0~5 years. As for the number of family member, 53.1% in total were 4 member families (mostly were parents with two children).

On the other hand, the daily lifestyle such as cooking period, bath length, and period of stay were also presented in **Table 5**. The appliances ownership and usage frequency relation with air conditioning system was presented in **Figure 2**. "Always use" means the operating period of appliances nearly equals to the occupancy period in the hot and cold seasons, "rarely use" means the operating period is only when the respondents feel uncomfortable (too hot or too cold) during occupancy period. From the results, 100% of respondents own room air-conditioner, only 6.5% is rarely using it. The survey also asked whether the households own other indoor thermal appliances (besides room air-conditioner) or not. The results show that only 5.8% don't own the electric room fan. While in the winter, the possession of oil (kerosene) heater is higher than electric and gas types.

Figure 4-2.Air conditioning equipment use and ownership

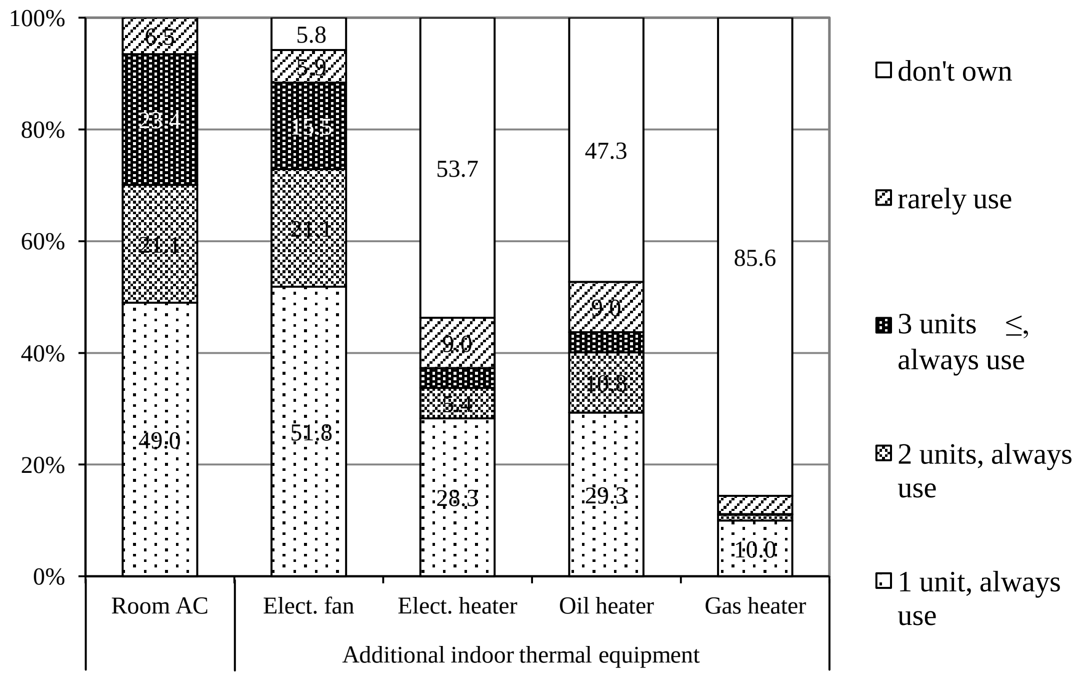


Table 4-5. Result of questionnaires*

Item	Categories	Composition (%)	Avg. energy use (GJ/(year*household))	Sample	Mean	St.D
House type	Detached	38.2	38.0	1196	-	-
	Multiple	61.3	30.7			
Floor area (m^2)	<50	20.3	27.0	1433	158.4	91.2
	50~100	40.5	33.2			
	100~150	28.4	37.3			
	150~200	6.8	37.5			
	>200	4.1	41.8			
Energy source	Elect. & gas	80.8	33.4	1451	-	-
	Elect. only	19.2	34.0			
Residence period (years)	0~5	38.7	29.0	1745	8.2	5.7
	6~10	29.5	33.4			
	11~15	20.2	34.2			
	16~20	6.9	36.4			
	>20	4.6	56.4			
Family size (person)	≤3	21.5	28.7	1774	4.2	0.97
	4	53.1	33.2			
	5	19.2	34.2			
	≥6	6.2	53.3			
Cooking period (times/day)	≤2	37.9	32.7	1809	2.6	0.57
	3~4	59.9	34.2			
	≥5	2.2	42.0			
Bath length (minutes/day)	≤30	4.5	31.8	1827	21.8	10.6
	30~60	33.3	34.5			
	60~90	49.4	37.2			
	>90	12.8	41.5			
Daily stay hour in home (hours/day)	<15	1.2	32.2	1784	17.5	1.39
	15~17	42.4	32.6			
	18~20	52.9	34.0			
	>20	3.5	39.0			

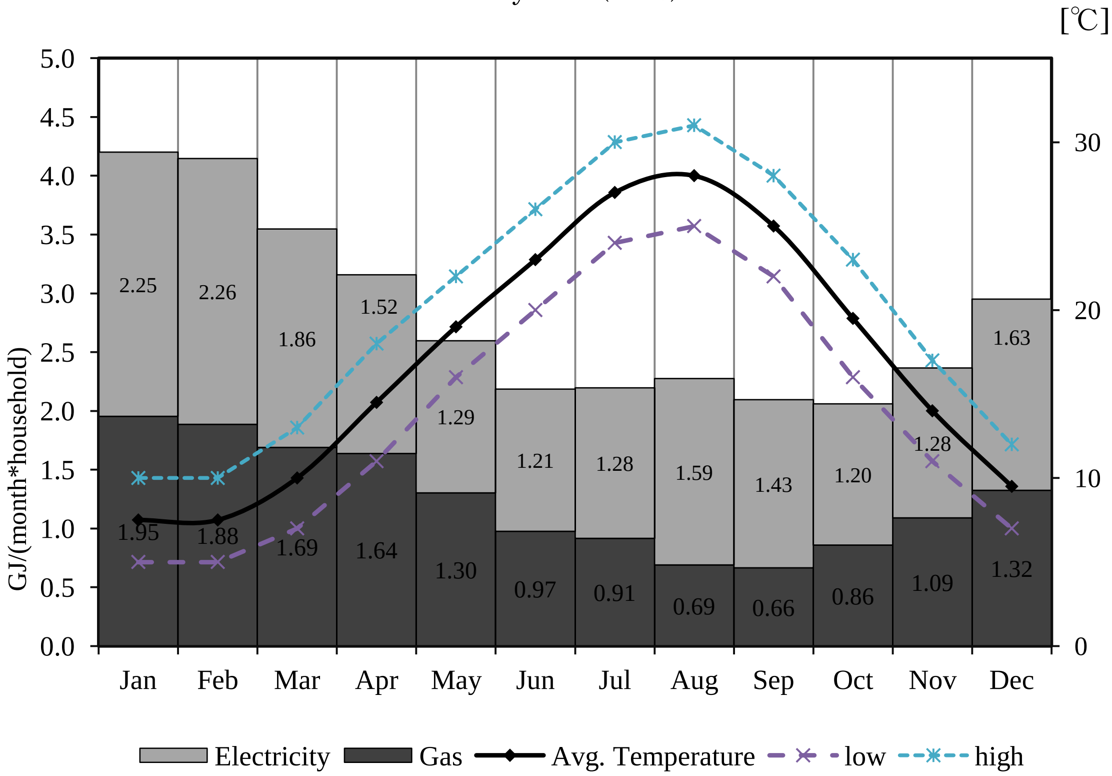
**this result only shows the basic information concerning the housing characteristics and lifestyle pattern*

All types of energy sources were converted into caloric value, and the unit caloric values of electricity and gas were shown in **Table 4-6**. The conversion calculations are using the values of secondary energy (demand side of energy use). Monthly averages of energy use were shown in **Figure 4-3**, commonly, the average of monthly electricity use was more than gas use. The monthly average value of electricity use ranges from 1.20 to 2.25 GJ/household. While the monthly average gas amount ranges from 0.66 to 1.95 GJ/household. The peak of total energy use appears on January, as the lowest temperature of Kitakyushu City, accounting for 4.2 GJ/household of total electricity and gas. This is due to the peak time of space heating from the end of December to February. During the winter, families also spent longer time on bathing than in summer. In the interim periods (spring and autumn), the use of gas decreases and reaches the lowest average in September (0.66 GJ/household), at this time the electricity use is almost three times that of gas.

Table 4-6. Energy conversion value

Energy Source	Electricity		Gas	
	Primary	Secondary	LP Gas	City Gas (13A)
Calorific values units	9.97 MJ/kWh	3.6 MJ/kWh	50.2 Kg/m^3	46.1 MJ/m^3

Figure 4-3. Residential energy use from surveyed data and average temperature in Kitakyushu (2013)



4-3-2 Energy use by house type

The questionnaire resulted the number of families who live in multiple dwelling (includes apartment, mansion, and governmental apartment) was higher than in the detached houses. The number of house under investigation by house type is showed in **Table 4-7**. Based on the questionnaire results, the multiple dwellings type in most cases has floor area smaller than detached house type, varying between 30~60m^2 (52.2m^2 in average). In the other hand, detached houses had a more varied floor size, rate between 50~300m^2 (186.7m^2 in average). Hence, there was a strong correlation between house size and house type. **Figure 4-4** explains the composition of residential housing in Kitakyushu City based on the house type. Generally, multi-dwelling types dominate the housing around elementary schools in Kitakyushu City, but in Wakamatsu District has the largest average number of detached houses. In the other hand, as it is expected, Kokura-Kita District which is located in the downtown Kitakyushu has the smallest average number of detached houses. Commonly, younger families in Japan stay in multi-dwellings such as rented apartment, mansion (higher class of apartment with bigger floor area), or municipal housing (apartment with local government subsidy). Later, after they have enough savings, they will move to and settle in detached houses for a longer time. In **Figure 4-5**, the comparison analysis of energy use in single detached housing and multiple floor housing were presented. Detached housing had spent higher energy use per year in each district, the difference rated from 3.3 to 23 GJ/ year. This is due to the single-detached having more air-conditioned floor area than multi-dwelling. By district, detached houses in downtown Kokura-Kita consumed the most energy per household compared to other districts followed by Kokura-Minami. In case of multi-dwelling, Moji consumed the most energy and has higher energy use for multi-dwelling than Kokura-Kita.

Table 4-7. Number of house under investigation by house type

Type	House size average (m^2)	Respondent
Single Detached	186.7	414
Multiple Dwelling	52.2	782
	Avg: 134.0	Total : 1196

Figure 4-4. Composition of house type by district

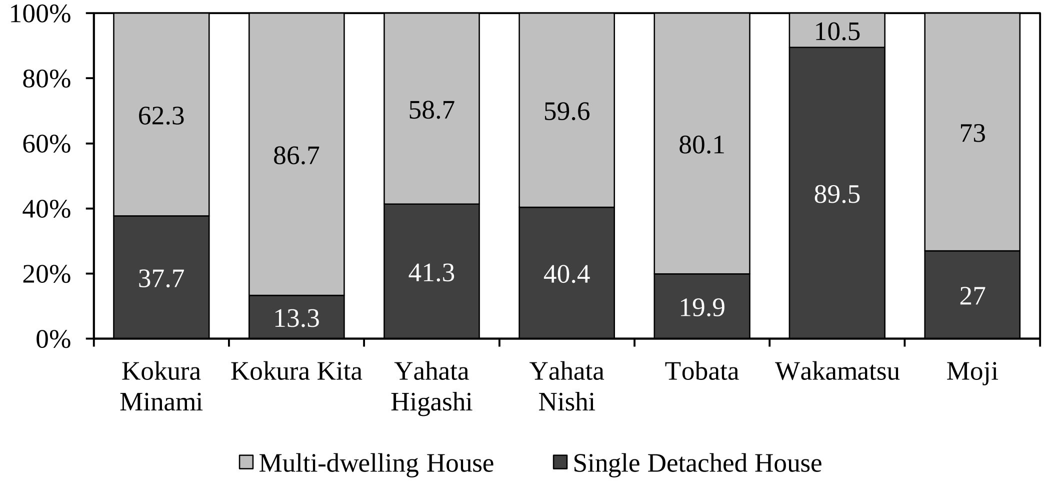
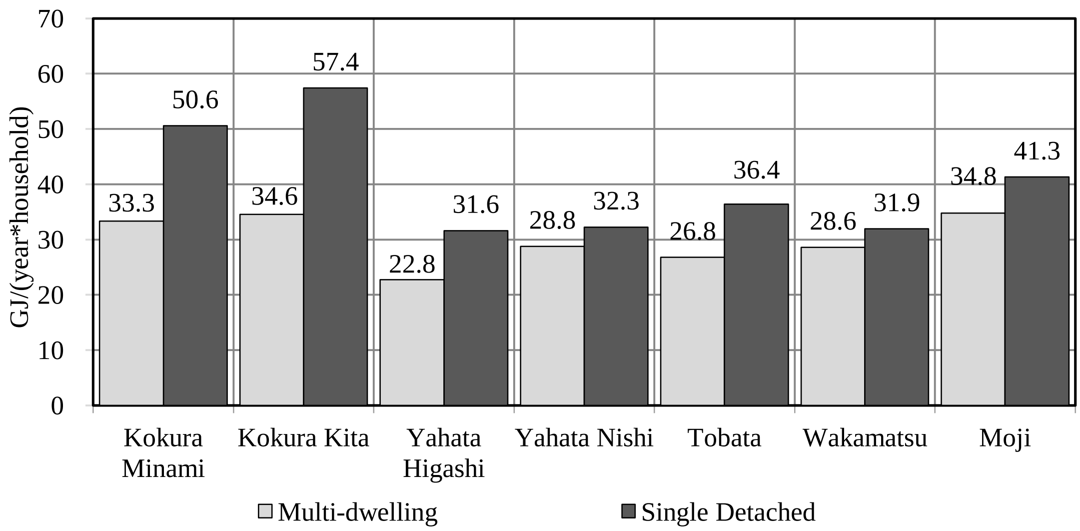


Figure 4-5. Annual average energy use by house type



4-3-3 Energy use by energy source type

Electric-only house (or more popular as all-electric-house in Japan) was a house that unified all the energy into electricity to be used. Electrical equipment to be used to operate this house was mainly for the water heater, electric cooker stove (IH=Induction Heating), air conditioning system, electric room heater or floor heating system, or regenerate heat pump. The type of energy source and end use was explained in **Table 4-8**. Based on the questionnaires result, the number of electric-only house in

Kitakyushu was 168 houses which is 13% from total valid feedback, especially in Wakamatsu District 30% of total households were electric-only type.

The world oil crisis might push the Japanese government to promote the electric-only house in Japan, which firstly introduced in 1980s and has become more popular from the early 2000s until now, not only applied on detached types of house but also on multi-dwellings. In the other hand, by early 2007, the needs of electricity in housing sector increased rapidly due to the increase of living standard and innovation in home electric appliances (the cooking appliances, furnace, water heater, and clothes dryer all become electric). Even so, tremendous damage of power generation infrastructure caused by Great East Japan Earthquake in 2011 resulted in the introduction of rolling blackouts and the weakness of electric-only houses were exposed leading the public to rethink its housing energy future.

In case of primary energy sector, the total energy use of electric-only houses from seven districts were much higher than the common electric-gas house's energy use, contrary, in demand side (secondary energy sector) the energy use of electric-only houses were much lower than electric-gas houses. The comparison between annual primary and secondary energy use per households were shown in **Figure 4-6**. In relation to cost, **Figure 4-7** presented the yearly energy use cost difference between electric-only type and common type. It could be explained that electric-only house has economical benefit than the ordinary house. The reason is in electric-gas house there were basic tariffs on each electric and gas bills separately. The difference varies from 11% (in Yahata-Nishi) to 28% (in Yahata-Higashi).

Table 4-8. End use type and number of houses

Type	Energy type	End use	Sample
Type 1	Electricity & Gas	Heating, cooling, lighting, appliances,	1283
		Cooking, hot water, appliances	
Type 2	Electric-only	Heating, cooling, lighting, appliances, cooking, hot water	168

Figure 4-6. Secondary (left) and primary (right) energy use by house energy type

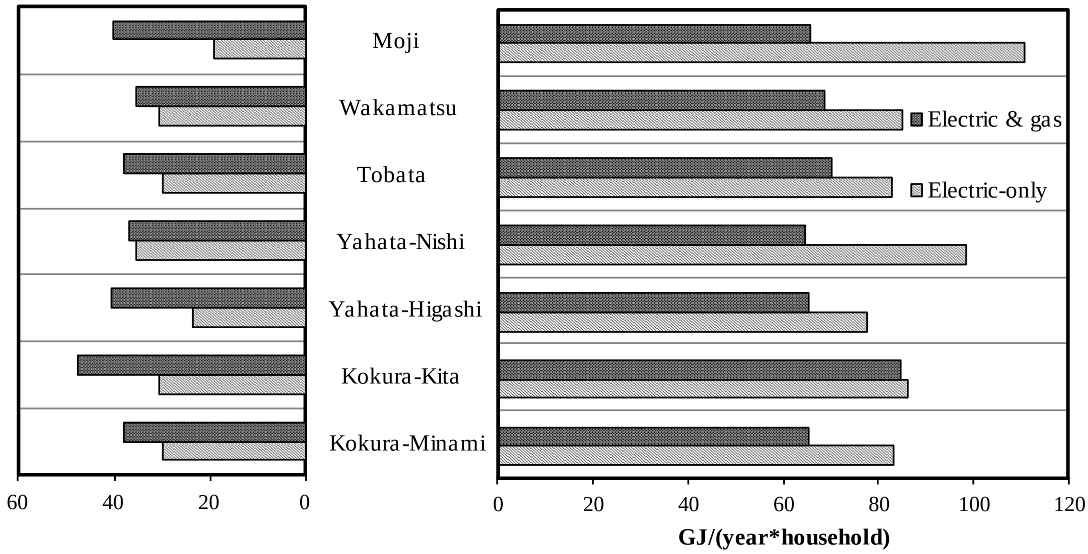
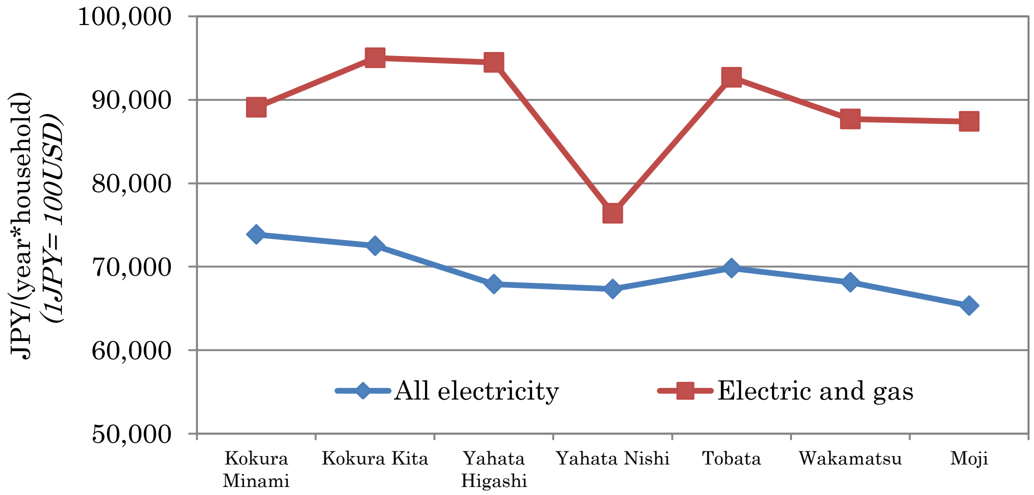


Figure 4-7. Annual cost by house energy type



4-4 Sensitivity analysis on correlation of household lifestyle and residential energy use

4-4-1 Influential Factors on Housing Energy Use

Multiple Regression Analysis (MRA) with *Quantification Theory 1* was used to weigh the contribution of independent variables (lifestyle types) to the dependent variable (total energy use per households). In the context of sensitivity analysis, MRA involves fitting a linear regression to the model response and using standardized regression coefficients as direct measures of sensitivity. In this method, the qualitative and quantitative variables of yearly energy use can be introduced into models and be analyzed together.

Firstly, the correlation analyses conducted to more than 40 variables and only the factors that have positive correlation were taken for the next stage of analyses. In this case, there were 24 variables used as independent variables. They were:

Table 4-1 independent variable included in the analysis

1. House size,	7. Daily stay hours in home,	13. Bath length per person,	19. LED lamp ownership,
2. Family size,	8. Wakeup/sleep schedule,	14. Cooking schedule,	20. Electric fan ownership,
3. Household age,	9. Sleeping hours per day,	15. House energy type,	21. AC ownership,
4. House type,	10. Toilet and kitchen lighting,	16. TV ownership,	22. Oil heater ownership,
5. Residential year,	11. Electric light pattern,	17. Solar PV ownership,	23. Elec. heater ownership,
6. Electricity current,	12. Bath method,	18. Computer ownership,	24. Gas heater ownership.

The significant test was taken to judge that to what extent the *Partial Correlation Coefficient* (PCC) was large enough, the factors will have effect the energy use. The bigger *Significance Probability* (SP) has the less PCC. It means the factor has a bigger influence on the housing energy use. In order to get valid results, the regression analysis was conducted on all predicted factors. As a result, 24 factors were revealed with a high correlation score. Then the regression was conducted once again to include 24 factors with the filtering method correlation score up to 95%. It means if SP less than 0.05, the factor has big influence on energy use. The score of each variable was used to analyze the influence extent of all the categories of qualitative variables (e.g. housing characteristic, family characteristic, and lifestyle characteristic), and quantitative variables (e.g. appliances ownership) on the dependent variable (yearly energy use).

On the other hand, the data filtering was conducted once again on 1,028 households. Only data with 100% validity was selected. In the end, there were a total of 70 households from seven different districts comprising the sample collectivity in the model. The results of a regression analysis were summarized in **Table 9**. The other 19 factors were not presented because the SP scores were higher than 0.05. According to the assumption that significance probability was smaller than 0.05 (or in other words has correlation score bigger than 95%), the factor had a big influence on energy use. As a result, the influence extent of the factors on energy use can be established in the following order: 1.House size (architectural area); 2.Possession of electronic air conditioner; 3.Residence year; 4.Daily cooking period; and 5.The number of family member. These are the important factors on energy consumption based on the values of SP. On the other words, the bigger house floor area, the larger use of electric air-conditioners, the longer stay of households, the more use of kitchen appliances and the bigger family member can result in the larger energy use of housing in Kitakyushu City. From this result, the prediction equation can be presented as follow:

$$y = 6.67x1 + 4.51x2 + 2.58x3 + 2.58x4 + 1.85x5 - 16.1 \quad \textbf{(eq. 4-1)}$$

where,

y: dependent variable (annual energy use)

x(n): quantitative independent variables

x1: House floor area; *x2*: AC ownership; *x3*: Residence year; *x4*: Daily cooking schedule; *x5*: Family size.

Other factors have little influence on annual energy use as their significance probability are larger than 0.05 (not included in Table 8). As for the categories weight, if the score is positive number, there is the direct proportion between the energy use and the variables.

Figure 4-8 shows the comparison between surveyed results and predicted energy use from regression models. The *coefficient determination* (R^2) was 0.816, indicating that the regression model is reasonably well fitted with investigated values. Therefore, the empirical regression equation was found to have a considerable predictive power. Adjusted R^2 tells the percentage of variation explained by only the independent variables that actually affect the dependent variable. We included the information of district name in each single value so that the regression can grasp which district group has the lowest or the highest energy use. But the result shows there are no significant impact of district characteristic on energy use since the data were scattered.

Table 4-9. Analysis result of influential factor on residential housing energy use

Factors	Categories	Sample	Categories Weight	PCC	SP
House Floor Area	<50	7		0.803	5.42E-16
	50~100	28			
	100~150	17			
	150~200	10			
	>200	8			
AC Ownership	rarely use	2		0.538	3.16E-06
	1	27			
	2	23			
	3 or more	18			
Residential Year	0~5	27		0.452	1.41E-04
	6~10	23			
	11~15	14			
	16~20	4			
	>20	2			
Cooking period	2 or less	1		0.279	0.023
	3	26			
	4	39			
	5 or more	4			
Family Size	2	2		0.261	0.034
	3	14			
	4	39			
	5	9			
	More than 5	6			

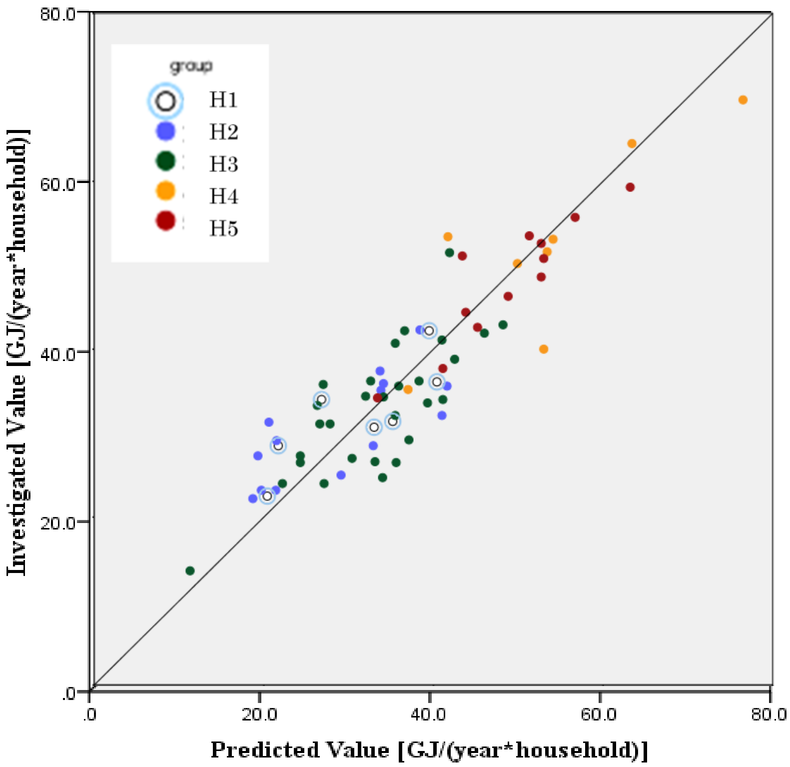
Figure 4-8. Multiple regression analysis result

R : 0.903

R^2 : 0.816

Adjusted R square : 0.801

Std. error of the estimate : 5.43



Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.722[a]	.521	.516	8.675998	.521	95.750	1	88	.000	
2	.749[b]	.562	.552	8.347852	.041	8.054	1	87	.006	
3	.775[c]	.600	.586	8.016631	.039	8.338	1	86	.005	
4	.790[d]	.624	.606	7.824341	.023	5.279	1	85	.024	
5	.800[e]	.639	.618	7.707209	.015	3.603	1	84	.061	
6	.809[f]	.654	.629	7.591360	.015	3.583	1	83	.062	1.130

a. Predictors: (Constant), HSIZE

b. Predictors: (Constant), HSIZE, RYEAR

c. Predictors: (Constant), HSIZE, RYEAR, AC

d. Predictors: (Constant), HSIZE, RYEAR, AC, TV

e. Predictors: (Constant), HSIZE, RYEAR, AC, TV, AMP

f. Predictors: (Constant), HSIZE, RYEAR, AC, TV, AMP, LIGHT

g. Dependent Variable: ENE

4-4- 2 Classification of Households Group

Besides the analyses on influential factors of the households yearly energy use, *Hierarchical Cluster Analysis (HCA)* was also conducted to identify the type of family characteristics and daily lifestyle related with the variant of housing energy use. Multiple regression analysis with *Quantification Theory 1* in **section 4** has resulted five major influential factors in housing energy use, then the result was used to determine the classification of households group. The multiple regression analysis was conducted once again by including *Partial Correlation Coefficien*t *(PCC)* from up to 0.2 (following the assumption that: if the factors have the *PCC* between *± 0.0~0.2* it means the factors are uncorrelated, if *PCC ± 0.2~0.4* means the factors have weak correlation, if *PCC ± 0.4~0.6* is strong correlation, if *PCC ± 0.6~0.8* means the factors have strong correlation, and if *PCC ± 0.8~1.0* means the factors have very strong correlation, it means more variables included and as a result we listed the variables in **Table 4-9**. Fourteen factors influencing the household energy use were included, and then categorized into numerical grade from grade-1 to grade-5.

The influence factors in **Table 4-10** were defined as variables, the *HCA* conducted by using the *Squared Euclidean Distance* with *Ward's Method Clustering* in *SPSS ver.20*. Based on the similarity and dissimilarity of variables attributes, the final dendrogram was presented in **Figure 4-9**. The maximum level of dendrogram is at point 24.756, means it is the point at which samples are cannot be clustered (100% similarity). The vertical dashed lines show the cutoff value which based on different clusters is differentiated. The branches cut at two different points: *p (50)* =12.378 and *p (25)* =6.189. *p (50)* is the point at which samples are exactly as similar to one another as they are dissimilar (50% similarity/dissimilarity), means if the branches are cut at *p(50)*, the characteristics of each cluster will be difficult to grasp due to the large number of samples. For that reason the most convenient method to get representative results to reflect the characteristics is by cutting at *p (25)*. At last, five clusters will be labeled as H1, H2, H3, H4, and H5 respectively. Checking back to the household's attributes, the interpretation of structure of data is made and showed in hierarchical tree diagram in **Figure 4-10**.

Table 4-10 Grade categories of influential factors in energy use

No	Factor	Grade Categories				
		1	2	3	4	5
1	House size (m^2)	0~50	51~100	101~150	151~200	Up to 200
2	AC ownership (unit)	0	rarely use	1	2	3 or more
3	Residential year (year)	0~5	6~10	11~15	16~20	21~
4	Cooking period (times/day)	0~1	2	3	4	5 or more
5	Family size (person)	2	3	4	5	6~
6	House type	Multi-dwelling	-	-	-	Single Detached
7	Kitchen lighting in daytime	no	-	sometimes	-	yes
8	Energy type	Elect.-gas	-	-	-	Elect. only
9	LED lamp use	no	-	some	-	yes
10	Solar PV use	no	-	-	-	yes
11	Toilet lamp in daytime	no	-	sometimes	-	yes
12	TV ownership (unit)	0	rarely use	1	2	3 or more
13	Sleep length (hour/day)	0~3	4~6	7~9	10~12	12~
14	Electric current (ampere)	15~20	30	40	50	60~

Figure 4-9 Dendrogram and energy use of samples

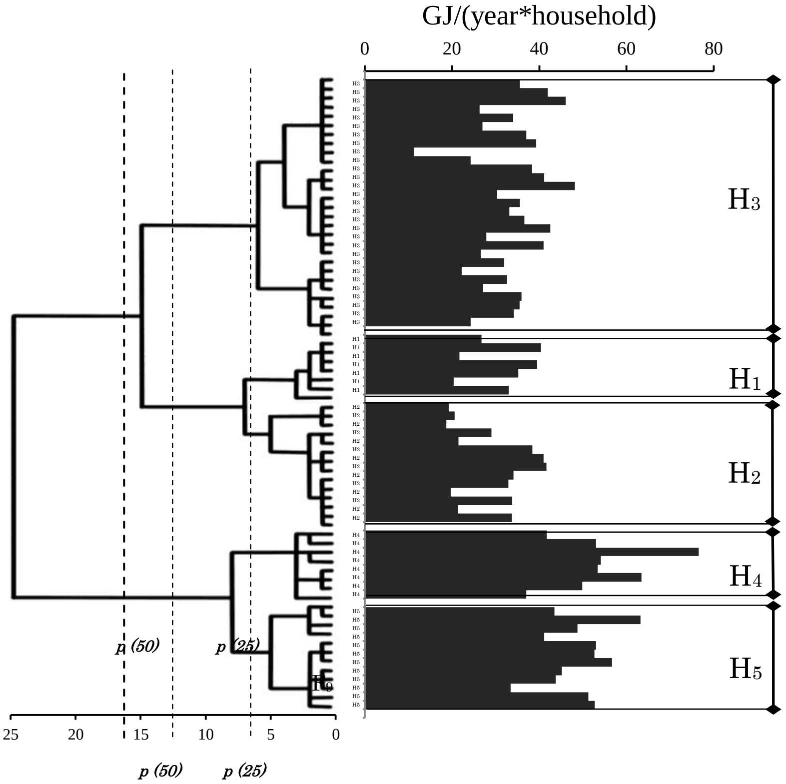


Figure 4-10. Tree diagram of family clusters

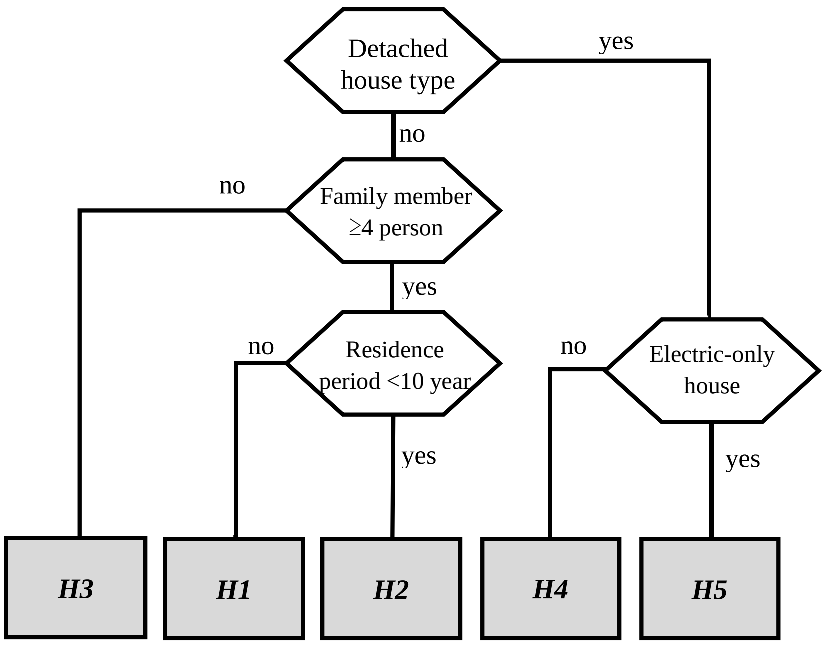


Figure 4-11 shows each cluster characteristics in terms of households attributes and lifestyle characteristics. While, **Figure 4-12** shows the average of energy use by group. In terms of households attributes, H1 group characteristics could be described as multi-dwelling types with family member of four person or more, using the combination of electric and gas for energy supply with electric current are not higher than 40 Ampere, and more than ten years of residence period. In terms of lifestyle attributes, households in H1 group are using electric lighting at daytime both in kitchen and toilet room, using AC not more than 1 unit, and cooking not more than two times a day. Compare to others, H1 group was the second lowest energy use in the clusters, 37.2 GJ/ (year*household). While, households in H2 group had the lowest electricity use per year 37.2 GJ/ (year*household). H2 group was multi-dwelling houses with the family size more than four persons, residence not longer than ten years of residence, AC ownership not more than two units and not using electric lighting at daytime in toilet. In terms of lifestyle attributes, H2 group was not so different with H3 group, except the behavior on using kitchen electric lighting in the daytime, but in terms of energy use the difference reach 2.8 GJ/(year*household). It means, electric lighting contribute significant change to energy use between these two groups. In the other hand, H4 had the highest of total energy use per year reach 64.4 GJ/ (year*household) with second highest electricity use (51.2 GJ/ (year*household)) and also first highest of gas use between groups (13.2 GJ/ (year*household)). The characteristic of H4 could be described as detached type of house with bigger floor area, powered with electricity and gas, often used more than 3 units of electric air conditioner, with residence year not more than 10 years. While H5 group consumed the highest electricity between the groups (58.6 MJ/ (year*household)) which is detached house type group with large floor area, powered with electric-only, and turn on electric lighting even in daytime when using kitchen and toilet. These results also show that behavior on using electric lighting in daytime and the energy sources type have an impact on changing the household's energy use.

In comparison with the average residential housing energy use of Kitakyushu City, H4 and H5 groups were 55% and 41% higher from average standard of Kitakyushu residential energy use. While the energy use of H3 group is nearly the average standard of Kitakyushu, or in the other words H3 group could represent the average of households characteristics in Kitakyushu City since the number of sample is also the largest among the clusters.

Figure 4-11. Group classification

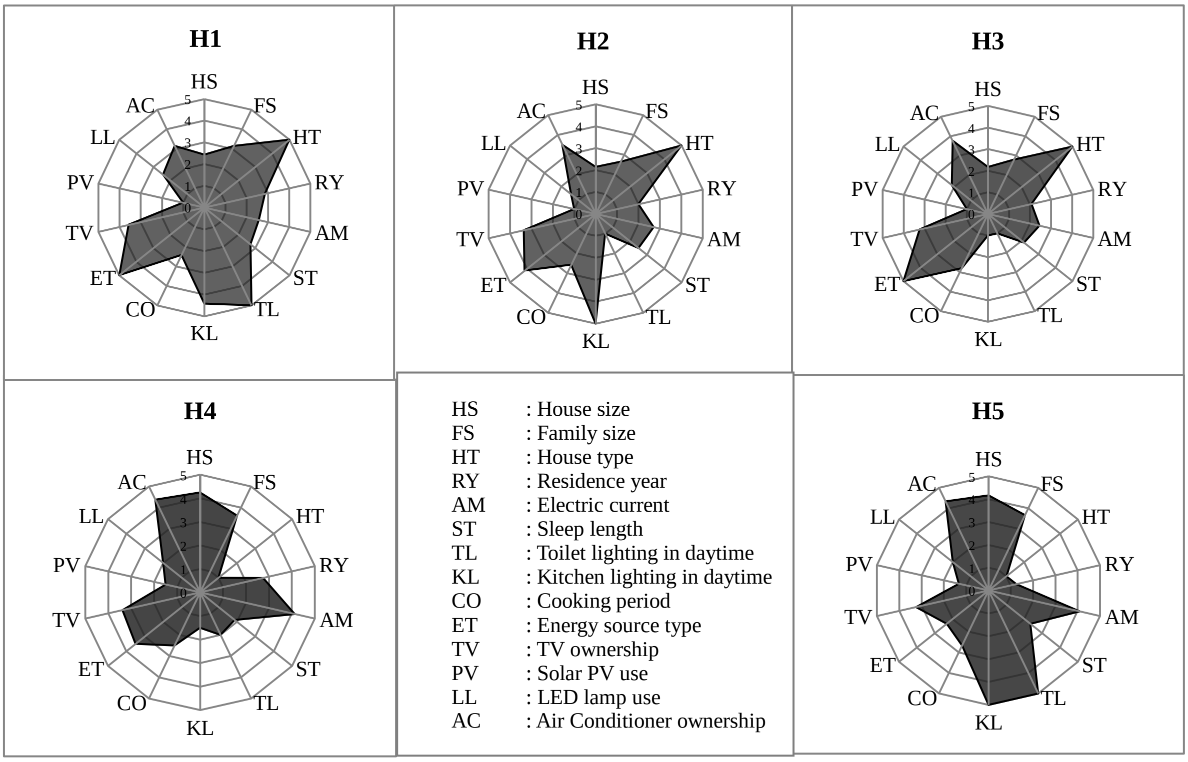
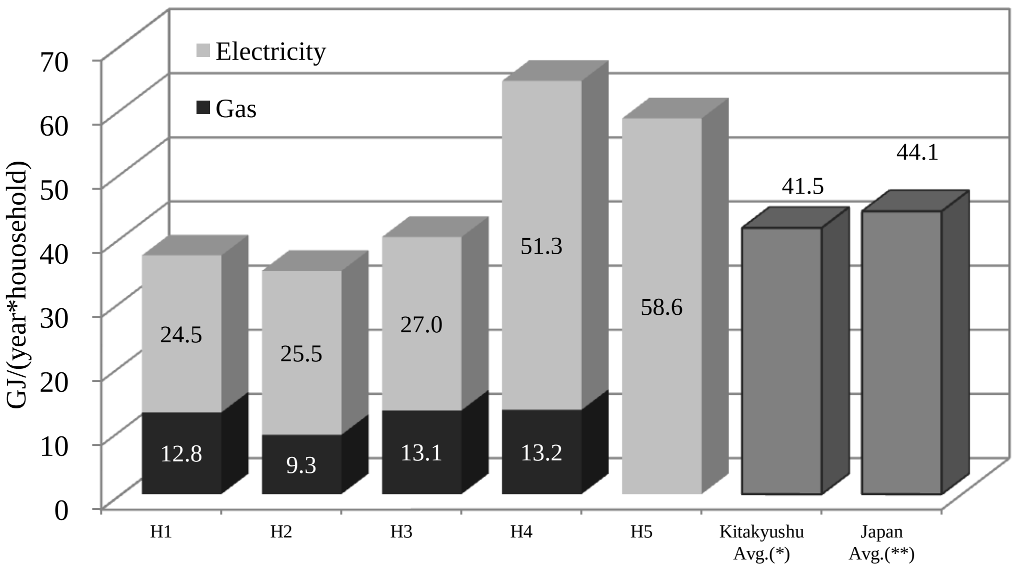


Figure 4-12. Annual average of energy use by group



**Statistics Bureau, 2012*
***Jyukankyo Research Institute, 2010*

4-5 Discussion

The results of questionnaire survey show that the types of house make significant difference on total annual energy use in average per household. But in the influential factor analysis, floor area is the major influential factors on household energy use and house types are judged as the non-influential factors. The reason is because there are number of houses that the type is different but the floor area is almost the same. Commonly, the single-detached houses have larger floor area, more rooms, and more storey than multi-dwelling type (**Table 5**), thus, the demands of energy used for space conditionings and lightings in single-detached houses amount higher than in multi-dwellings. Based on the analytical results (**Figure 11, 12**) the multi-dwellings have the potential on practicing energy-saving lifestyle rather than single-detached. Compared to the whole Japan, number of detached house in Kitakyushu City is about 10% higher (Japan Statistic Bureau, Housing and Land, 2013). Considering to the improvement of living standard, it is expected that the number of single-detached will continue to increase and more energy will be consumed in the near future if no efficiency energy-saving countermeasures are adopted from now on.

The results also found that the electric-only houses have an economical benefit in terms of annual energy cost compared to combined gas & electric houses but in primary energy sector the electric-only houses consumed more energy. Since electric-only house is not popularly adopted, Japan can save the primary energy use more than other developed countries can (such as The US and in EU countries that mostly dominated by electric-only houses[5]). The estimates from *Residential Energy Consumption Survey* of *US Energy Information Administration* show that 48% (which is the highest share) of end-use energy in US homes was for space heating-cooling [6]. The situation is different compared to Japan, where the energy use for space heating and cooling almost same as the energy use for appliances and lightings, while the highest share of end-use energy is for hot water. Therefore, deeper studies on end-use energy and its relationship with the use of hot water need to be conducted.

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[5] GEA, 2012: Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.

[6] Residential Energy Consumption Survey (RECS), 2009. Independent Statistics & Analysis. U.S. Energy Information Administration: http://www.eia.gov/

On the other hand, AC use and possession shows the second highest impact on yearly energy use in household. Many studies also found that the energy demand in housing sector is expected to increase continuously as well as the increase of housing appliances ownership[7][8]. Further analyses revealed that the building insulation such as wall material and windows material did not work at maximum efficiency in keeping the indoor temperature. The high dissatisfaction rate of the indoor thermal environment in winter and summer peaks, lead the lifestyle on using air-conditioner equipment become hard to control. It is expected that in the future more energy will be consumed in order to make the indoor thermal environment more comfortable. In addition, a study in Shanghai shows that housing energy use were affected by the satisfaction rate of thermal environment, the possession and use of AC, and house type[9]. Meanwhile a study in Japan cold climate (northern area) found that space-heating, space-cooling, lighting and usage of electronic entertainment appliances are the major influence on energy use[10]. Many of the results show that the AC use and possession have a remarkable effect on energy use, therefore, to increase the energy efficiency of air conditioners and to apply energy-saving behavior are recommended to lower the housing energy use.

The other major factors influencing household energy use is residence year, the reason can be described as the longer a family stayed the more electrical appliances they buy, the more appliances they have, the more energy will be consumed. It might be also correlating with the electronic appliances aging factors; the older electronic appliances may have lower efficiency of energy use.

Cooking period in a day is also become one of the influential factors on household energy use. Besides more cooking will consume more gas, as we all know that

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[7] H. Nakagami, Annual report of household energy consumption, Jyukankyo Research Institute Inc., Japan, 2002. (in Japanese).

[8] H. Nakagami, Appliance standards in Japan, Energy and Buildings 26 (1997) 69-79.

[9] S. Chen, H. Yoshino, M.D. Levine, Z. Li, Contrastive analyses on annual energy consumption characteristics and the influence mechanism between new and old residential buildings in Shanghai, China, by statistical methods, Energy and Buildings 41 (2009) 1347-1359.

[10] W.K. Fong, H. Matsumoto, Y.F. Lun, R. Kimura, Influences of indirect lifestyle aspects and climate on household energy consumption. Journal of Asian Architecture and Building Engineering, 402 6(2) (2007) 395-402.

the electrified of domestic appliances are more and more prevalent recent years and household energy use is increased accordingly.

Family size is also affecting the household energy use in this survey. Therefore, energy-efficient behavior such as gathered in the living room in the night, so that the use of air conditioning, lighting, and entertainment equipment can be reduced, should be promoted. In the future study, more attention will be put on the investigation on home activity related with the room design layout which affect to the use of home appliances.

Meanwhile, result of Hierarchical Clustering Analysis found that three of total five groups of households have lower annual energy use than the average of Kitakyushu City and whole Japan. It is very important that these types of younger families are potential groups in realizing energy conservation behavior in the future since Japan are facing an increase in the number of one-person households and rise in the proportion of elderly households. The results from this analysis can be used to help government to make baseline on developing the future residential buildings.

4-6 Summary

In this study, the housing energy use investigations were carried on in the southern local city of Japan. The yearly energy use and its relationship with households' behavior were also analyzed. The conclusions of this paper could be described as follows:

1. In terms of house building characteristics, it was found that about 65% of respondents are living in multi-dwelling house type. The multi-dwelling house type consumed 35% less energy yearly than the detached houses.

2. The study also found that only 11% of households are using electric-only energy sources while 89% use a combination of gas and electricity. Averagely, the electric-only house consumed more energy (in primary energy sector) than combined gas and electric house even the annual consumption cost is lower.

3. This research revealed the correlation of households' attributes and behaviors to the annual energy use. By statistical analyses, some evidence can be found to explain the energy use. The lowest average temperature in January and February affected the highest monthly energy use in a year. Unlikely electricity use which almost constant every month, the use of gas in the winter were almost three times than in summer.

4. The influential factor analyses show that the house size, AC use and ownership, residential year, cooking period, and family size greatly affect the annual energy use of residential housing in Kitakyushu City. Two factors related with occupant's behavior (AC use and cooking period) are very important influence factors besides above factors. The use of energy-efficiency appliances (especially related with space conditioning and food preparation) is the most effective way to save energy in residential houses.

5. By conducting the Hierarchical Cluster Analyses the lifestyle of households could be grasped and divided into five groups, each represents the general characteristic of Japanese households. Based on those results, the future of residential area should consider these main groups in order to preserve city energy use and strengthen the policy to build environmental friendly community.

6. Compared with the urban residential areas in other big cities of Japan, based on the results of this paper, Kitakyushu City has more efficiency of energy use in households.

However, the housing energy demand will increase if the energy-saving lifestyle and use of renewable energy utilization such as solar panel, fuel cell, and heat-pump are not rapidly popularized in households.

Further, the study will investigate and measure the real residential house includes of home appliances, space cooling-heating, and design performance in order to understand the major sources on residential energy use.

第五章

住宅ライフスタイルと住環境の影響に関する統計及び地理的な分析

Chapter five: Investigation on Residential Living Environment Condition from the viewpoint of Household Behavior and its Relationship with Energy Use

5-1 Background

Urbanization and the aging population have become increasingly important issues of urban planning in developed countries [1]. Migrants moved to the bigger cities tend to be young therefore the population aging will be more severe in rural and local cities than in big cities. Over the years, the urbanized environment of big cities has become the main subject of urban planners, policy makers, and many researchers have devoted to evaluating residential environment satisfaction as an indicator of citizen's quality of life. Therefore, it is necessary to clarify the present residential environment situation evaluated by actual residents especially in terms of the neighborhood facilities. Considering the deep relationship between people's behavior and physical components characteristic, we tried to conduct the comprehensive analysis by using statistical data and geographical tools.

People's behaviors are complicated with numerous influencing factors such as of social, economic, psychological, and natural conditions. Since the 1930s, researchers from various disciplines have conducted studies on measuring the lifestyles and the quality of life, not only that, the international organization such as UN, UNDP, UNESCO, and WHO have established various measurement method [2]. In this study, we adopted the WHO's four concepts of the residential environment to evaluate the satisfaction on the basic living requirement of human beings which firstly presented in 1961 [3]. The four concepts are the satisfaction of safety, satisfaction of health, satisfaction of amenity, and satisfaction on convenience.

This section presents a study on the method of evaluating residential environment condition in terms of neighborhood facilities and urban planning. Subjective evaluations on the residential environment through questionnaire survey were performed in order to grasp the resident's behaviors and preferences. In 2013, questionnaires were distributed to more than 4,000 households of younger families located in seven districts of Kitakyushu City, Japan. In this paper, we analyzed the result of questionnaires with

[1] http://www.un.org/esa/population/publications/pop_challenges/Population_Challenges.pdf

[2] Morita T, Noda K, Horiuchi Y. A computation of environment indices according to evaluation by residents: for environmental management in Kitakyushu City. City Planning Review, Annual Conference of the City Planning Institute of Japan 1985; 20: 133–147.

[3] Ge J, Hokao K. Residential environment index system and evaluation model established by subjective and objective methods. Journal of Zhejiang University Science 2004; 5(9):1028–1034

statistical software and discussed a unique result with Geographical Information System (GIS) software. As results, several findings could be described as follow: 1) almost of residents were unsatisfied about the safety, even the safety level score has increased during 10 years in the same area; 2) more than 60% of households group were realized their comprehensive wish on living condition, which mean the target of residential environment plan and design nearly achieved; 3) the convenience level of neighborhood facilities could be clearly explained by combining the statistical analysis results and GIS database.

This study is focusing the research on the residential environment in the local city, especially targeting the younger age (20 to 40) of multi-person household type (with children) rather than one-person household type or elderly couples in order to get more sensitive response to the urban characteristics such as safety and urban form. This paper hopes to meet the following objectives: (1) to investigate the actual situation from the viewpoint of nuclear family whether they are satisfied or unsatisfied in some component of residential environment; (2) to develop the method to understand the diversification of residential behaviors by making clear the residential emphasis influencing factors in local city; (3) to compare the residential satisfaction on living environment between data of 2003 and 2013 in same areas; (4) to establish the relation system between the subjective data from questionnaire survey and objective data from Geographical Information System (GIS) database.

Despite an increasing number of studies and many researchers have been performed to evaluate residential environment, and some evaluation models and index systems have been presented on the evaluation of residential areas, only a few have paid attention to the identification of the components that influence the degree of residential satisfaction and the literature on residential lifestyles is not rich, especially in Asian societies.

5-2 Survey outline

The study flow of this research is shown in **Figure 5-1**. The questionnaire survey was carried out at the beginning of 2013 among 4,450 households targeted the families and selected in the high density of local residential areas. In order to obtain representative samples, the sampling method was designed in three levels. In the first level, the seven wards/districts in Kitakyushu City were decided then we classified each based on the district characteristics. In the second level, we selected the most populous residential area of each district to get a high number of respondents. In the third level, by using Geographical Information System (GIS) we selected the nearest elementary school in each selected residential area. Through the elementary school, the questionnaires were distributed randomly from first-grade to sixth-grade students and let the parents or householders fill in the answers. **Figure 5-2** shows the location of distributed questionnaires in Kitakyushu City. Later, the name of the district will be used to represent the data results of each area. The basic information of districts and feedback numbers are shown in **Table 5-1**.

Table 5-2 shows the main contents of the questionnaire survey, divided into four categories including the questions concerning family characteristics, housing characteristics, four concepts of satisfaction evaluation, and residential preferences. The householders were asked to evaluate their present residential situation with respect to residential satisfaction on multi-attributes. Table 5-3 shows the example of question related with the satisfaction on amenity. Evaluations were given in terms of satisfaction degree elicited from "very much" (2 score) to "not at all" (-2 score). Through the survey, residential environment situation evaluated by residents all over Kitakyushu City could be grasped.

In the case of data processing, the households are taken as the respondents and all the questions are taken as variables. In the process of data filtering, we deleted the feedback with no answers for the whole questionnaire. We also partially deleted the feedback in the cases where a household just filled in a very small part of the questionnaires so that the feedbacks are useless for the one variable analysis, but still valid for other variables. As a result, the final valid feedback percentages are shown.

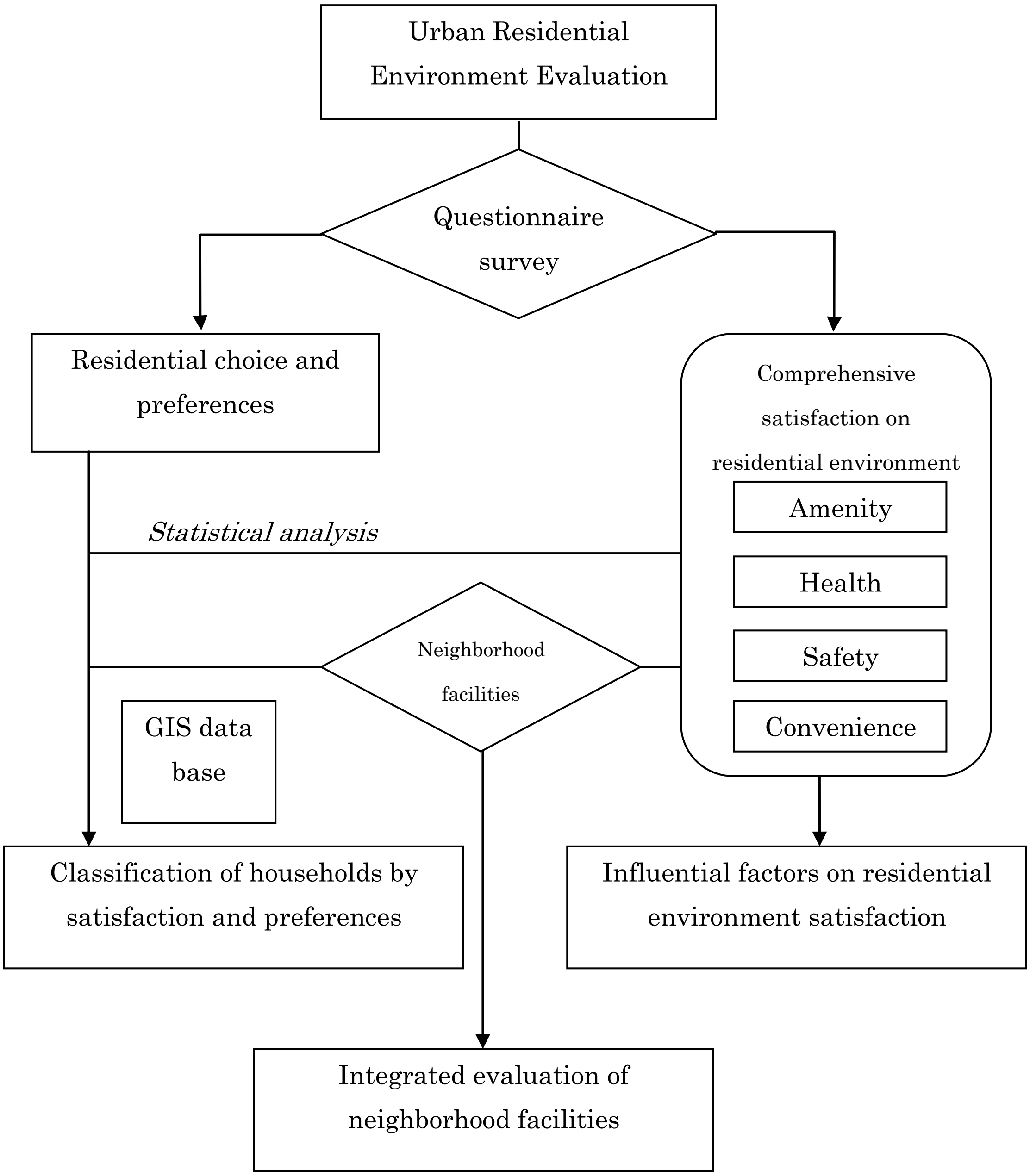


Figure 5-1.Research framework

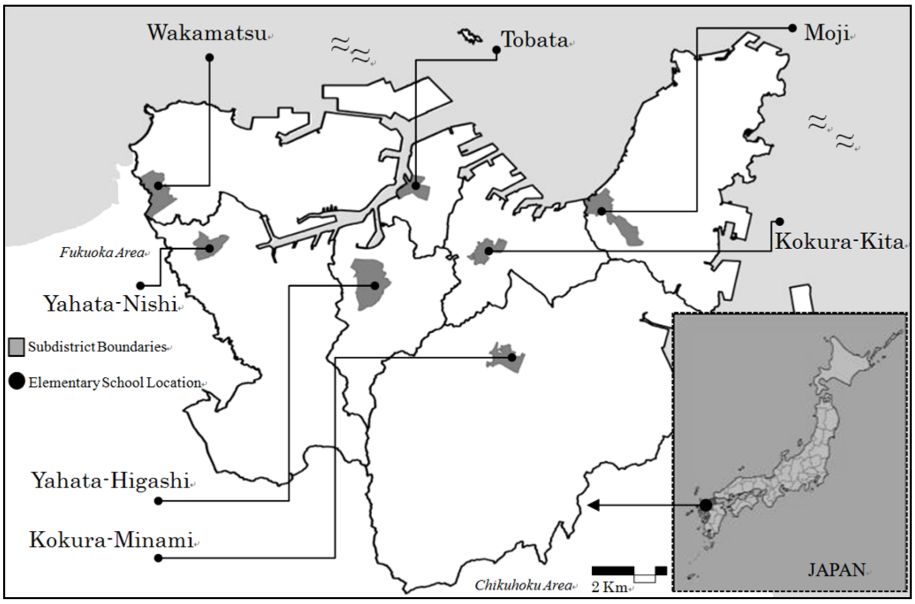


Figure 5-2.Location of investigated area in Kitakyushu

Table 5-1.Basic information of Kitakyushu City and feedback number

District		Characteristic	Area (km^2)	Households number**	Distributed	Valid feedback*
1	Moji (MJ)	Port & tourist area(slope)	73.3	50,825	550	150
2	Kokura-Kita (KK)	Commercial & business (plain)	39.2	98,044	450	48
3	Kokura-Minami (KM)	Nature & commuter (slope)	170.2	99,321	650	227
4	Wakamatsu (WM)	Nature & residential (slope)	67.8	39,699	450	179
5	Yahata-Higashi (YH)	Leisure & tourist (slope)	36.3	35,711	600	37
6	Yahata-Nishi (YN)	Residential (plain)	83.0	121,656	1,150	237
7	Tobata (TB)	Industrial (plain)	16.6	29,885	600	150
Total			486.4	475,141	4,450	1,028

**valid feedback for conducting statistical analyses*
***2012 Data, City of Kitakyushu, (http://www.city.kitakyushu.lg.jp/)*

Table 5-2. Questionnaire structure and contents

Categories	Questionnaire Contents		
Basic information	1) district name 2) address	3) household characteristics	
Housing characterist	1) house type 2) house size	3) construction year	
Satisfaction of neighborhood	1) Amenity (A)	A) Nature (A1)	
		B) Park & green space (A2)	
		C) City/town beauty (A3)	
	Comprehensive satisfaction of amenity		
	2) Safety (S)	A) Street light (S1)	B) Bicycle path (S2)
		C) Blind spot (S3)	D) Traffic situation (S4)
		E) Road maintenance(S5)	F) Shelter (S6)
		G) Pedestrian (S7)	H) Security post (S8)
		I) Disaster (S9)	
	Comprehensive satisfaction of safety		
	3) Health (H)	A) Sewage (H1)	B) Vibration (H2)
		C) Noise (H3)	D) Garbage (H4)
	Comprehensive satisfaction of safety		
	4) Convenience (C)	A) Supermarket (A1)	B) Elementary school (A2)
		C) Post office (A3)	D) Middle/high school (A4)
		E) Bank (A5)	F) Train station (A6)
		G) Library (A7)	H) Bus stop (A8)
		I) Medical facility (A9)	J) Leisure place (A10)
	Comprehensive satisfaction of convenience		
Residential Preferences	1) Convenience of shopping	2) Security from crimes	
	3) Convenience of commuting	4) Safety of walking, bicycle, and car	
	5) Nearby the workplace	6) Medical and welfare services is easy	
	7) Convenience of children going to school	8) Cleanliness is high	
	9) Access to neighbor city is good	10) Social connection is good	
	11) Beauty of nature	12) Education for children	
	13) Beauty of city	14) Economic reason	
	15) Noise and air quality of outdoor	16) House design	
	17) Sunshine and ventilation are	18) Good for leisure	
	19) Safety from disaster	20) There is inner (special)	
	21) Nearby the parent's house (independent)		

Table 5-3.Items evaluated for satisfaction on amenity

Items	Scores				
	-2	-1	0	+1	+2
Amenity of nature in the neighborhood					
Amenity of park & green space neighborhood					
Amenity of city/town beauty neighborhood					
Comprehensive satisfaction of amenity					

5-3 Result of questionnaire survey on living environment quality in Kitakyushu

5-3-1 Satisfaction of living environment condition

Table 5-3 shows the household characteristics and residential conditions of the seven districts respectively. The family member of the survey subject is mostly four persons per house and the age ranges are mainly from the 30s to 40s. House types are dominated by multiple apartment overalls but in some district detached house number is higher. Other residential conditions such as floor space and years of residence were also shown.

The mean scores and standard deviations of attributes of Stage 1 and Stage 2 are presented in Table 5-5, which indicate the degree of satisfaction with various residential attributes. It can be seen that, the overall evaluation of residential environmental quality in terms of "Satisfaction of residential environment" revealed that residents were fairly satisfied with the quality of residential environment, with the average score (standard deviation) of 0.66(0.99), which is close to the midpoint of the point scale (0.00). The scores of amenity, safety, health, and convenience are 0.94(1.02), -0.03(1.11), 0.86(1.00), and 1.03(0.94) respectively. Further, Table 6 shows the satisfaction scores of each contributed factors of residential satisfaction. There are a high average of scores in Amenity, and Health, but in case of Safety and Convenience negative scores were founded. Especially in terms of Safety of Blind Spot, Bicycle Path, and Security from Crime, average satisfaction scores are very low in all of investigated districts. It may because most of the respondents are parents of elementary school children who have high attention on the safety of their children from home to school. Blind spot (unidentified space) and low-security monitoring could lead any criminal activities which are very unpredictable. The Safety of Bicycle Path is also being a concern of the householders since their children may use the bicycle for commuting.

Based on the hierarchical scheme in Figure 5-4, Table 5-7 summarized the results of regression analysis. It shows that 80.7% of the variance in the assessment of "Residential Satisfaction" (Stage 1) can be explained by the four Stage 2 attributes. Satisfaction with "Amenity" appeared to be the most important attribute (R^2 =0.807), then come the attributes of satisfaction with Health, Safety and Convenience (R^2=0.755, R^2 =0.694, R^2 =0.615). Three attributes A1, A2 and A3 (Stage3) can explain 70% of the variance in satisfaction with amenity.

The amenity of neighborhood/town beauty appears more important than the amenity of natural environment and open space. The three of Stage 3 attributes H1, H2, and H3 appears to explain 75.5% of the variance in satisfaction with Health (stage 2), in which Health from noise seems to be much more important than air and water. As to the satisfaction with safety (Stage 2), the three attributes S1, S2, and S3 (Stage 3) can explain about 69.4% of the variance, in which Safety of disaster seems more important than Safety in mobility and crime.

From the analysis, it may also be noted that the model fitness (R^2) is quite high, which is indicating that the hierarchical multi-attributes evaluation system established in this study can offer a promising and valuable theoretical framework for modeling residential environment quality. Our questionnaire ended with the question "Is there any other items not mentioned in the questionnaire that will affect the residential environment quality in your life?" Almost all of the answers consider no such item, which shows that the present model has captured most attributes of residential environment quality.

Table 5-4. Basic characteristic of households

Item	Categories	Percentage	Sample
House type	Detached	38.2	1196
	Multiple	61.3	
Floor area (m^2)	<50	20.3	1433
	50~100	40.5	
	100~150	28.4	
	150~200	6.8	
	>200	4.1	
Residence period (years)	0~5	38.7	1745
	6~10	29.5	
	11~15	20.2	
	16~20	6.9	
	>20	4.6	
Family size (person)	≤3	21.5	1774
	4	53.1	
	5	19.2	
	≥6	6.2	

Table 5-5.Comprehensive evaluation results on residential environment

Area			Stage 1	Stage 2			
			Comprehensive satisfaction of living environment	Comprehensive satisfaction of Amenity	Comprehensive satisfaction of Safety	Comprehensive satisfaction of Health	Comprehensive satisfaction of Convenience
1	MJ	Mean	0.69	1.08	-0.11	1.05	1.14
		(StD)	1.02	1.00	1.14	0.85	0.85
2	KK	Mean	0.98	1.04	0.02	0.96	1.26
		(StD)	0.8	0.92	1.11	1.01	0.85
3	KM	Mean	0.71	1.09	-0.12	0.91	1.11
		(StD)	0.97	0.85	1.11	0.96	0.79
4	WM	Mean	0.91	1.2	0.18	0.97	0.65
		(StD)	0.78	0.83	1.04	0.93	1.06
5	YH	Mean	0.67	1.06	-0.12	0.97	1.45
		(StD)	0.92	1.00	1.14	0.95	0.79
6	YN	Mean	0.52	0.82	-0.02	0.69	0.91
		(StD)	1.09	1.07	1.13	1.13	0.99
7	TB	Mean	0.32	0.35	-0.08	0.66	1.23
		(StD)	1.04	1.19	1.11	1.04	0.9
Kita-kyushu		Mean	0.66	0.94	-0.03	0.86	1.03
		(StD)	0.99	1.02	1.11	1.00	0.94

Table 5-6.Evaluation results of each residential satisfaction factors

Categories (Stage 3)		YN	YH	KK	KM	TB	MJ	WM
Amenity	Nature	0.80	0.83	0.79	1.11	-0.04	1.20	1.37
	Park&Green space	0.54	0.29	1.08	1.01	0.04	0.99	1.01
	Town beauty	0.54	0.63	0.90	0.76	0.35	0.70	1.22
Safety	Street light	0.03	0.34	0.04	0.08	-0.04	-0.24	0.15
	Blind spot	-0.31	-0.20	-0.31	-0.31	-0.45	-0.41	-0.42
	Road maintenance	0.20	0.20	0.50	0.00	0.14	0.02	0.68
	Pedestrian	0.19	0.31	0.50	0.03	0.29	0.08	0.61
	Bicycle path	-0.41	-0.89	-0.17	-0.69	-0.55	-0.76	-0.38
	Road traffic	-0.19	0.00	-0.19	-0.09	-0.13	0.01	0.69
	Shelter	0.35	-0.03	0.52	0.24	0.28	0.46	0.61
	Security/monitoring	-0.17	-0.43	-0.13	-0.26	-0.11	-0.09	-0.06
	Natural disaster	-0.06	-0.26	0.02	-0.07	-0.14	-0.09	0.16
Health	Sewage	0.97	1.17	1.27	1.14	1.09	1.25	1.31
	Noise	0.02	0.57	0.63	0.54	0.10	0.66	0.29
	Vibration	0.77	0.83	1.00	0.92	0.73	1.03	0.93
	Garbage	0.77	0.94	1.00	0.94	0.81	1.01	1.18
Conve-nience	Sp.market	1.28	1.34	1.38	1.44	1.31	1.83	1.18
	Post office	0.68	0.94	0.98	0.63	1.52	0.91	1.21
	Bank	0.76	0.89	0.81	0.73	1.22	0.04	1.06
	Library	0.38	1.06	0.79	0.61	1.13	0.39	0.10
	Medic. Fac	1.08	1.60	1.25	1.14	1.10	1.19	-0.99
	Element.Sch	0.90	1.11	1.42	1.28	1.13	1.39	1.50
	Mid.Sch	0.65	0.77	1.38	0.96	0.30	0.11	0.71
	Train St.	0.39	0.94	0.92	1.18	1.45	0.77	-0.55
	Bus stop	0.84	1.43	1.54	-0.58	1.58	1.50	1.20
	Open space	0.97	0.91	1.21	0.97	-0.74	1.17	0.98
Comprehensive evaluation		0.46	0.59	0.74	0.53	0.53	0.58	0.67

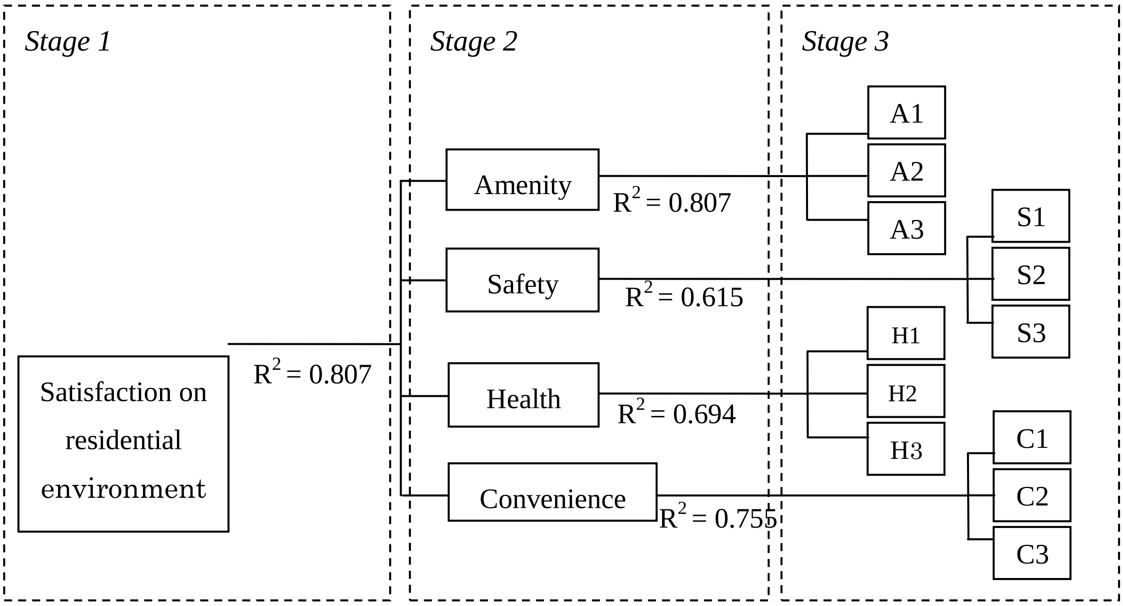


Figure 5-4.Hierarchical evaluation method

Table 5-7.Multiple regression analysis result

Factor (label)	Regression equation	R square
Amenity (A)	y= 0.439(*A3*) + 0.224(*A1*) + 0.235(*A2*) + 0.410	0.700
Safety (S)	y= 0.451(*S3*) + 0.383(*S2*) + 0.204(*S1*) - 0.108	0.694
Health (H)	y= 0.482(*H2*) + 0.317(*H3*) + 0.177(*H1*) + 0.085	0.755
Convenience (C)	y= 0.420(*C2*) + 0.262(*C3*) + 0.337(*C1*) - 0.025	0.615
Comprehensive	y= 0.229(*A*) + 0.209(*S*) + 0.190(*H*) + 0.139(*C*) + 0.667	0.807

5-3-2 Satisfaction change between year of 2003 and 2013

In 2003, the same questionnaire survey was performed in three residential areas in Kitakyushu City to a thousand households. The two urban residential areas were selected according to geographic location: Yahata-Higashi in east and Yahata-Nishi in the west. It was collected 800 valid feedbacks from the two same areas of total seven areas of questionnaire survey in 2013. The data comparison between 2003 and 2013 might not represent the change of personal evaluation during 10 years due to the targets of families were may be different. But as the public environmental evaluation, by using the same approach of method and target areas, the residential satisfaction change during 10 years could be grasped and represent the areas development. **Figure 5-5** shows the comparison of environment satisfaction between 2003 and 2013 among two districts. The minus axis values show the people's non-satisfaction average values of total respondents.

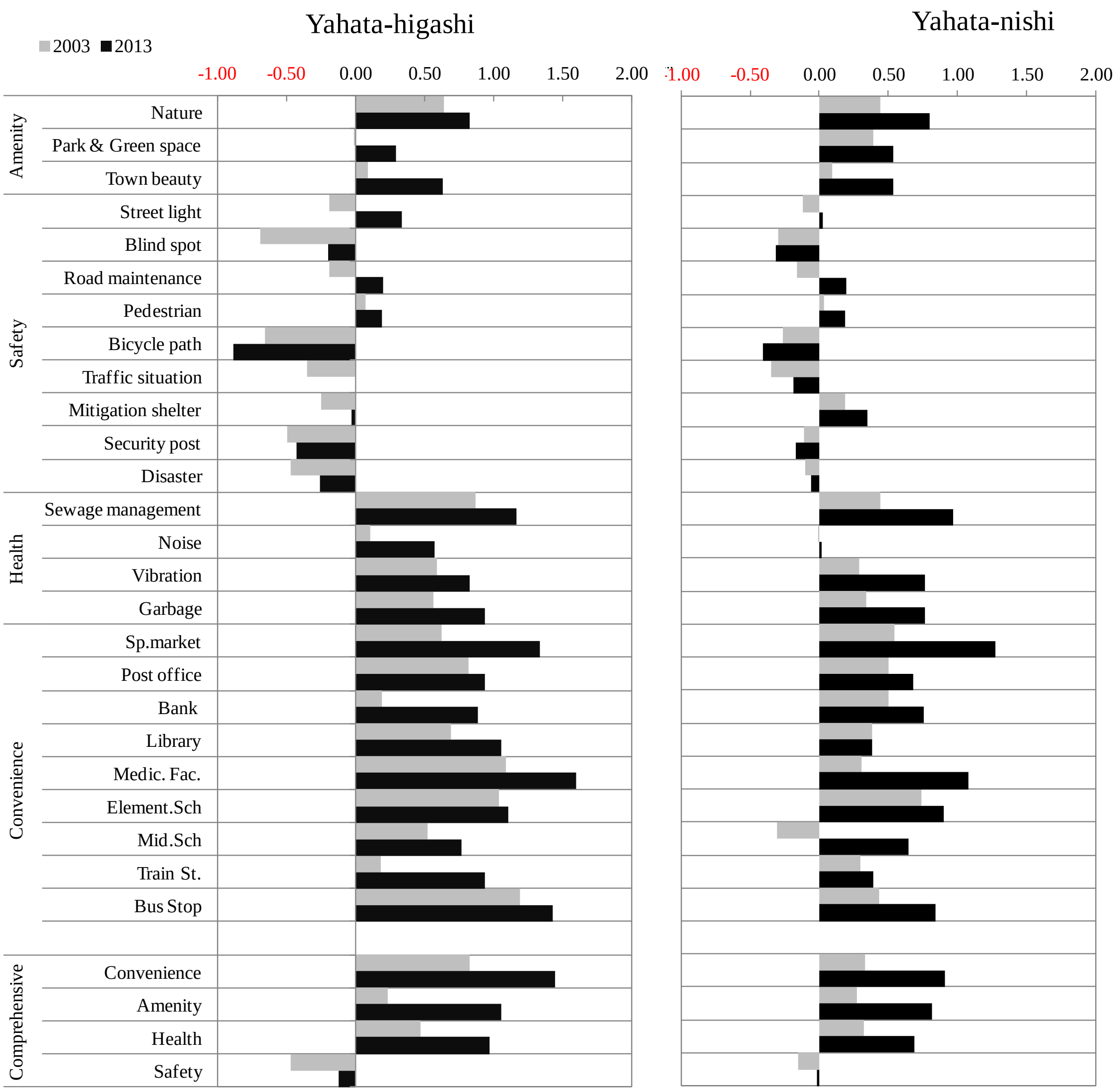
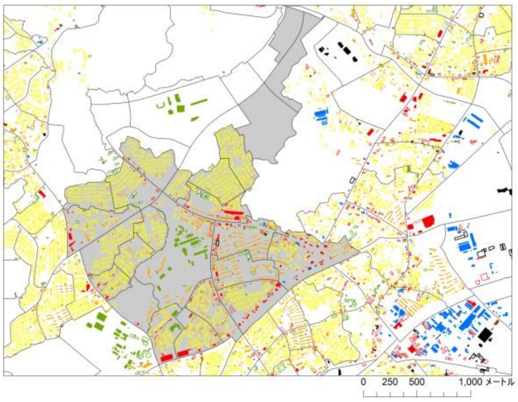
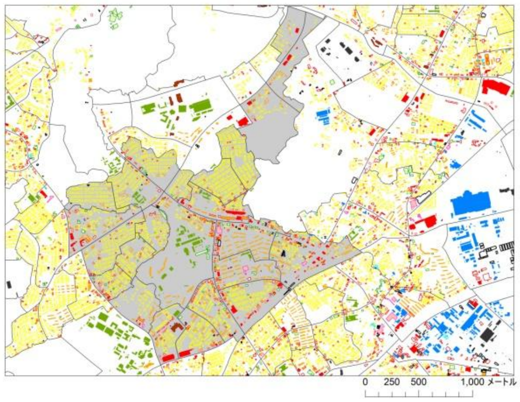
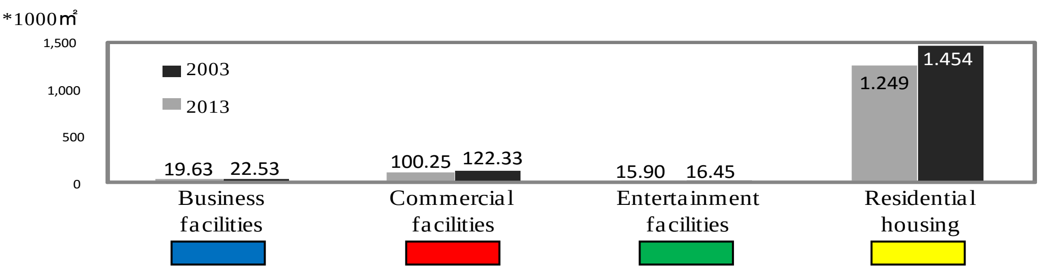
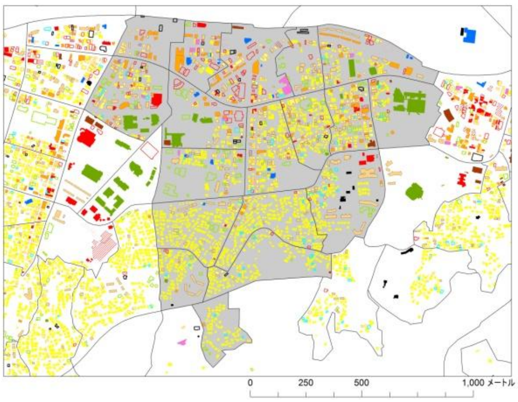
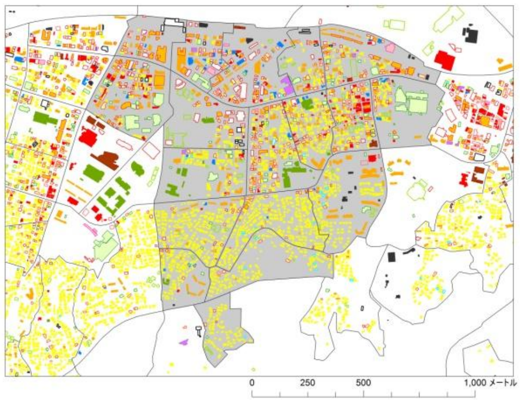


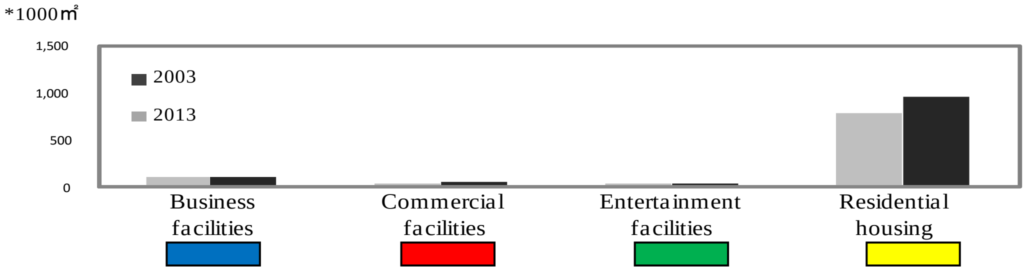
Figure 5-5.Environment evaluation comparison between year of 2003 and 2013

Figure 5-6. Land use comparison between 2003 and 2013 data

a) Yahata-Nishi 2003	b) Yahata-Nishi 2013
	



c) Yahata-Higashi 2003	d) Yahata-Higashi 2013
	



While **Figure 5-6** shows the land use maps of these two districts in the year of 2003 and 2013. From the results, most of the variables show the increase of satisfaction levels, in other words, during ten years the city facilities and environment qualities improved significantly. The increased number of residential housing also can be an indication that the quality of life in these areas also had increased. Although, further study are needed due to understanding what kind of household's type is increasing which very important to predict the future lifestyle's trend of the citizen.

5-4. Hierarchical analysis on residential satisfaction in living environment

The hierarchical evaluation method was firstly introduced by Ge and Hokao [4] established in four levels considering the residential concepts present by the *WHO*, as described in **Figure 5-7.** Safety/security, Health, Convenience and Amenity/comfort are the four concepts of the residential environment to satisfy the basic living requirements of human beings. According to this method, "comprehensive satisfaction of residential environment" in Stage 1 depends on "comprehensive satisfaction of Amenity, Safety, Health, and Convenience" in Stage 2. Attributes of Stage 2 are assumed to depend on satisfaction with Stage 3 items. For example, "comprehensive satisfaction of Amenity" (Stage 2) is assumed to depend on A1 (Amenity with natural environment), A2 (Amenity of park & green space), and A3 (Amenity of town beauty) which is the items in Stage 3.

[4] Ge J, Hokao K. Residential environment index system and evaluation model established by subjective and objective methods. Journal of Zhejiang University Science 2004; 5(9):1028–1034.

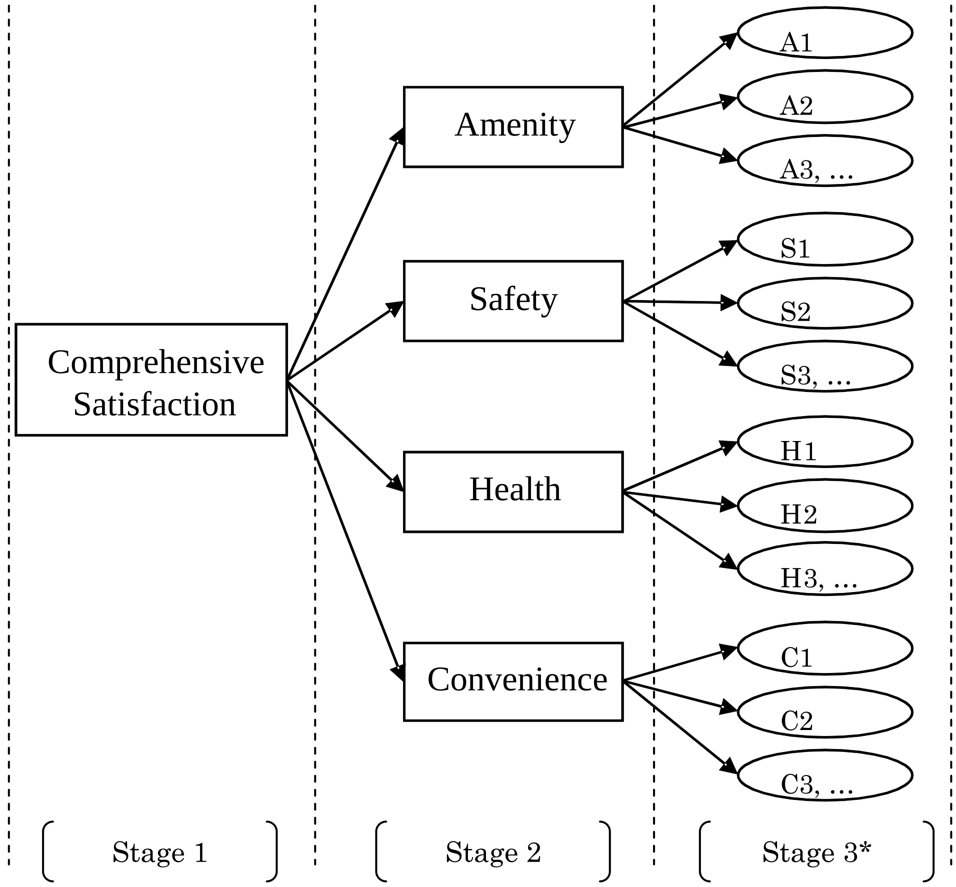


Figure 5-7.Hierarchical evaluation method on residential environment

5-5. Investigation on performance of neighborhood facilities by Geographical Information System analysis

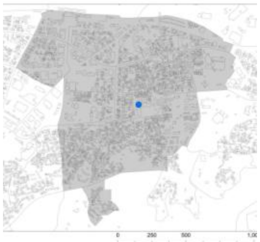
In the last decade, there has been considerable research to identify landscape values using participatory of GIS methods, especially in fields of urban planning, landscape, and built environment. In this study, GIS was used as a tool to build a database in terms of household's satisfaction of neighborhood. By integrating GIS with the data of respondents from questionnaire results, we can represent the geographical map to support and validate the statistical analysis results. The application of GIS software was presented in the discussion section of this paper.

5-5-1 Integrated evaluation by GIS and discussion

Commonly, it is difficult to get the GIS database of Japanese local cities such as

Kitakyushu City due to protecting the citizen's privacy. But in this paper, through local cooperation with schools and universities, the research team could get the access to the database that makes this paper provide a unique database. The *ArcGIS ver. 10* was used to provide the geographical map in this paper. Related with the evaluation of convenience factors, this paper combined the results from questionnaire survey with the GIS database so the numerical data from survey can be explained as geographical map which is easier to understand and ensure the real condition on the site. **Table 5-12** shows the study location (grey colored) from total seven districts in Kitakyushu, location of the cooperative elementary school (dot) and some basic information of surveys.

Table 12. Location of valid feedback

Area map (GIS 2012)				
District name	Yahata-Nishi		Kokura-Kita	Kokura-Minami
School name	Mitsusada	Isegaoka	Kiyomizu	Kikugaoka
Valid feedback	165	127	60	235
Number of block	22		13	15
				
Yahata-higashi	Tobata		Moji	Wakamatsu
Sarakura	Tobata-chuo		Nishi-moji	Aoba
41	163		160	183
12	18		16	12

It is difficult to ensure the concept of amenity, safety, and health with GIS database due to many other influential factors that not in the scope of urban planning and environmental study. Therefore, GIS analysis will be conducted to measures the concept of convenience since it is the only concept that strongly affect the urban development and lifestyle changes. In addition, based on the satisfaction evaluation results (**Table 5-6**), the convenience score is the higher among other concepts and based on preference evaluation (**Figure 5-6** and **Table 5-9**) more than 80% of total respondents concern about the convenience level. The GIS-based evaluations are including some comparison between two residential areas, one with the highest score of convenience and other with the lowest.

Figure 5-10 shows the train lines and stations in Kitakyushu City. Referring to the convenience satisfaction score in Table 6, Wakamatsu District has the lowest score of satisfaction on the convenience of going to train station. It is not only because of the surveyed residential area far from train lines but also the number of train stations are the lowest (four stations) among other districts in Kitakyushu City. In the other hand, convenience score of going to train station in Tobata District is the highest due to the surveyed area was between two big stations and the train line is the main line of Kitakyushu City which connected towns and districts in Kitakyushu to the other prefectures in Kyushu Island. Although the surveyed area in Kokura-Minami district is surrounded by many train stations, it is not the highest score at convenience. This is due to the stations are serving for local loop lines only by monorails. Based on these results the score of convenience are not only affected by the distances from homes to the nearest stations but also affected by service ranges of train lines.

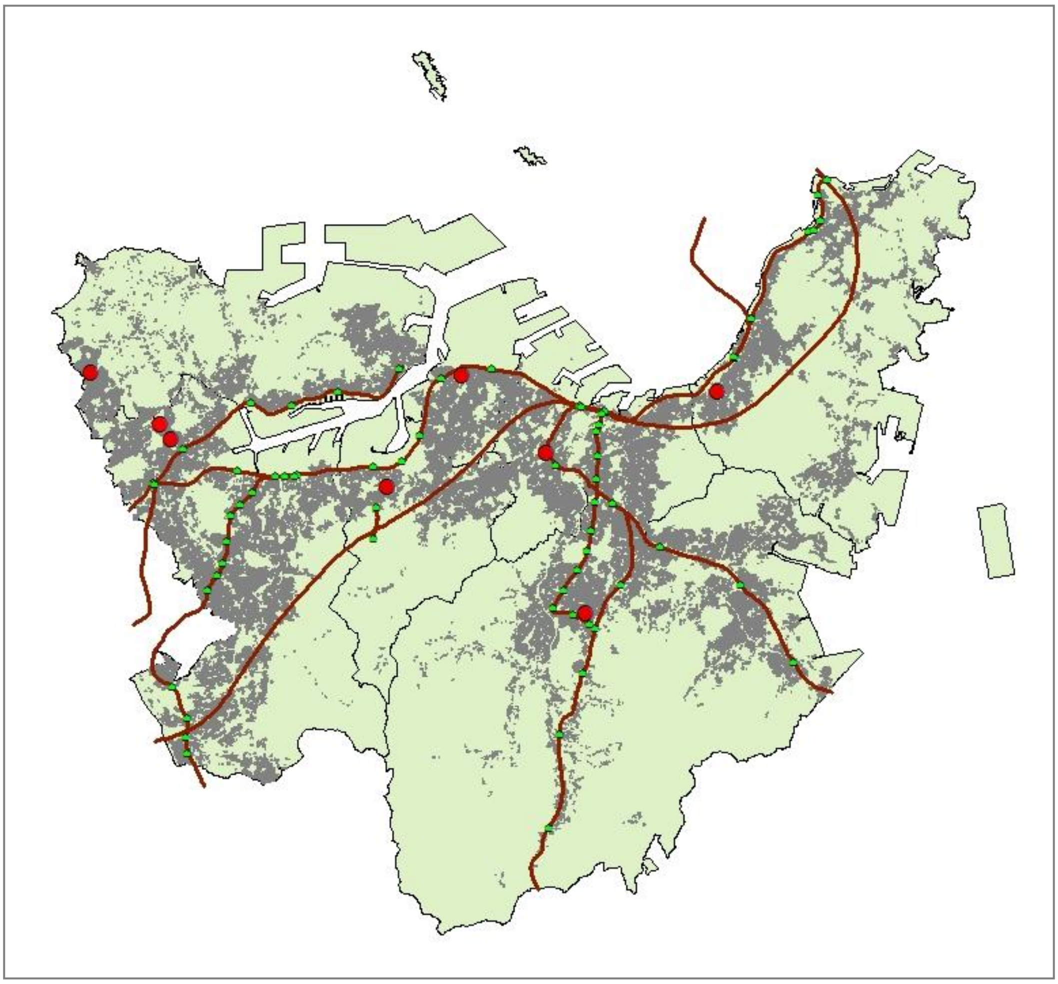


Figure 5-10. Train line and stations in Kitakyushu City

In terms of convenience on going to the nearest bus stop, the highest convenience of the bus stop is in Tobata, the lowest evaluation result is in Kokura-Minami. Public bus or popular as city bus in Japan have strict rules to follow the decided routes from local government and only stops (dropping and commuting passengers) in decided bus stops. **Figure 5-11** shows the geographical map between bus stop positions around the investigated areas. Three hundred meters of the radius was used as an assumption for the distances that can be easily reached by children and elders and it's categorized as short distances for a walk [25]. Bus lines in Tobata can reach more residential areas than in Kokura-Minami.

Figure 5-12 shows the location of the public park and open spaces in Kokura-Kita and Tobata, which are the highest score of convenience and the lowest respectively. The number of public parks and open spaces includes in surveyed residential area of Kokura-Kita is more than in Tobata. Even there are some big open spaces outside border lines some of the open spaces are commercialized which may affect the local residents unwilling to use it.

Figure 5-13 shows the medical facilities include of clinic, hospital, and health care facilities in Wakamatsu and Yahata-Higashi districts. Yahata-Higashi clearly has more medical facilities even inside or outside the boundaries than Wakamatsu. Commonly, in Japan, the medical facilities were separated based on the specialization (internal disease, surgical, children clinic, dentistry, etc.) rather than merged to be one such as a hospital.

Figure 5-14 and Figure **5-15** show the comparison between highest and lowest convenience score of the nearest post offices and banks service respectively. Various size of buffers radius were used in order to grasp the coverage and distances to these public facilities from targeted areas. When the buffers radius size is increased to 1,500-2,000 meters the coverage scores are become 100%, it means to reach the nearest facilities the maximum distances are between 1,500-2,000 meters from residential areas.

Figure 5-12. City park and open spaces of Kokura-kita (left) and Tobata (right)

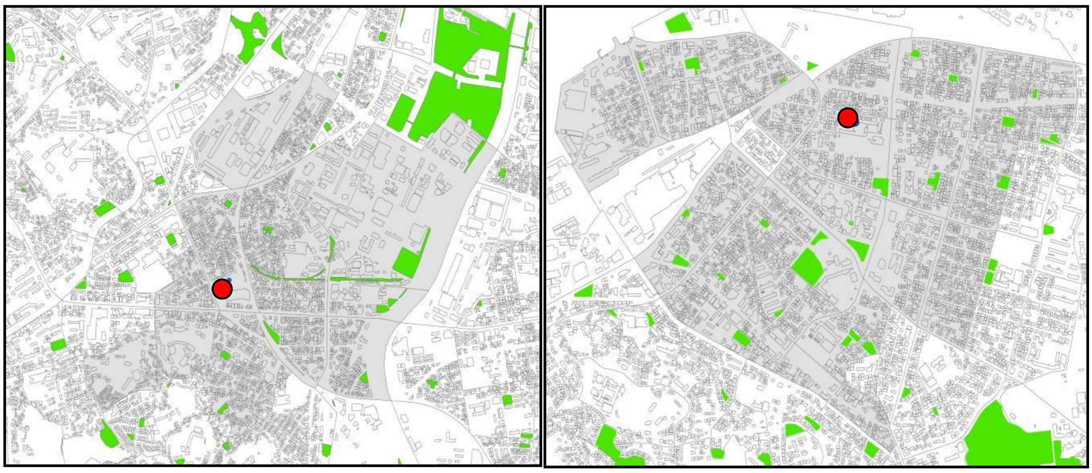
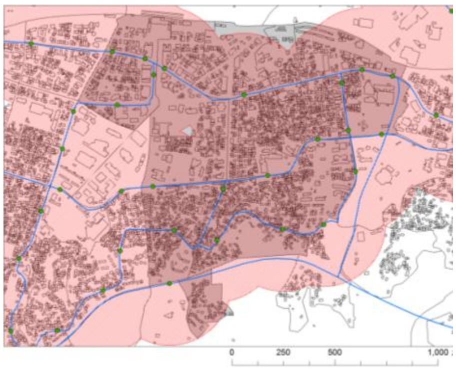


Figure 5-11.Area map of bus stop and coverage (300 m radius)

YN *CS: 0.84 **Cvg: 78.6%

YH CS: 1.43 Cvg: 97.4%

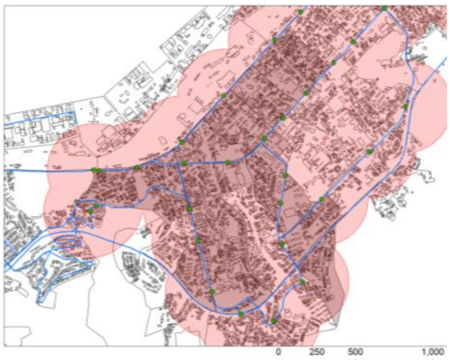


KK CS: 1.54 Cvg: 92.3%

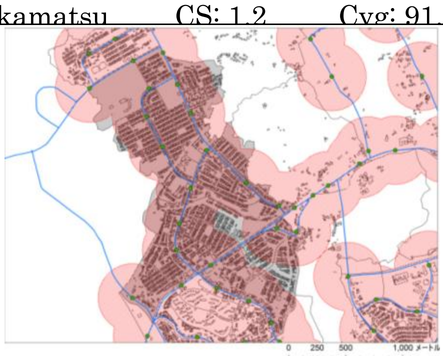
KM CS: 0.58 Cvg: 57.8%

TB CS: 1.58 Cvg: 96.5%

MJ CS: 1.5 Cvg: 99.8%



Wakamatsu CS: 1.2 Cvg: 91.3%



*CS : Convenience Score

**Cvg : Coverage of Bus Stop (ratio of covered area to total surveyed land area)

Figure 5-13.Medical Facilities of Wakamatsu (left) and Yahata-Higashi (right)

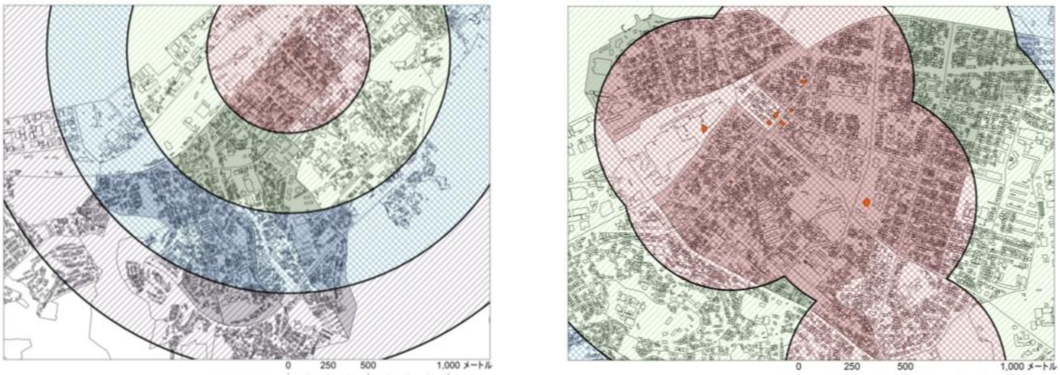
Figure 5-14.The convenience comparison of post office

Kokura-minami	Tobata
	

Area	Buffer radius (coverage)				Convenience score
	0～500m	500～1000m	1000～1500m	1500～2000m	
Kokura-minami	(59.2%)	(99.5%)	(100.0%)	(100.0%)	0.63
Tobata	(94.4%)	(100.0%)	(100.0%)	(100.0%)	1.52

Figure 5-14.The convenience comparison of bank service

Moji	Tobata



Area	Buffer radius				Convenience score
	0～500m	500～1000m	1000～1500m	1500～2000m	
Moji	20.7%	40.9%	89.3%	100.0%	0.04
Tobata	79.6%	99.7%	100.0%	100.0%	1.22

5-4-2 Correlation between neighborhood satisfaction and residential preferences

In order to identify the personal residential preference, there are twenty-one choices presented for the residents about their preference when choosing the present dwelling, including residential convenience factors (1)~(5), amenity and comfort factor (6)~(9), safety factor (10)~(15), community factor (16) and (17), economic factor (18), and other factor such as good design(19), good leisure(20), and special attachment(21).

Firstly, to focus on the residential environment itself, the principle component analysis was performed considering only residential environment factors. The analysis was performed by SPSS ver. 19.0, by extraction method of *Principle Component Analysis*, and *Rotation of Varimax with Kaiser Normalization*. In Table 8, five principle components have been extracted: *1st =Amenity + Safety*; *2nd =Convenience related with children education and economy*; *3rd –Convenience of daily mobility*; *4th =Community and other*; *5th =Health*. According to these results, the main preferences of selecting dwellings are in the order of *Amenity & Safety*, *Convenience*, *Safety*, *Health*, *Community,* and *Economic*. The total variance shows that the above five principle components can explain the residential preference quite well, with the cumulative 56.1%, and the first and second factors served as the 38.3%.

In order to analyze the personal preference residential type, the scatter plot of the distribution of component value of the 1st and 2nd factors (which can explain about half contribution of the total factors) of each resident is plotted in Figure 7, the X-axis is the *1st factor (amenity + safety); Y-axis is the 2nd factor (convenience).* By thus, four groups pattern can be identified, which are Group I (amenity and safety type); Group II (convenience type); Group III (comprehensive type: amenity + safety + convenience) and Group IV (other type). Table 9 shows each group composition by personal preferences.

Table 5-8. Principal Component Analysis on residential preferences

Extraction method : Principal Component Analysis.
Rotation method : Varimax with Kaiser Normalization.

Variance Factor	Component				
	1	2	3	4	5
8. Noise and air quality of outdoor	**0.740**	0.181	0.046	-0.024	-0.100
12. Security of crimes is good	**0.722**	0.026	0.050	0.114	0.149
10. Safety from disaster is high	**0.681**	0.143	0.153	0.027	0.108
13. Safety of commuting is high	**0.674**	0.102	0.147	0.164	0.305
15. Cleanliness is high	**0.636**	0.294	0.019	0.178	0.126
9. Sunshine and ventilation are good	**0.615**	0.036	0.122	0.201	0.038
17. Education (for children) is good	**0.548**	0.220	0.028	0.138	-0.045
20. Good for leisure	0.062	**0.685**	0.184	0.330	0.181
7. Beauty of city/town	0.496	**0.610**	0.044	-0.163	-0.119
6. Beauty of nature	0.461	**0.597**	0.123	-0.211	-0.061
21. There is inner attachment	-0.002	**0.591**	0.155	0.113	0.492
16. Social connection is good	0.285	**0.578**	0.039	0.140	0.212
2. Convenience of commuting	0.071	0.039	**0.820**	0.120	-0.016
3. Nearby the workplace	-0.042	0.218	**0.739**	0.040	-0.106
1. Convenience of shopping	0.287	-0.059	**0.567**	0.016	0.318
19. House design is good	0.171	0.209	0.077	**0.777**	-0.066
18. Economical reason (rent/house price)	0.182	-0.022	0.100	**0.726**	0.086
11. Nearby the parent/relative house	0.103	0.161	-0.001	-0.029	**0.800**

Excluded Variables *					
**Variables with score of component lower than 0.5 are not included in result*					
4. Convenience of children going to school	*0.459*	*-0.018*	*0.415*	*0.011*	*0.092*
5. Access to neighbor city is good	*0.22*	*0.313*	*0.455*	*0.092*	*0.162*
14. Medical and welfare services is easy	*0.486*	*0.242*	*0.229*	*0.137*	*0.393*

Figure 5-7.Scatter plot of component values of 1st factor and 2nd factor

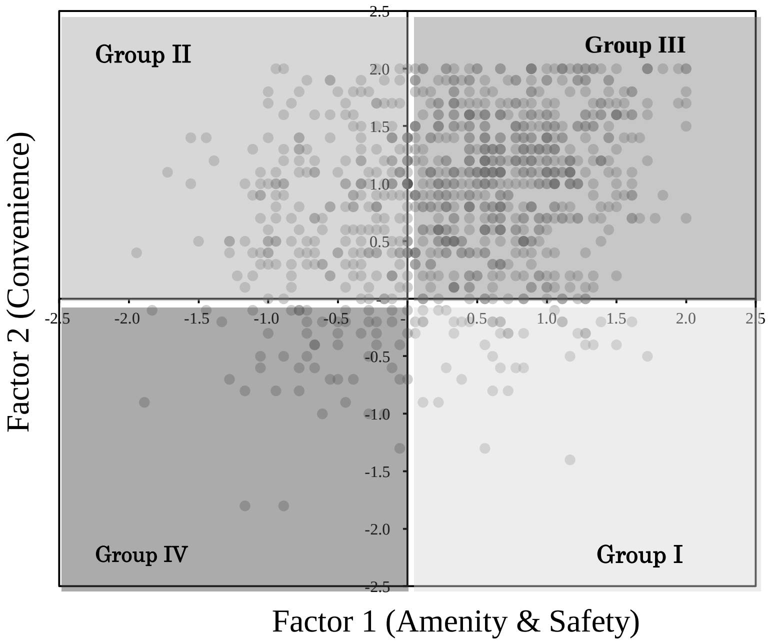


Table 5-9.Group composition by residential preference

Group label	Number of samples	Percentage (%)
I	61	6.55
II	226	24.27
III	582	62.51
IV	62	6.66
Total	931	100

5-4-5 Classification of households by residential preferences

In order to understand the characteristics of each group, the satisfaction scores and importance (preference) scores from four types of the group are analysed, shown in Table 5-10 and Table 5-11. Then each group characteristic will be presented base on these two judgments (satisfaction type and preference type). Figure 5-8 and Figure 5-9 are the graphical radar based on numerical data in Table 5-10 and Table 5-11.

Group I: Amenity and safety type. The evaluation on satisfaction and importance of the amenity attribute are both quite high among all types, much higher than the comprehensive score of total samples. The same tendency can be noted in the case of the safety attribute, where importance evaluation is above the average, and the satisfaction evaluation is the highest among the four types. On the other hand, the evaluation on convenience is the lowest among all types, which may illustrate the difficulty in pursuing the satisfaction with amenity, safety and convenience simultaneously. Families in group I regard amenity and safety as their first preference and this seems to have been realized while the aspect of convenience is compromised.

Group II: Convenience type. This type is focused on convenience, and the evaluation on convenience importance is the highest. It is also shown that the satisfaction evaluation on convenience is quite high, much higher than the average. The importance evaluation on amenity and safety are the lowest, and satisfaction with amenity and safety are also quite low among 4 types, much lower than the average.
Similar to the group I, group II chooses the convenience as the most important factor on the dwellings, and in consequence their requirement on amenity and safety are given up to some extent.

Group III: Comprehensive type. The importance evaluation on amenity, health, and safety are highest among all types, and the importance evaluation on convenience is also high. In addition, their satisfaction with convenience, amenity, health and safety rank the first among all types. It can be seen that their comprehensive wishes on living condition are realized to the largest extent, which is also the target of residential environment plan and design. Also, the number of this group is as the highest as 582 residents, among all the residents, the percentage of this group is largest (62.51%).

Group IV: Other types. The preference emphasized on other factors instead of amenity, safety, and convenience. As we see in Table 5-7 and Table 5-8, the evaluation on satisfaction and importance with 4satisfaction factors are all very low, while convenience is the worst, and other 3 factors bear the worst. The comprehensive satisfaction on the residential environment is also the second lowest. The reason may be related to their un-clearness of residential preference. The residential environment condition of this type is also worth being studied, in order to improve their residential environment, as well as their residential awareness.

Table 5-10. Evaluation on residential satisfaction by group of personal preferences

Satisfaction type	I	II	III	IV
A) Amenity	1.26	0.06	1.37	-0.23
S) Safety	0.23	-0.85	0.36	-1.02
H) Health	1.10	0.41	1.06	0.45
C) Convenience	-0.38	1.07	1.33	-0.55
Co) Comprehensive	0.97	-0.04	0.98	-0.18

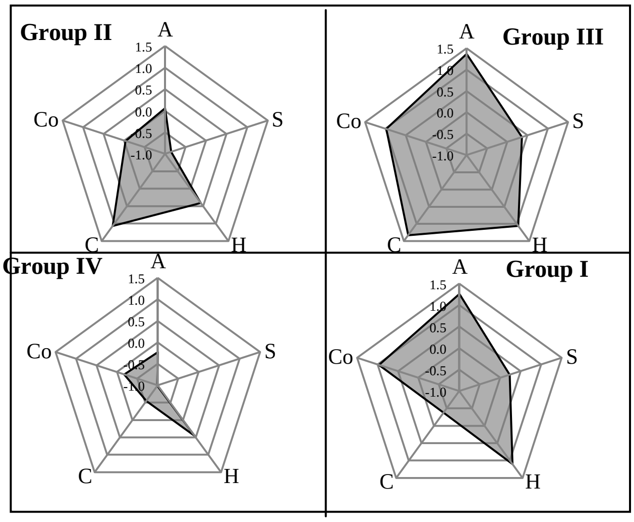
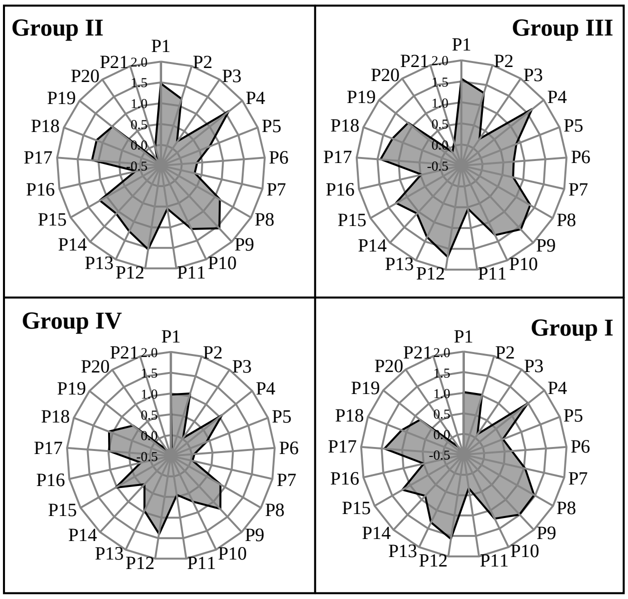


Figure 5-8. Group characteristic upon satisfaction type

Figure 5-9.Group characteristic upon preferences type



Considering with time spent from their homes to the city facilities, the choice of transportation mode were also investigated using the 5 grade categories of time range. 0~5 minutes, 6~15 minutes, 16~30 minutes, more than 30 minutes, and never use kind of transportation mode. The score in table 6 means the smaller number the shorter time to get there. It can briefly explain as the score up to 2.00 means the time was to reach such place was not short. Based on the results in **Table 5-5** and **Table 5-6**, the correlation between convenience of city facilities and the time spent to reach the city facilities could be grasp. **Figure 5-12** shows the correlation of these 2 factors is high enough, more than 50% of respondents who feel not convenience is because the time spent to reach the facilities are too long. Time spent to reach the city facilities is an important factor influencing satisfaction on convenience so as the transportation mode choices. In local city such as Kitakyushu, public transportation needs to be developed in order to reduce the carbon footprint. Based on this study the citizen still prefers to transport by private car rather than city bus due to the limited bus route.

Table 5-11. Evaluation on residential preferences by group

Preferences type	Group of households			
	I	II	III	IV
P1) Convenience of shopping	1.02	1.46	1.56	0.97
P2) Convenience of commuting	1.02	1.17	1.30	1.06
P3) Nearby the workplace	0.10	0.19	0.26	0.02
P4) Convenience of children going to school	1.49	1.59	1.64	1.06
P5) Access to neighbor city is good	0.52	0.77	0.90	0.42
P6) Beauty of nature	0.67	0.38	0.74	0.06
P7) Beauty of city	1.03	0.34	0.76	0.03
P8) Noise and air quality of outdoor	1.48	1.14	1.39	0.87
P9) Sunshine and ventilation are good	1.5	1.57	1.57	1.24
P10) Safety from disaster	1.23	1.20	1.34	0.73
P11) Nearby the parent's house (independent)	0.33	0.56	0.55	0.45
P12) Security from crimes	1.57	1.54	1.70	1.40
P13) Safety of walking, bicycle, and car	1.33	1.26	1.39	0.97
P14) Medical and welfare services is easy	0.87	1.08	1.06	0.44
P15) Cleanliness is high	1.21	1.19	1.29	1.03
P16) Social connection is good	0.49	0.12	0.48	0.24
P17) Education for children	1.43	1.15	1.43	0.98
P18) Economic reason	1.11	1.15	1.25	1.10
P19) House design	0.85	0.99	1.12	0.66
P20) Good for leisure	-0.28	-0.37	-0.12	-0.34
P21) There is inner (special) attachment	-0.51	-0.04	0.08	-0.56

Table 5-12 Time spent to the neighbourhood facilities

Facility	Mode	TB	WM	KM	KK	YN	YH	MJ
Super-market	Bus	1.50	1.75	1.42	2.00	2.00	1.83	1.00
	Car	1.14	1.33	1.26	1.28	1.29	1.41	1.05
	Bike	1.40	1.44	1.33	1.42	1.50	1.60	1.17
	Walk	1.69	1.68	1.41	1.25	1.47	1.58	1.21
	Train	2.00	X	1.75	X	2.00	1.00	X
Post office	Bus	1.25	1.00	1.00	X	3.00	2.00	1.00
	Car	1.04	1.25	1.23	1.05	1.17	1.14	1.23
	Bike	1.18	1.77	1.36	1.25	1.75	1.00	1.20
	Walk	1.29	1.80	1.58	1.65	1.65	1.58	1.51
	Train	X	X	1.50	X	X	X	X
Bank	Bus	1.57	1.14	1.20	2.00	2.00	1.50	2.14
	Car	1.18	1.34	1.26	1.24	1.39	1.36	1.58
	Bike	1.40	2.19	1.49	1.31	2.06	1.00	1.87
	Walk	1.59	2.27	1.65	1.68	1.76	1.76	2.02
	Train	X	X	1.33	X	X	X	X
Library	Bus	1.43	2.29	2.96	1.71	2.13	1.00	1.93
	Car	1.36	1.92	2.30	1.50	1.83	1.40	1.52
	Bike	1.56	2.36	3.06	1.89	2.10	1.40	2.08
	Walk	1.63	1.94	2.32	2.24	2.37	1.85	2.28
	Train	1.00	X	2.85	X	2.00	X	X
Medical Facility	Bus	2.00	1.17	1.00	2.17	2.00	X	2.14
	Car	1.58	1.56	1.36	1.47	1.53	1.46	1.42
	Bike	1.65	2.00	1.64	1.25	1.58	1.80	1.73
	Walk	1.66	1.82	1.45	1.40	1.85	1.76	1.49
	Train	X	X	1.50	X	X	X	X
Element. School	Bus	2.00	1.00	2.00	2.00	1.00	2.00	1.00
	Car	1.46	1.22	1.19	1.40	1.44	1.36	1.24
	Bike	1.69	1.67	1.60	1.83	2.09	1.00	1.56
	Walk	1.96	2.17	1.87	2.00	2.23	1.98	1.72
	Train	X	X	X	X	X	X	X
Middle School	Bus	2.33	2.33	3.00	X	X	2.00	2.40
	Car	1.50	1.53	1.42	1.33	1.49	1.55	1.59
	Bike	1.90	1.93	1.82	1.33	2.15	1.67	2.30
	Walk	2.52	2.43	2.05	1.55	2.43	2.25	2.60
	Train	4.00	2.00	3.00	X	2.50	X	4.00
Train Station	Bus	1.56	2.87	1.50	1.89	2.06	2.00	1.99
	Car	1.26	2.39	1.26	1.38	1.83	1.40	1.62
	Bike	1.74	3.00	1.80	1.78	2.23	1.86	2.45
	Walk	1.84	3.00	1.63	1.94	2.22	2.07	2.61
	Train	X	X	X	X	X	X	X
Bus Stop	Bus	X	X	X	X	X	X	X
	Car	1.12	1.08	1.13	1.00	1.36	1.00	1.13
	Bike	1.31	1.13	1.43	1.33	1.13	1.00	1.17
	Walk	1.15	1.07	1.50	1.11	1.29	1.09	1.06
	Train	2.00	1.00	1.67	X	1.00	X	3.00
City Park	Bus	1.00	X	X	2.00	1.25	X	X
	Car	1.27	1.30	1.50	1.67	1.44	1.36	1.09
	Bike	1.11	1.33	1.56	2.00	1.15	1.17	1.10
	Walk	1.25	1.16	1.27	1.42	1.15	1.27	1.13
	Train	X	X	X	X	1.00	X	X

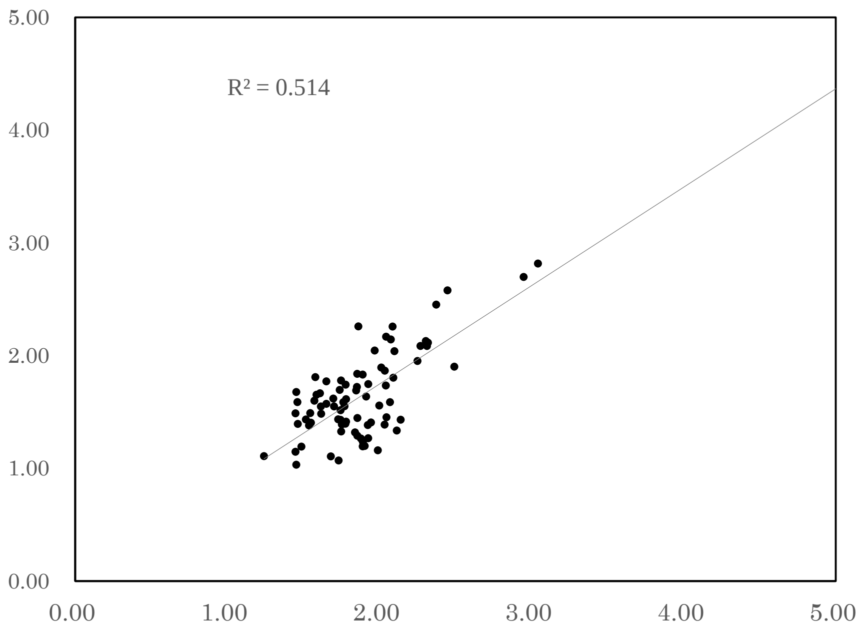


Figure 5-10 Correlation between time spent and convinience level

Table 5-13 Convenience on neighbourhood facilities impact the energy use

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	32.286	8.475		3.809	.000			
	Conv	-2.464	2.143	-.141	-1.150	.254	-.080	-.133	-.132
	Ame	2.664	2.498	.163	1.067	.290	.119	.124	.123
	Saf	1.300	2.047	.084	.635	.527	.086	.074	.073
	Hea	-.960	2.460	-.059	-.390	.698	.056	-.046	-.045

In order to investigate the relation between living environment satisfaction to the use of energy in households, the multiple regression analysis was conducted once again between four concept of residential satisfaction and energy use. In terms of residential lifestyle related with their living environment condition, there is positive correlation between the people satisfaction on convenience in using the neighbourhood facilities and household energy use. This can be explained, to build sustainable community in the future, the convenience of the neighbourhood facilities will also play important role. More time spend to the neighbourhood facilities will provide a choice for the household whether they want to spend time in the outside (such as shopping mall, park, sports hall, etc. or in the inside home with the consequences of using the energy.

On the other hand, satisfaction on health shows highest negative correlation with energy use. It means, if the satisfaction on environment health is low the use of household energy use will increase. Simple example, when the quality of air in outdoor is low, household will prefer to close the window in all season and using electric AC all day long.

5-6. Summary

In this chapter, conclusion can be described as follows:

1. The present residential environment situation evaluated by actual residents can be grasped all over Kitakyushu City, as well as the regional characteristics and the influence on residential environment evaluation, which can be served as the database for the urban planning and decision-making. The findings of this research showed that conveniences of the neighborhood facilities were found to be important in accounting for higher comprehensive satisfaction. Many studies also found that the satisfaction with social service, educational service, transportation service, workplaces, and the quality of neighborhood maintenance also affected resident satisfaction [2, 3, 5, 11, and 14].
2. Indexing systems to evaluate the urban residential satisfaction were also conducted by including non-physical variables such as community, comfort, economic, and social [2, 8, and 22]. In this paper, hierarchical analysis on residential environment evaluation considering local city properties was developed, and the relative importance of each attribute was also studied according to multiple regression analysis. The study on model fitness shows that the evaluation system developed in this study captured most attributes that underlie residential environment and can offer a promising and valuable theoretical framework for the evaluation of residential environmental quality.
3. By comparing the results of 2003 and 2013, the increase of satisfaction levels of city facilities and environment qualities during ten years can be described. Especially in terms of convenience, amenity, and health factors, it shows significant improvement. However, in case of safety, the satisfaction scores are still very low and it will become important issues for the future if the items related to safety such as bicycle path, blind spot, and monitoring system are not rapidly improved. Satisfaction related with safety and security was found to be one of the most dominant predictors in explaining satisfaction with the general living conditions in Japanese urban communities (people who are strongly dissatisfied with safety and security are those strongly dissatisfied with the current living conditions, whereas people who are strongly satisfied with safety and security are those strongly satisfied with the current living conditions) [2]. Community and public spaces, however, have been identified as having a close

association with safety and security in previous studies [23, 24].

4. Four groups of nuclear family's personal residential preference types in Kitakyushu City are identified and their influences on residential environment evaluation are also studied. It was found that more than half of total respondents comprehensive wish on living condition are realized to the largest extent, which mean the target of ideal residential environment plan and design nearly to achieve.
5. GIS is capable of collecting, revising, and calculating the objective data conveniently, accurately and effectively [22]. In this study, the convenience level of neighborhood facilities could be clearly explained by combining the statistical analysis results and GIS database.

6. Through regression analysis, there is positive correlation between the people satisfaction on convenience in using the neighborhood facilities to the household energy use.

Further, deeper and wider research on residential behavior and its relationship with residential environment satisfaction in terms of commuting should be performed to develop and improve the city compactness. In the other hand, Japan is facing the aging populations which affected by many factors such as social and economic, therefore, research on different types of family groups are also needed to propose the sustainable city and community development in the futures.

第六章

北九州エコハウスモデルにおける世帯挙動に関する現場計測実験

Chapter six: Field Experiment on Household Behavior in Kitakyushu Eco-house model

6-1 Background

Energy consumption is constantly increasing every year by the improvement in living standards. This means that the housing device has a great effect on the demand side of the energy consumption. As a result of a great deal of effort citizens, companies, local government, Kitakyushu City was selected as environmental model city in 2008. As one of the famous city of conservation of the environment in which to deal with this problem, Kitakyushu City has proposed a model of smart communities. Eco-house in the Higashida District is a part of the smart community project. Eco-house is utilized to maximize the natural light and the flow of air into the house. Further, it is designed as a passive building design. Advanced technologies such as hydrogen fuel cells and solar panels are used for the Eco-house. This study aims to conduct investigation on people lifestyle and energy consumption in Eco-House Model of Kitakyushu, Fukuoka, Japan. In this paper, the result in winter season will performed. Further the results will be compared with different type of life style.

In Japan it has been found that in the housing sector and the second largest energy consumption across the country following the industrial sector. Japan after the Great East Japan Earthquake faced with energy and economic crisis. Environment has been significantly improved to solve the pollution problem in Kitakyushu. In addition, Kyoto Protocol was made for the purpose of energy conservation and reduction of carbon emissions in the world. This study purpose to perform the experimental study of the hybrid system combined solar power in Kitakyushu Hydrogen Town. This research also purposes to set the life style of housing, building design and evaluation criteria of the hybrid system and the development of basic data for practical application. There are three main results to aim. Firstly is to investigate the correlation between the cogeneration system and lifestyle. The second is to investigate verification the HEMS (Home Energy Management System) control and smart meter, also evaluate the technique applied in the house. The third is to help to provide basic data to verify the management and support tools of practical guidelines of the Eco-house low-carbon technologies. The flow of the study is shown in **Figure 6-1**.

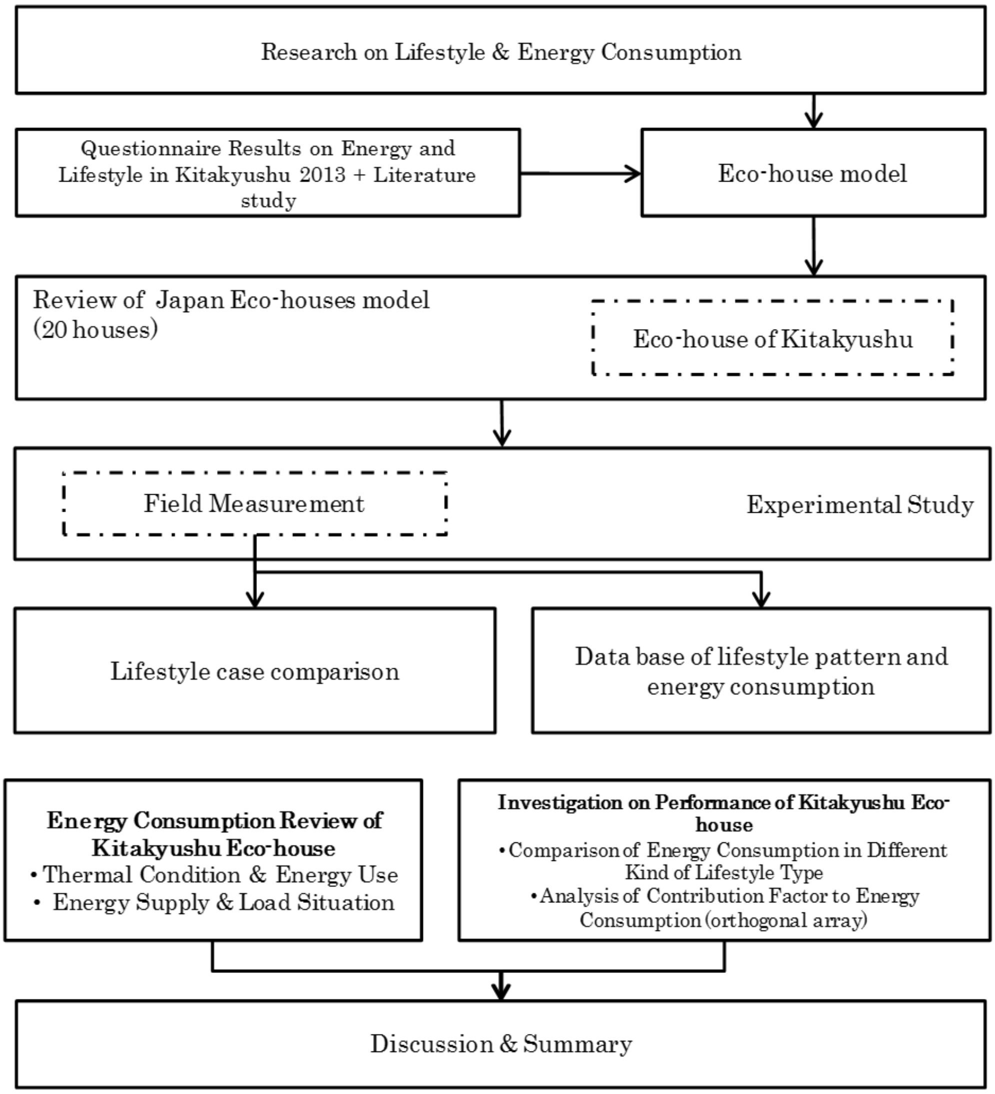


Figure 6-1 Study flow

6-2 Introduction of Kitakyushu eco-house

Eco-house Kitakyushu is located in the "Kitakyushu Environment Museum", which is a center for environment-related learning and exchange of information that can be used by citizens. This model house provides detailed information and the place to experience an eco-friendly house through the guides from the museum. The purpose of this building has been built is aiming at not only dissemination of information regarding eco-houses but also proposal of "an eco-friendly lifestyle and way of living".

The eco-house has many features, including a simple structure with high durability; a layout that can be easily changed in accordance with the changes of lifestyle or life stage; improved thermal conditions owing to breeze 'paths' and others; and the use of various environmentally friendly materials. A frame with a central support column associated with the hardware jointing method provides a robustness as well as freedom of design. The other purpose of the government is the environment-friendly basic performance of the eco-house can enables public to minimize the energy for living as well as to enjoy a comfortable daily life. In addition to the achievement of environment-friendly basic performance, this house model uses as much natural energy as possible without relying on fossil fuels whenever possible. The maximum effort is made to utilize sunlight, solar heat, winds, underground heat, water and differences in temperature in ways suitable for Kitakyushu. The way of living is become the main concept of comfortable living through utilization of water and plants as well as flexible changes according to life stages.

Currently, the building is to be functioned as exhibition, education, and a tourist purpose. Therefore, there is no occupant or residences live in there; mean it does not function as housing. It is designed in a simple structure with high durability of material. So, it may be changed according to the change in life stage and lifestyle easily. In addition, it has are incorporating the traditional style of Japan with adoption of conventional technologies and materials such as *Doma* at the entrance, verandah, and bamboo lattice and plaster walls. Kitakyushu Eco-house also adopted the newest technologies and products including so-called eco-premium products approved by Kitakyushu City.

Table 6-1 Basic information of Kitakyushu Eco-house

Location	33°52'05.5"N 130°48'28.8"E #Kitakyushu Environment Museum
Housing type	Wooden two-story
Total floor area	183.43 m^2
Building structure	Conventional wooden construction method
Total cost	95,000,000 JPY

Figure 6-2 Physical appearance of Kitakyushu Eco-house

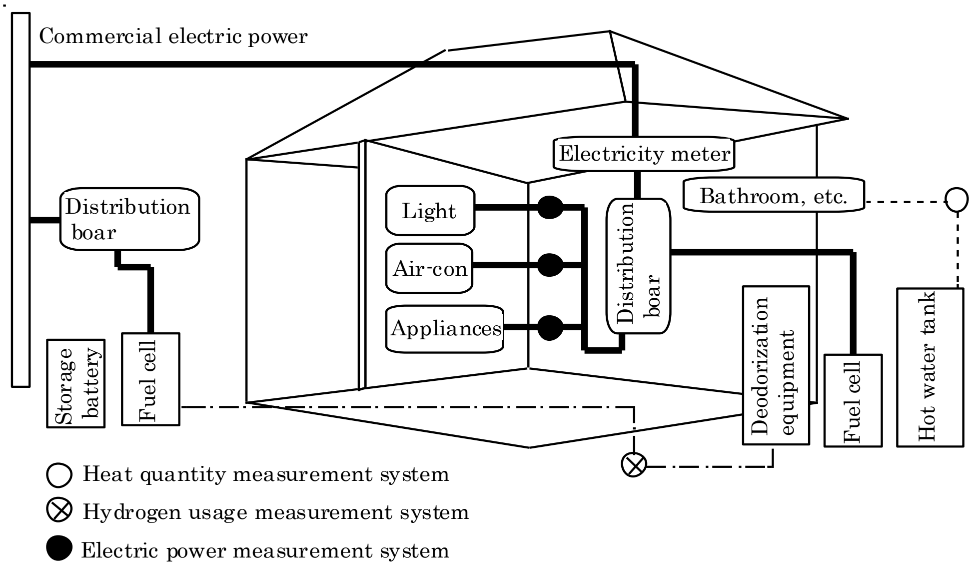


Figure 6-3 Building energy system

The Eco-house energy system is combination between active (technology) and passive design. It is not only designated to supply the energy for its own need but also to produce the energy for the community. The electricity collected from solar PV, fuel cell, will be distributed to the electric company if it is not in use. However, when the demand is high it is still buying the electricity from the electric power company.

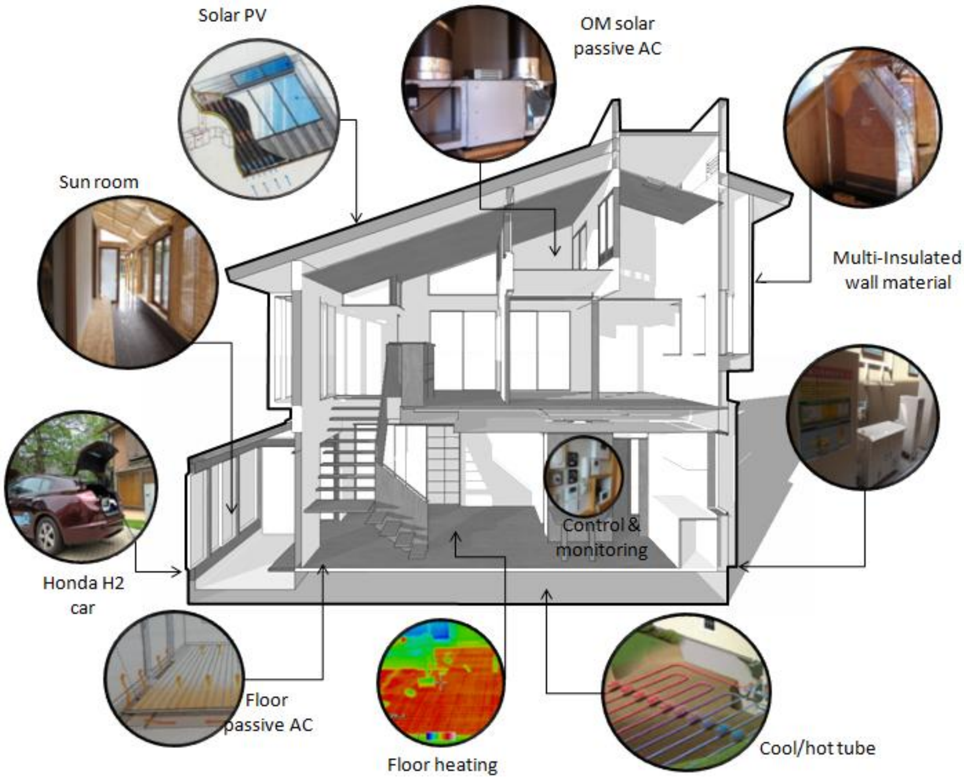


Figure 6-4 Eco-house model building features

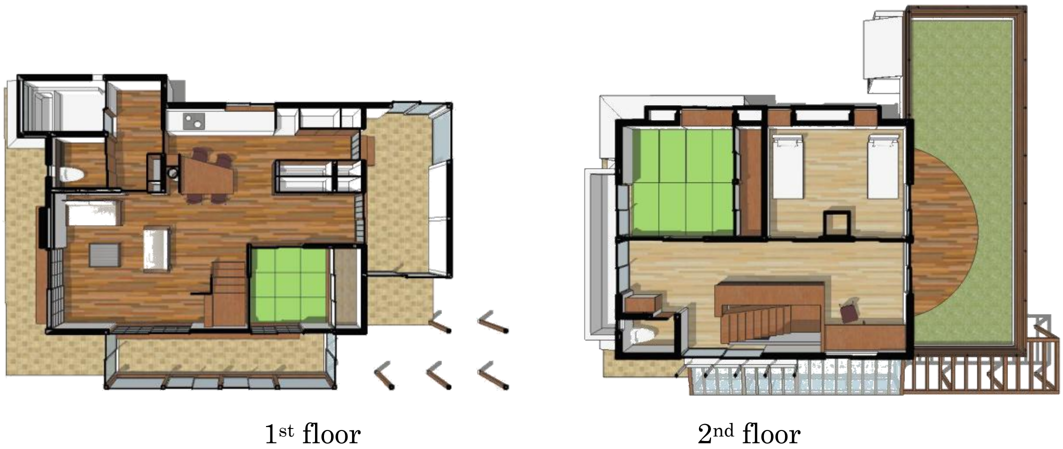


Figure 6-5 Building floor plan

The eco-house layout is representing the Japanese detached house with the combination of traditional and western style of room layout. It is equipped with various special equipments such as OM solar which can absorb the heat from solar radiation in the roof then circulate the warm air to the building in the winter. While in the summer, OM solar can control the indoor temperature by moving the hot air outside. The attached floor heating system also installed in the living room to reach the high comfort of the occupants. Kitakyushu eco-house also constructed the cool/hot tube under the ground which can maintain the comfort temperature inside the house.

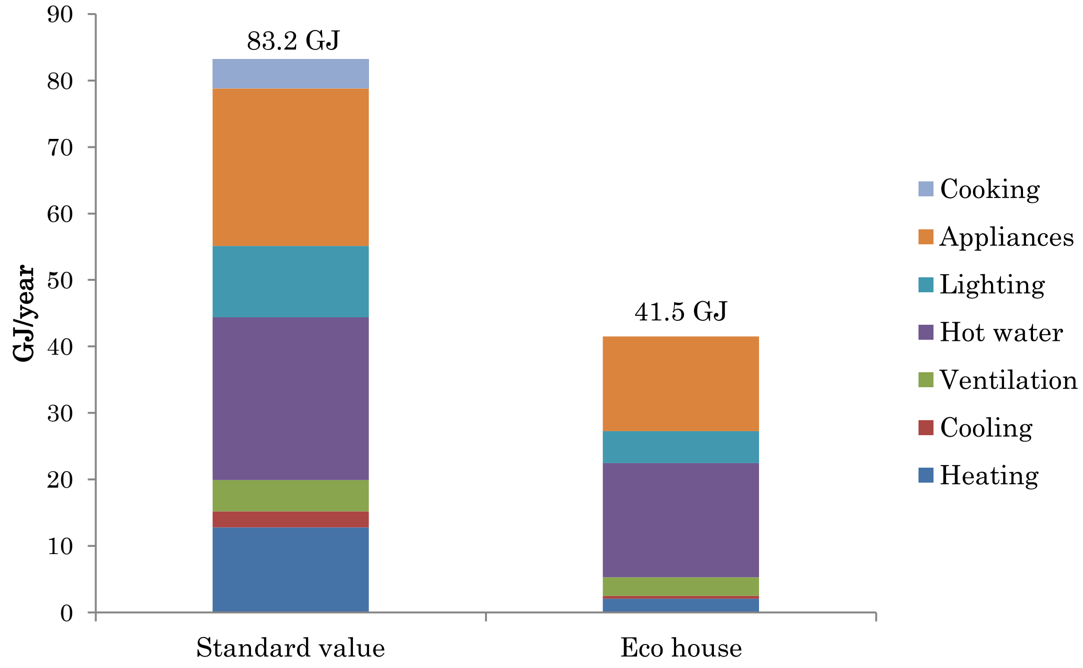


Figure 6-6 Kitakyushu Eco-house energy use reduction[1]

The government claims that the Kitakyushu Eco-house model can cut or reduce the energy use to more than 50.12%, based on standard value of average detached housing energy use in Japan. Reduce the heating by its high performance of wall insulation; reduce the lighting by using LED; reduce the hot water energy use by using *Eco-cute*, etc. For that reason, we conducted the study to test and investigate the performance of the house related with passive and active design, energy use, and its efficiency on reducing the heating and cooling loads.

6-3 Method of field experiment

6-3-1 Set of home appliances

Since the current building is to be functioned as exhibition, education, and a tourist purpose, therefore, there is no occupant or residences live in there. The basic

[1] Kitakyushu Eco-house. http://www.env.go.jp/policy/ecohouse/challenge/challenge17.html

home appliances such us rice cooker, washing machine, refrigerator, etc., were attached and installed by the research team in the existing house for about one year. The list of home electronic appliances is shown in **Table 6-2**. The toilet sheets were already installed in the Eco-house before. The home appliances selection was based on the questionnaire results which collected to Kitakyushu City households (**Chapter 4**). The specification of each electricity consumed appliances was also described in **Table 6-3**.

Table 6-2 Home appliances installation in Eco-house

				
TV	DVD	Microwave	Rice-cooker	Electric fan
				
Elect. heater	Aroma steamer	Washing machine	Refrigerator	Toilet sheet

Table 6-3 Home appliances specification

Categories	Appliances name	Year	Brand	specification
Entertainment	TV 1st Floor	2012	SHARP	100V 24Hz/30Hz/60Hz 140kWh/year
	TV 2nd Floor	2012	TOSHIBA	100V 50/60Hz 74W
	DVD Player	2012	SONY	100V 50/60Hz 16W(0.3W)
	Computer	2013	FUJITSU	100V 50/60Hz 13W / 71W / 0.6W
Kitchen	Refrigerator	2012	TOSHIBA	100V 50-60Hz 84/87W
	Microwave	2012	SHARP	100V 50/60Hz 970/1300W
	Rice Cooker	2006	SHARP	100V 50/60Hz 640W
	Pan	2012	ZOJIRUSHI	100V 50/60Hz 1300W
	Electric Water Pot	2008	ZOJIRUSHI	100V 50/60Hz 985W
Cleaning	Washing Machine	2013	HITACHI	100V 50/60Hz 470／540W
	Toilet Seats 1st Floor	2009	TOTO	100V 50/60Hz 114kWh/year
	Toilet Seats 2nd Floor	2009	TOTO	100V 50/60Hz 114kWh/year
Conditioning	Electric Heater	2012	HITACHI	100V 50-60Hz 1000W
	Aroma Steam	2012	TOSHIBA	100V 50/60Hz 310W
Other	Phone Charger	2009	DOCOMO	100V 50/60Hz 100W
	Hair Drier	2007	TESCOM	100V 50-60Hz 1200W

6-3-2 Set of field measurement tools

This study focused to measure the energy use, includes of electricity and gas. Although, the thermal environment measurement was also conducted in order to have objective parameter on temperature, humidity, velocity, and PMV. Since Kitakyushu Eco-house has adopted the non-ordinary equipment, the measurement on electricity was conducted with clamp which recording the electric current of each appliances or electrical outlet. **Figure 6-7** shows the installation on data logger in the Eco-house control room. The record of every one second to every one second were tested, until it is decided to record the electric current of every second in order to know the detail about how the performance of each home electronic appliances and its impact to the total energy use.

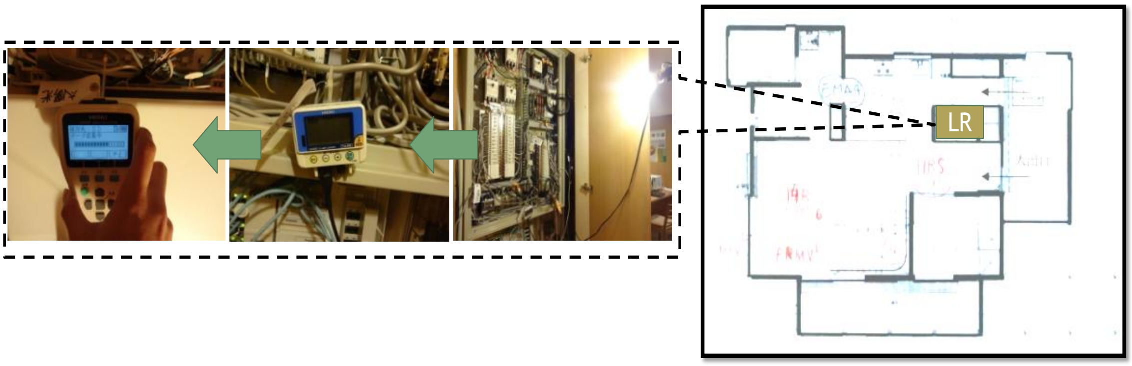


Figure 6-7 The installation of electricity use measurement tools

Figure 6-8 The installation of thermal environment measurement tools

Figure 6-8 shows the installation of thermo-recorder inside of the house. The field measurement was conducted during in the beginning of the week when the Eco-house is not in the operation (Eco-house open to the public from Thursday to Sunday).

6-3-3 Set of lifestyle and occupancy

In this study, the team did the experiment on living in Eco-house for 24 hour. Four members of research team have role as nuclear family member, which is a couple (parent) and two children. We tried many scenario cases of which was decided based on the experience and life schedule data base from questionnaire in Chapter 4 and was also supported by literature reviews. The daily pattern and hourly occupancy of household were shown in **Table 6-4** and **Table 6-5** respectively.

Table 6-4 Daily schedule of household

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Home	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	■■■■	■■■■	■■■■	■■■■	■■■■
Sleep	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□■■■
Meal	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	■■□□	□□□□	□□□□	□□□□	□□□□	■■□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□■	■□□□	□□□□	□□□□	□□□□
Cleansing	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□■□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□
Dressing	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□■	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□
Bathing	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	■■□□	□□□□	□□□□
Work	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□■■■	■■■■	■■■■	■■■■	□□□□	■■■■	■■■■	■■■■	■■■■	■■■■	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□
Commuting	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□■■	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	■■■■	□□□□	□□□□	□□□□	□□□□	□□□□
Living room	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	■■□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	■■■■	■■■■	□□■■	■■■■	□□□□
News	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□■□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□□□	□□■■	□□□□	□□□□	□□□□

Table 6-5 Hourly schedule for each family member

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Father	Bed room	Bed room	Bed room	Bed room	Bed room	Bed room	Kitchen	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Living	Kitchen	Living	Living	Living	Living	Living
Mother	Bed room	Bed room	Bed room	Bed room	Bed room	Kitchen	Kitchen	Living	Living	Living	Living	Kitchen	Living	Living	Living	Kitchen	Outside	Kitchen	Kitchen	Kitchen	Living	Living	Living	Living
Child 1	Bed room	Bed room	Bed room	Bed room	Bed room	Bed room	Kitchen	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Kitchen	Bed room	Kitchen	Living	Living	Living	Bed room	Bed room
Child 2	Bed room	Bed room	Bed room	Bed room	Bed room	Bed room	Kitchen	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Outside	Kitchen	Bed room	Bed room	Kitchen	Living	Living	Living	Bed room	Bed room

Bed room	Kitchen	Living	Outside
(yellow)	(dark blue)	(green)	(red)

6-4 Result of field measurement on Kitakyushu eco-house model

Table 6-7 Measurement 1 basic information

Date	16 Feb 2014~17 Feb 2014
Time	3:30 to 21:30
Weather	Cloudy, rain
Activity	Ordinary lifestyle

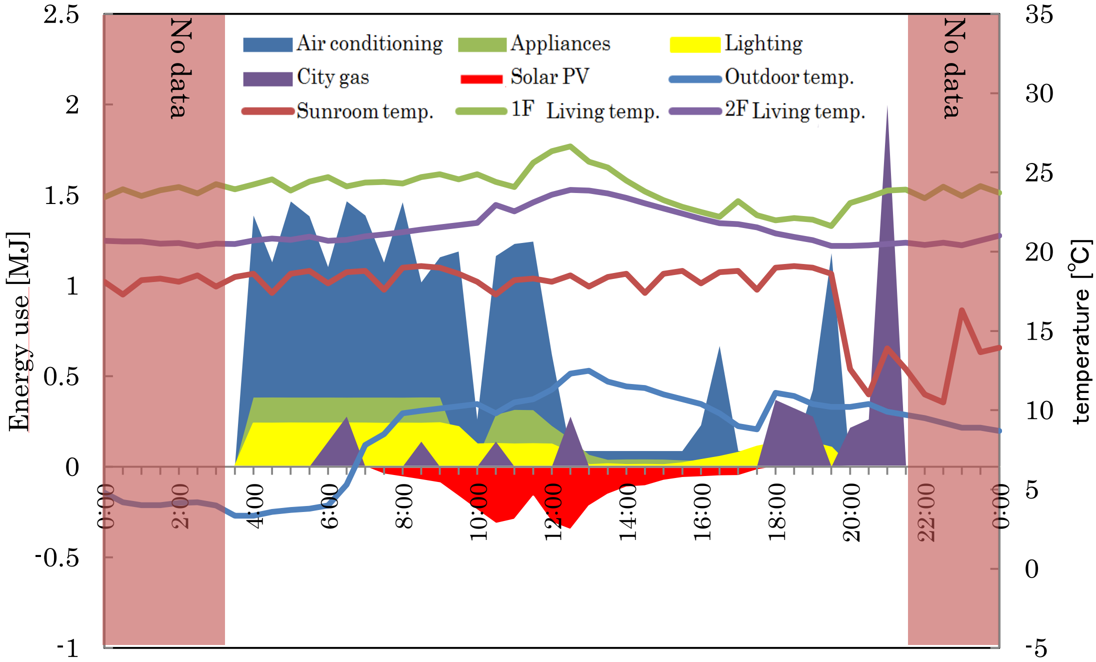


Figure 6-9 Result of measurement 1

The first measurement was conducted in the winter season. This measurement start from 4:00 o'clock in the morning, with the air conditioning and floor heating turned on and. Air-conditioning temperature was set to 25 degrees. Then, breakfast preparation from 5:30 o'clock, started using gas and kitchen equipments. Washing machine used from 10 o'clock to 11 o'clock. At 10 o'clock the housewife leave for shopping then made lunch by using gas from 12:00 o'clock. The weather was a little cloudy, which make the room become cooler. Then around 11:30 the electric use has became higher again due to the use of floor heater. Dinner from around 17:30 and start using gas. And it began to accumulate hot water bath from 19:30. At 22:00 is the time of going to bed, floor heating does not give even air conditioning. While not in the energy saving, was carried out in the life style of the actual investigation first time that not even overuse.

Table 6-8 Measurement 2 basic information

Date	10 Mar 2014~11 Mar 2014
Time	00:00 to 24:00
Weather	Sunny
Activity	Ordinary lifestyle

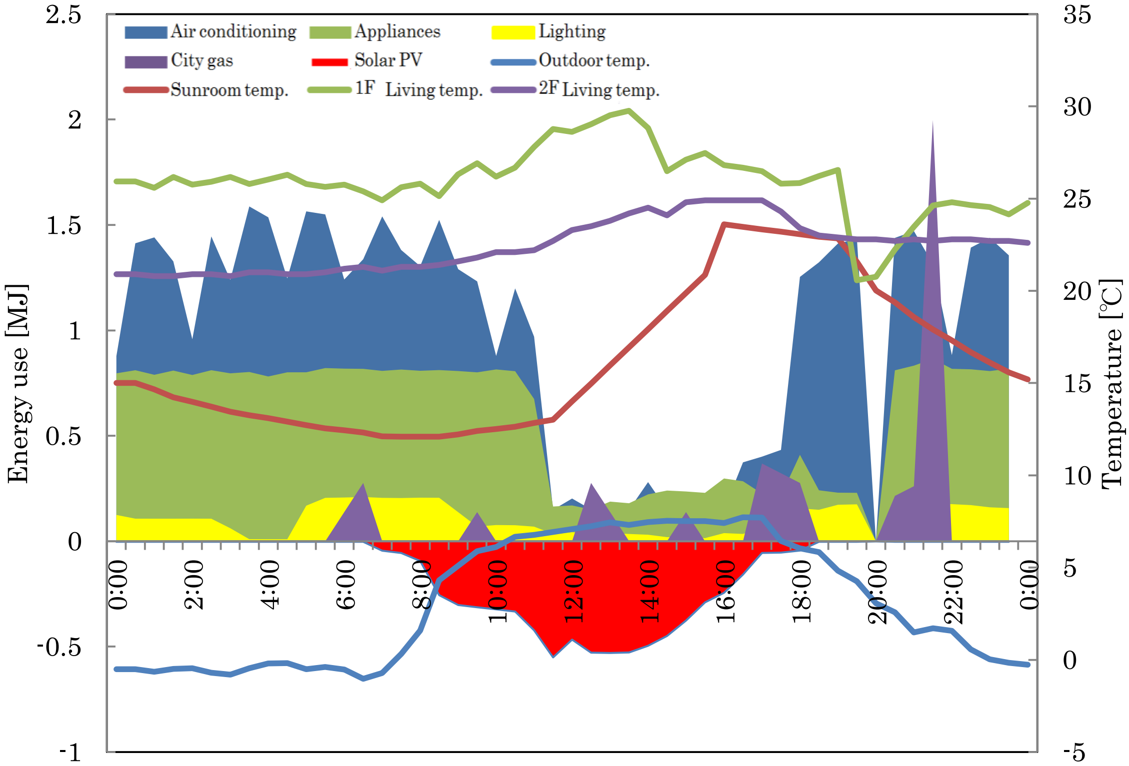


Figure 6-10 Result of measurement 2

The second measurement was cooler than the first one even it was already in the middle of March. The outside temperature was reached to minus 1 in the morning. The air conditioner was operated in the between 26-27 degrees. Around 5:30 gas has been used to make breakfast and to make lunch at 12 o'clock. Since this day was sunny, it was possible to greatly use power sunlight. The temperature on sunroom increased in the daytime even the AC is turned off, but it was start to fall down after 15:00 then AC was turned on again to maintain the comfort in the room. Amount of power supply from PV has reached the peak at around 11:30. This day was using the gas to the snack-making at around 15:00. And it began to accumulate hot water for bath from around 20:00. Even at the time of going to bed, we have to set the floor heating and air conditioning due to very low temperature at night.

Table 6-9 Measurement 3 basic information

Date	29 Apr 2014~30 Apr 2014
Time	0:00 to 22:00
Weather	Cloudy, rain
Activity	Ordinary lifestyle

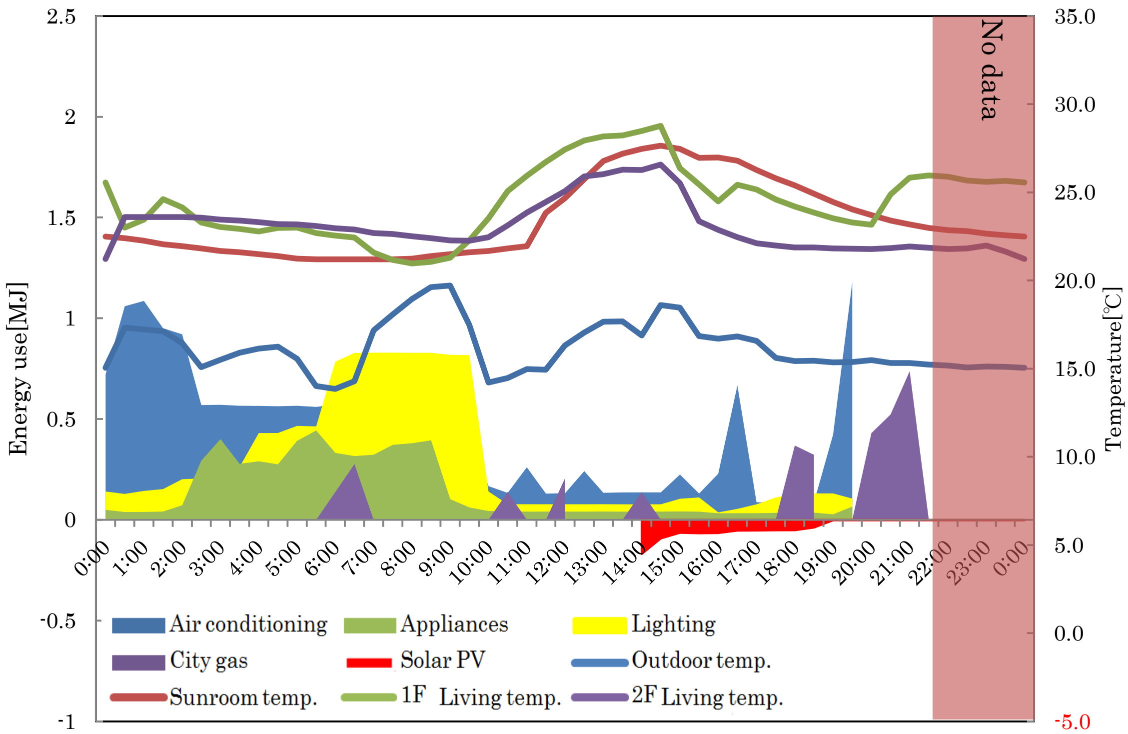


Figure 6-11 Result of measurement 3

The outside temperature was started to increase but the PMV still showed minus value. Room air conditioner settings were operated in the 24 degrees. Since it was in the interim period, the use of air conditioning system was only when needed. Since this day was rain, the supply of electricity from PV was very low. This day we were using the gas for the dishwasher at around 10:00 and 14:00. And it began to accumulate hot water for bath from around 20:00. The electric lighting energy use was become high due to the rainy weather. Lack of sunlight entering the room was the reason. Using electricity to slightly more in percentage of the interim period, but the gas was carried out in the actual survey third time the setting of lifestyle home that is not used very often.

Table 6-10 Measurement 4 basic information

Date	02 Jul 2014~03 Jul 2014
Time	0:00 to 24:00
Weather	Sunny with cloud
Activity	Energy conservation

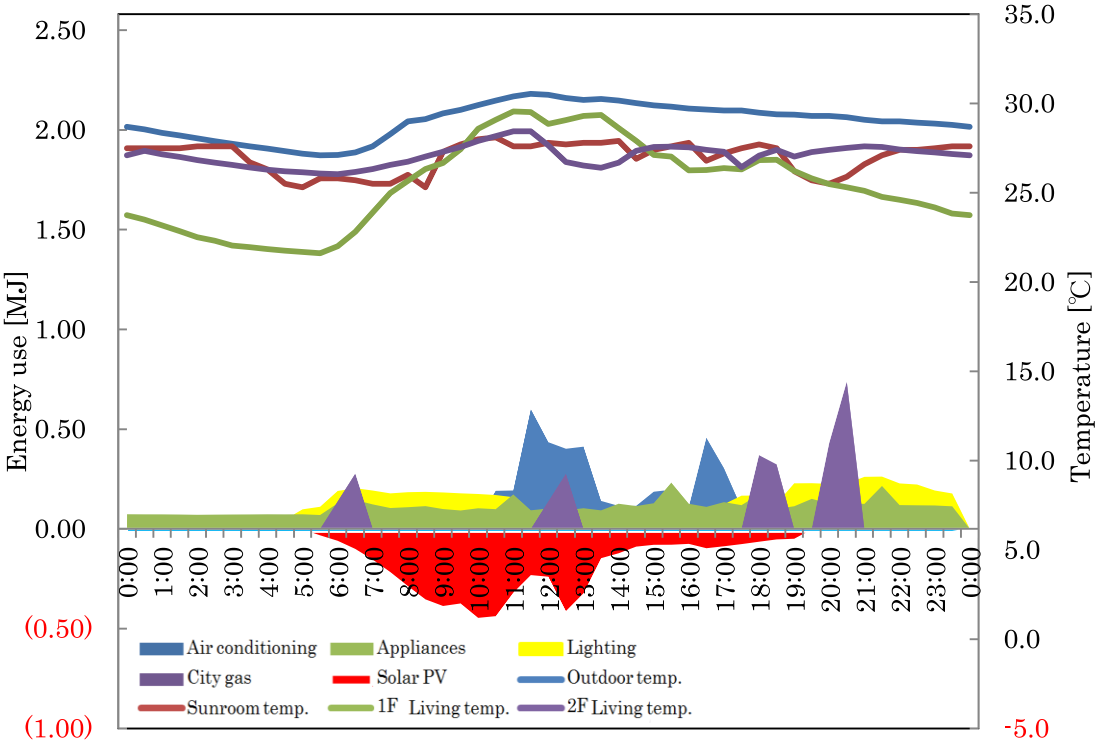


Figure 6-12 Result of measurement 4

The outside temperature was become high since it was summer. Air conditioning settings in the 24 degree in daytime and it were operated when needed only. Air conditioning was operated from 11:00 around that summer temperatures reach a peak until about 14:00. The cooling method by opening the door in the daytime was also practiced. In this day, it had been sunny in the morning to afternoon and it began to rain. The amount of solar PV power generation reached a peak at around 10 o'clock. As the use of the bath, because it is summer, it is not pooled too much hot water for bath, with shower only. At the time of going to bed, it was on the set of not with the air conditioning and still maintain the comfort. Lifestyle survey of the day the air conditioning also necessary minimum only without using, it was the setting of the life style of a considerable energy saving home to save even usage of gas.

6-5 Investigation on lifestyle and energy use performance of Kitakyushu eco-house model

Table 6-6 Lifestyle scenario

Family member	4 person		
Family structure	Couple 2 person, children 2 person		
Lifestyle scenario	CASE 1	CASE 2	CASE 3
Heating	Natural ventilation + air conditioning	Natural ventilation + air conditioning	Air conditioning and floor heating
Cooling	Natural ventilation	Natural ventilation and air-conditioning	Air conditioning
Heating temperature (℃)	18	20	22
Cooling temperature (℃)	26	24	20
Indoor air ventilation method (winter)	Close all doors and windows	open and close the doors	open and close the doors
Indoor air ventilation method (summer)	To ensure the ventilation to the fullest by opening the doors and windows	It will ensure a certain degree of ventilation by opening windows only	It does not ensure the ventilation and close the doors and windows
Lighting	Use lighting only night	Use the lighting in the morning and evening	Use the day lighting in some room
Hot water supply	Do not use	To use only winter	Use all year round
Bath and shower activity	Using alternative of shower only	Use both tub and shower	Use both tub and shower
Appliances	Plug off when not in use	Only turn off without plug off	Only turn off without plug off

Three types of lifestyle scenario proposed in order to know how much the energy use difference if those type of lifestyle applied in the eco-house. Lifestyle scenario of CASE no 1 pretends to be the energy conservation type by using the passive equipment such as OM solar in the winter and natural ventilation in the summer season. CASE no 2 was designated for ordinary behavior pattern without energy saving effort. While CASE no 3 pretends to be the non-energy conservation lifestyle. In this type of lifestyle the house is fully air conditioned for 24 hours, with the basic lifestyle without thinking about energy conservation effort.

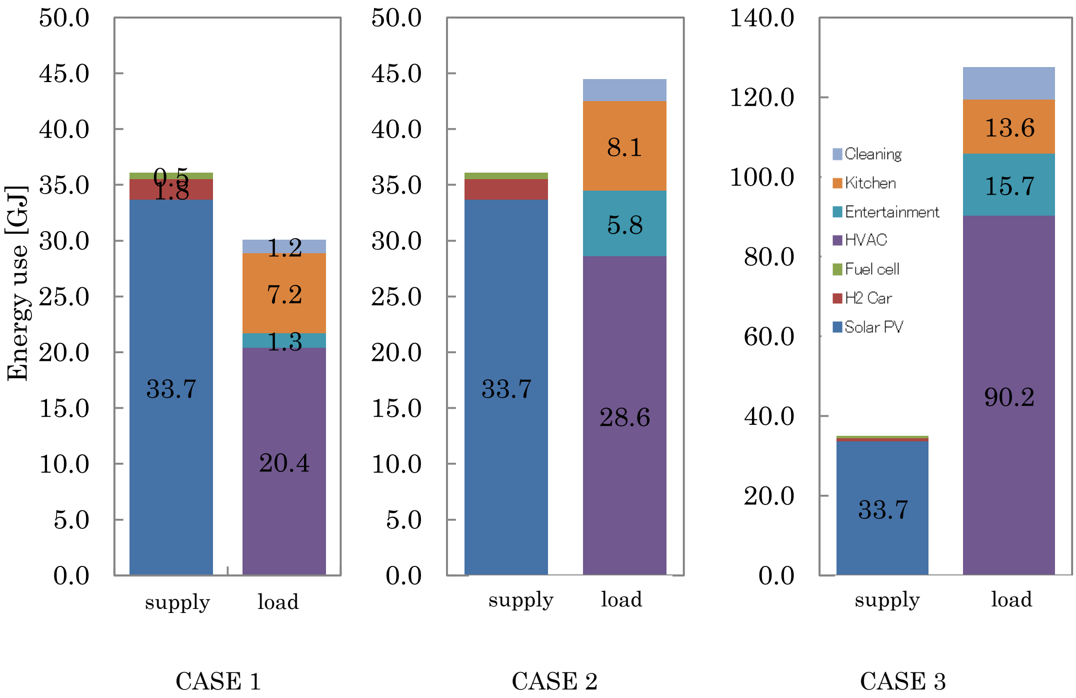


Figure 6-13 Simulation result of annual energy use of various lifestyle types

Based on several field measurements which have been conducted, the data base were built so the characteristics of each appliances energy usage could be grasped. Then simulations on annual energy use in eco house were performed based on these statistical results.

As a result, in CASE 1 the supply is higher than the energy load, means the target of plus energy house can be achieved by applying this lifestyle pattern. By applying the natural ventilation system in the summer and intermediate seasons, the energy use of HVAC can be reduced.

On the other hand in CASE 2, with the assumption of the energy supply is same with CASE 1, even it is not much the house energy load has exceeding the supply. In other words, the nearly zero energy use house can be achieved by applying the lifestyle type in CASE 2.

Differ with CASE 1 and CASE 2, the impact of non-conservation lifestyle in CASE 3 shows high difference between supply and load of energy.

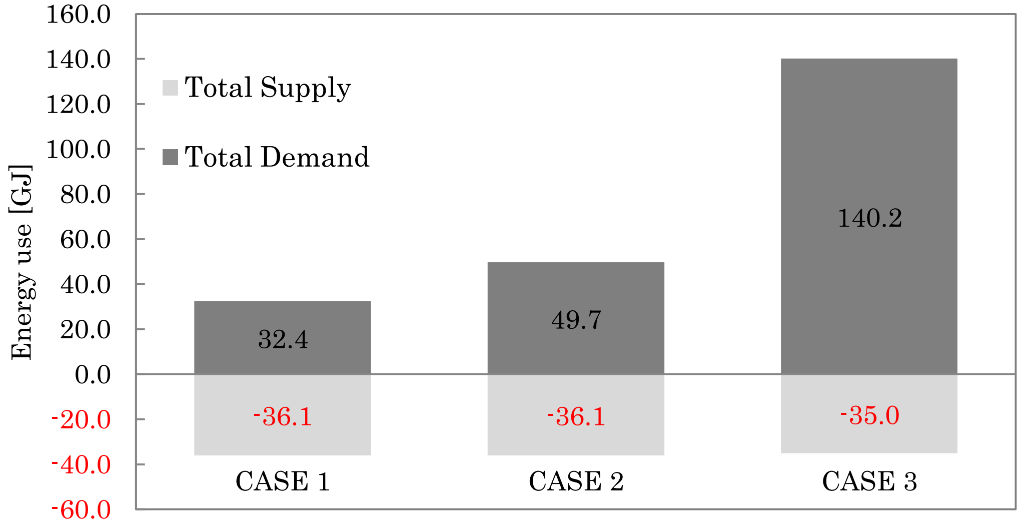


Figure 6-14 Comparison of CASE 1, CASE 2, and CASE 3

6-5-2 Development of energy load prediction equations for Eco-house model

This study intends to develop the energy load prediction equations so it can be easier to use in estimating the energy use in Eco-house during the early stage of design. There have been a number of studies which developed simple load prediction models for commercial and office buildings, but no attempt has been made yet to present a simple energy prediction equation for ecological house model in Japan. Based on many possibilities and literature research, energy related design parameters and performance levels which affect energy consumption were established for baseline building. This method was proposed by *Kang et al.*[2] in Korean multi-residential buildings. Here, the same mathematical method was applied and tested to predict the influential factor on Eco-house energy use. To analyze the sensitivity of each energy-related design parameter to overall building performance, the *Taguchi Orthogonal Array* was used to decrease the number of experiments to 81 in spite of the fact that the required number for carrying out the simulation was 3^{12} (=531,411). The computer simulation was performed using *Energy-Plus* as the engine and *Design-Builder* as the interface. Then, the multiple regression analysis was conducted to estimate the relative importance of each energy parameter. Through statistical software, *SPSS*, data for multiple regression analysis was developed to find the prediction equations.

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[2] Kang, HJ., Rhee, EK., A development of energy load prediction equation for multi-residential buildings in Korea. Journal of Asian Architecture and Building Engineering. November 2012/383-389.

Ｔａｂｌｅ **6-7** Parameters setting for simulation

	Parameter/factor	Level		
		1	2	3
X1	Family member	3	4	5
X2	Wall material	Wooden	Concrete	Brick
X3	Building direction	South-North	Southeast-Northwest	West-East
X4	Wall thickness	200	300	400
X5	Cooling temperature [℃]	22	24	26
X6	Heating temperature [℃]	28	26	24
X7	Cooling COP	3.3	4.3	5.3
X8	Heating COP	3.7	4.7	5.7
X9	Air conditioning power	Electric	Natural gas	Biogas
X10	Air conditioning method	Fan coil unit	Ventilation system	Hot water circulation radiator
X11	Window-wall ratio	13%	18%	30%
X12	Ventilation method	none	Natural ventilation	Mechanical ventilation

In order to determine the relative importance of each parameter on energy use, the parameters should be fixed and one variable should be manipulated diversely to review how the results will change. For that reason the twelve variables presented in Table 6-7, are changed on only three levels, as many as 3^{12} which is equals to 531,441 simulations will be required, making the analysis almost impossible. In experimental design using Orthogonal Arrays, the same results from the calculation of entire simulation can be induced by implementing a small number of simulations only. According to the Orthogonal Arrays it is possible to reduce the number of simulation to 81, $L_{81}[3^{40}]$.

The relative importance of each parameter was obtained by the following equation.

$$P_{A_0} = \frac{Y_1+Y_2+Y_3+\cdots+Y_{27}}{27} - T_m \qquad \text{(Eq. 1)}$$

$$P_{A_1} = \frac{Y_{28}+Y_{29}+Y_{30}+\cdots+Y_{54}}{27} - T_m \qquad \text{(Eq. 2)}$$

$$P_{A_2} = \frac{Y_{55}+Y_{56}+Y_{57}+\cdots+Y_{81}}{27} - T_m \qquad \text{(Eq. 3)}$$

$$P_{B_0} = \frac{(Y_1+\cdots+Y_{27})+(Y_{28}+\cdots+Y_{54})+(Y_{55}+\cdots+Y_{81})}{27} - T_m \qquad \text{(Eq. 4)}$$

$P_{Ai,Bi}$ Contribution of each parameter on i level.
Y_i Energy consumption at each experiment
T_m Total average of energy consumption of 81 experiments

$$\rho_T(\%) = \frac{SS_{T'}}{SST} * 100 \qquad \text{(Eq. 5)}$$

ρ_T Percentage contribution of nominal
$SS_{T'}$ Variation of nominal only
SS_T Sum of squares (total variation)

Table 6-8 Orthogonal array table $L_{81}[3^{40}]$

1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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1	1	1	1	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3
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The simulation for cooling and heating load calculations were undertaken by using the Energy-Plus software and a database for the analysis of variance was established based on the simulation results in **Table 6-8**.

Table 6-8 Simulation result of heating and cooling load

No	Cooling load	Heating Load	No	Cooling load	Heating Load
	GJ/year	GJ/year	41	46.40	47.33
1	41.43	32.62	42	47.87	63.02
2	43.09	26.35	43	39.02	47.98
3	45.99	19.20	44	35.66	45.25
4	41.63	27.52	45	37.11	64.41
5	36.27	24.20	46	41.19	48.26
6	38.35	18.29	47	37.68	42.45
7	32.11	27.78	48	39.45	60.78
8	35.67	19.72	49	31.64	46.55
9	30.36	17.55	50	34.11	34.87
10	28.77	62.87	51	28.64	62.96
11	39.01	47.98	52	44.89	45.25
12	26.99	44.05	53	46.42	35.01
13	43.71	61.14	54	49.18	32.02
14	44.21	48.11	55	41.13	17.59
15	46.99	36.33	56	45.03	27.79
16	39.46	62.91	57	46.42	21.24
17	36.09	60.49	58	41.51	18.37
18	37.38	47.76	59	36.44	33.49
19	40.88	49.62	60	38.47	26.46
20	36.86	43.90	61	32.04	18.28
21	43.74	47.84	62	35.50	26.57
22	31.59	61.89	63	30.30	24.67
23	34.07	48.39	64	28.67	46.69
24	30.31	43.00	65	30.42	63.34
25	44.66	63.67	66	27.08	48.54
26	46.86	46.83	67	44.20	44.90
27	49.49	34.77	68	45.66	53.00
28	41.25	24.11	69	47.28	48.48
29	44.97	17.53	70	39.16	36.01
30	46.36	28.15	71	35.69	62.25
31	41.70	20.42	72	37.04	50.06
32	36.30	17.67	73	40.86	33.89
33	38.35	27.62	74	35.96	62.01
34	31.83	25.82	75	38.99	46.24
35	35.12	17.84	76	31.77	34.78
36	30.08	33.37	77	34.55	47.97
37	28.98	48.94	78	30.05	44.39
38	30.85	36.56	79	46.65	43.24
39	27.13	60.09	80	48.08	62.09
40	44.87	59.70	81	50.33	46.77

Energy simulation tools are required to evaluate the energy performance of buildings and to provide more flexible building energy design standards. A series of linear regressions were performed using stepwise method. The criterion used for improvement of prediction was the coefficient of determination (R^2), which is represents the square of the correlation between predicted value and actual value (simulation). As a result of multi regression analysis, a mathematical model is developed that illustrates the relationship between the parameters and energy use. This result indicates that the model is significant.

Table6-9 Regression model of cooling load

R	R^2	modified R^2	Std. error
0.974	0.948	0.945	1.49701

Table 6-10 Correlation Coefficient of cooling load

	Non-standard constant	Std. error	ß	t
(constant)	45.719	0.831		54.97
cooling temperature	-7.144	0.204	-0.92	-35.068
WWR	2.295738	0.204	0.296	11.269
building orientation	0.685	0.204	0.088	3.364
wall structure	0.578	0.204	0.074	2.836

Table 6-11 Regression model of heating load

R	R^2	modified R^2	Std. error
0.816	0.665	0.648	8.764229

Table 6-12 Correlation Coefficient of heating load

	Non-standard constant	Std. error	ß	t
(constant)	44.96741	1352.501		9.235
wall structure	11.65247	331.295	0.649	9.77
heating temperature	-7.85019	331.295	-0.437	-6.582
Wall thickness	-3.19451	331.295	-0.178	-2.678
WWR	-2.6725	331.295	-0.149	-2.241

Influential factor on cooling load can be described as follows:

$$y = 45.719 - 7.144X5 + 2.296X11 + 0.685X3 + 0.578X2$$

where,

X2 : wall material

X3 : building orientation

X5 : cooling temperature

X11 : WWR

While, the Influential factor on heating load is:

$$y = 44.967 - 11.652X2 - 7.850X6 - 3.195X4 - 2.673X11$$

where,

X2 : wall material

X4 : wall thickness

X6 : heating temperature

X11 : WWR

The correlation of Energy-Plus simulation model results and the regression model results is shown in **Figure 6-15** and **Figure 6-16**. As shown in the figures, the coefficient determination were 0.947 for the cooling load and 0.665 for the heating load indicating that the regression model is reasonably well fitted with the computer simulated values. Therefore, the regression equations here were found to have a considerable predictive power.

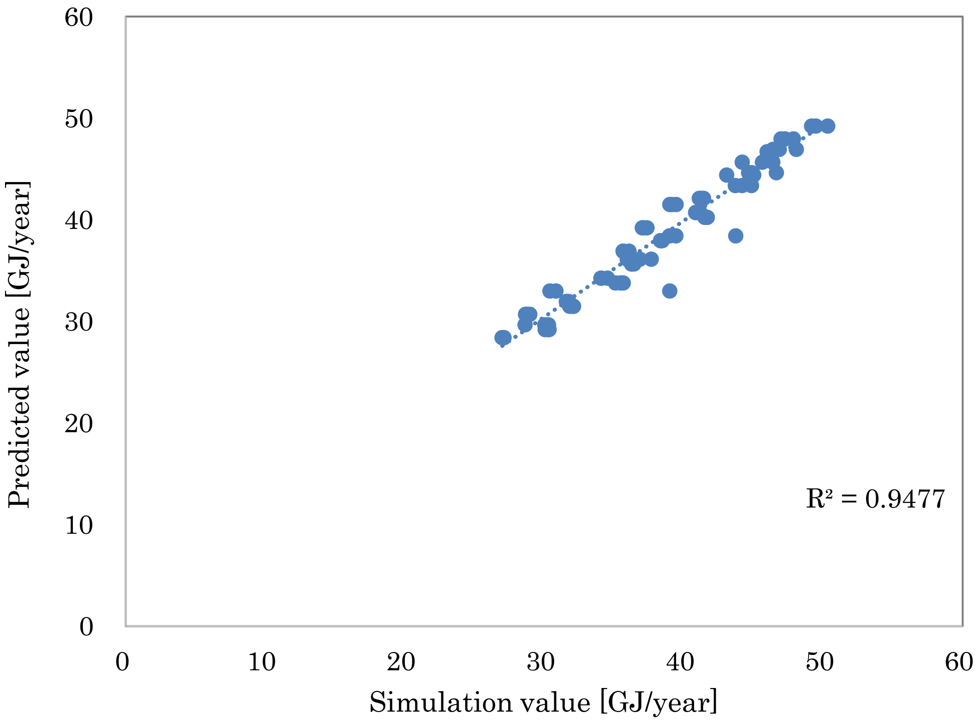


Figure 6-15 Correlation between predicted value and simulation value of cooling load

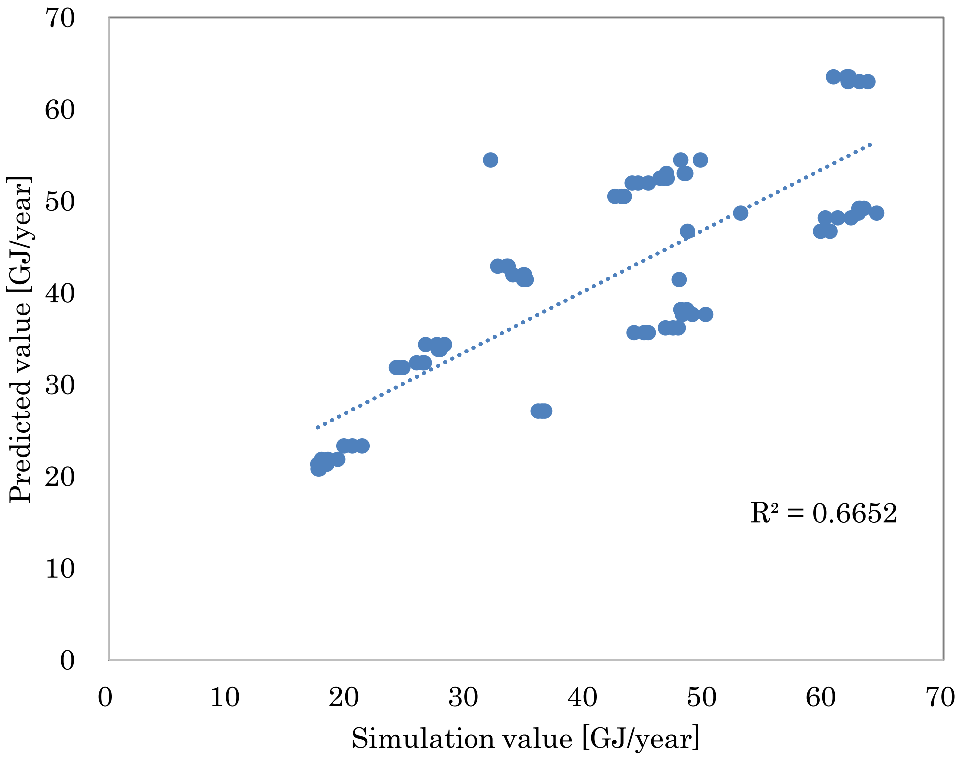
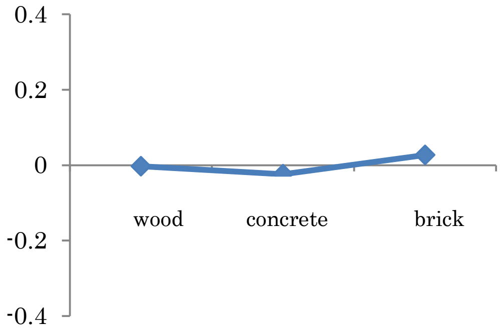
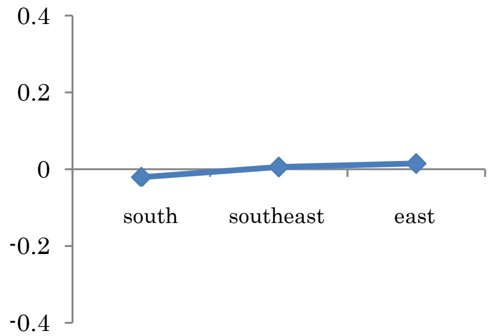


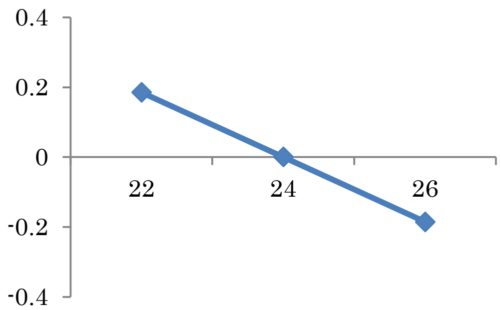
Figure 6-16 Correlation between predicted value and simulation value of heating load



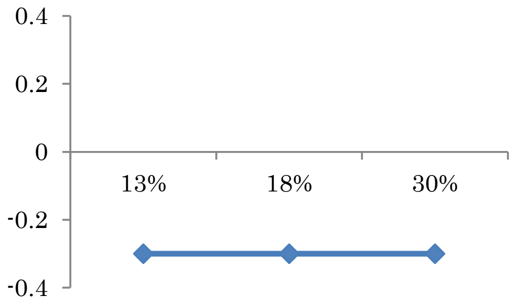
(a) wall structure



(b) Direction of the building

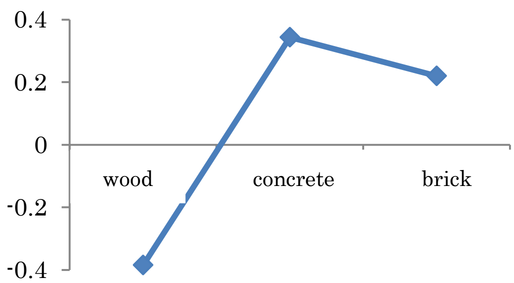


(c) Cooling temperature

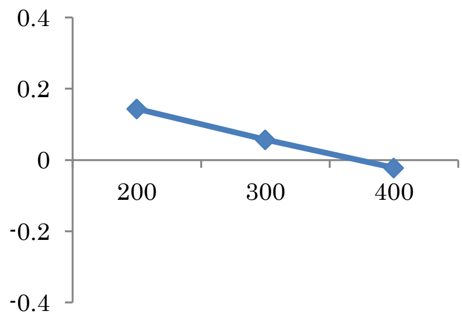


(d)WWR

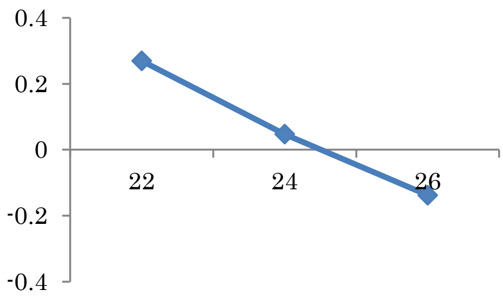
Figure 6-17 Correlation coefficient weight contribution on cooling load



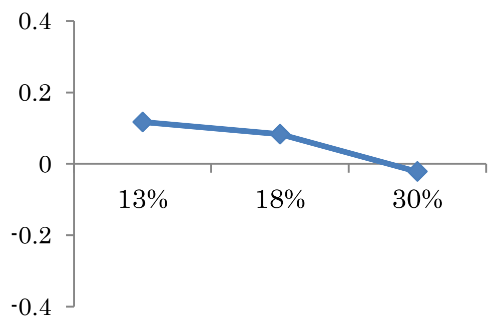
(a) wall structure



(b)Wall thickness



(c)Heating temperature



(d)WWR

Figure 6-18 Correlation coefficient weight contribution on heating load

6-6 Summary

This study investigated the type of Japanese lifestyle pattern correlation with energy consumption (electricity use) which is then applied in the eco-house model in Kitakyushu City. The conclusions were drawn as follows:

1) Based on the field measurement results, the largest share of energy use in eco-house model is the use of the electronic home appliances, especially in the winter, which reached nearly 65% share of total load in a day.

2) The comparison analysis between the measured value of each consumer electronics appliances and the measured value of the whole of the electricity of waste type of house lifestyle pattern were conducted. It is found that Eco-house can effectively operate if the practice on the energy conservation lifestyle performed. By scenario of Case 1 as the energy conservation type, the yearly energy use can be reduced 34.8% from Case 2 which is the ordinary lifestyle type. While, by the scenario in Case 3, the yearly energy use increased 182%, almost 3 times of Case 2.

2) Based on questionnaire survey in Chapter 4, and intensive literature search, the main factors affecting energy use reduction were selected. It is found that both heating and cooling loads are influenced by wall material, WWR, and temperature setting. The R-square results show high number which means the model is valid to predict the cooling and heating load.

3) According to the Orthogonal Arrays it is possible to reduce the 531,441 number of simulation to be 81 (depends on number of factors included). By using orthogonal arrays the development on the method to evaluate the eco-house design can be preformed. This method can reduce the simulations number for the early design stage.

第七章

日本全国のエコハウスモデルにおける ライフスタイル及び住宅エネルギー消費に関する シミュレーション

Chapter seven: Building Energy Use and Lifestyle Simulation of Various Japanese Eco-house Models

7-1. Background

Japan's ambitious *Eco-house* project has already completed twenty-two unique sustainable homes throughout the country in an aim to set a new national standard for environmental design. At *34th G8 Summit* in *Hokkaido*, Japan and the other member nations agreed to reduce carbon emissions by 50% before 2050. Japan is working to surpass this goal and achieve a truly *Low-Carbon Society* by reducing emissions by as much as 80% within the next 40 years. A critical component of the plan is to reduce household's energy consumption which has risen by an alarming 40% since 1990[1]. Therefore, the government has committed itself to improving the overall quality and performance of new and existing homes. The Ministry of Environment established the *Eco-House Model* program to build twenty sustainable houses from *Okinawa* in the south to *Hokkaido* in the north (twenty municipalities) to each design and construct and operate an experimental *Eco-House Model* responding to the local climate and site conditions. Each house has been designed by a different local architect in conjunction with the city governments and the Ministry of the Environment. Most are designed to utilize passive solar heating and use natural ventilation techniques to circulate warm and cool air throughout the houses. All but one of the projects is constructed from timber. The designs are combining the inherent sustainability of many traditional Japanese elements with modern layout.

However, these model houses are built without occupation of the families. For that reason, this paper purposed to conduct study on energy load estimation in Eco-House models through building simulation software by considering the physical characteristics of each model and including some assumption. Literature studies were conducted to collect the information [2] and to develop the methodology on conducting the simulation. *Daniel et al.*[3] examined occupant behavior in low energy houses in the context of the Australian regulatory house energy rating scheme and, using simulation, demonstrates the impact of alternative occupancy settings on the validity of the predicted house energy rating. The results clearly show that current occupant

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[1] Statistical Handbook of Japan, Chapter 7, Energy, Statistics Bureau, Japan (2013) 77-82.

[2] Eco-House Follow-up Working Group, Japan Institute of Architects. "Introduction of Japan's Eco-House-performances from cold region to hot region-". Japan (2014). (in Japanese)

[3] Daniel, L., Soebarto, V., Williamson, T. House energy rating schemes and low energy dwellings: The impact of occupant behaviors in Australia. Energy and Buildings 88 (2015) 34-44.

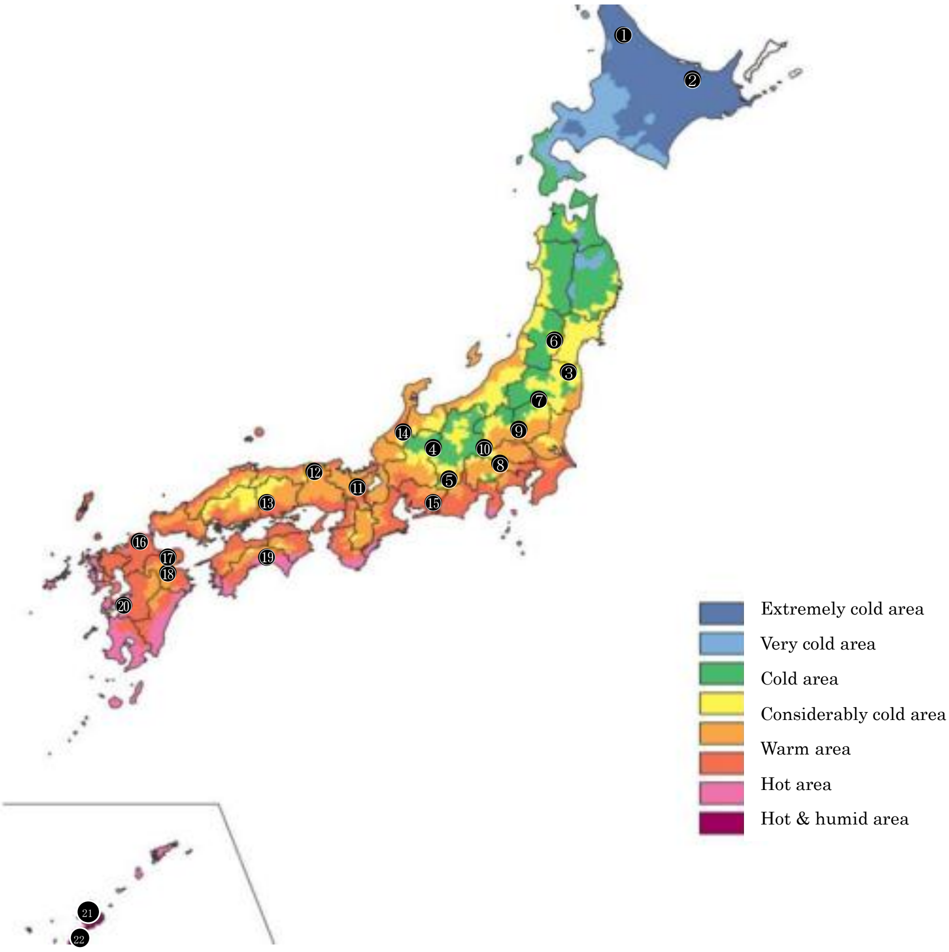
assumptions within the scheme fail to adequately reflect actual heating and cooling practices in low energy dwellings and, as such, overestimate energy consumption within these households. Based on these results it is suggested that, for equitable assessment of these house-holds, settings within the simulation engine used for assessment must be modified to align with actual user behavior. *Ubinas et al.* [4] analyzed the passive strategies and houses services with assessment which has been compared with the behavior of the houses during the monitoring period. Comparative studies make emphasis on the energy aspects, houses functioning and their interior comfort. *Wiberg et al.* [5] investigated whether it is possible to achieve a net Zero Emission Building (nZEB) by balancing emissions from the energy used for operation and embodied emissions from materials with those from on-site renewable in the cold climate of Norway, found that the only use of roof mounted PV production is critical to counterbalance emissions from both operation and materials (ZEB-OM). The results also show that the single-family house has a net export to the electric grid with a need for import only during the coldest months. *Kang et al.* [6] has developed the energy load prediction equations for multi-residential buildings in Korea, by using mathematical *orthogonal array* method in order to reduce the number of simulation and found some factors influencing the heating and cooling load of apartment building in Korea. Some literature studies mostly were conducted in western societies, only small number of this study conducted in Asia, since the ecological house concept is still new and some countries still developing the house model.

[4] Ubinas, E.R., Rodriguez, S., Voss, K., Todorovic, M.S. Energy efficiency evaluation of zero energy houses. Energy and Buildings 83 (2014) 23-35.

[5] Wiberg, A.H., Georges, L., Dokka, T.H., et al. A net zero emission concept analysis of single-family house. Energy and Buildings 74 (2014) 101-110.

[6] Kang, H.J., Rhee, E.K. Development of energy load prediction equations for multi-residential buildings in Korea. Journal of Asian Architecture and Building Engineering (2012) 383-389.

7-2 Introduction of twenty-two Japanese eco-house models



Climate	No	Name*	Climate	No	Name*
Cold area	1	Shimokawa	Warm area	9	Ota
	2	Bihoro		10	Yamanashi
	3	Itate		11	Omihachiman
	4	Takayama		12	Toyoka
	5	Ida		13	Bizen
	6	Yamagata		14	Ishikawa
	7	Yaita		15	Hamamatsu
	8	Tsuru		16	Kitakyushu
Hot area	19	Kochi		17	Bungotakada I
	20	Minamata		18	Bungotakada II
	21	Miyakojima I			
	22	Miyakojima II			

*****:*in this paper the name of city or prefecture of eco-house located were used*

Figure 7-1 Location of twenty-two Japanese Eco-house

Figure 7-1 shows the twenty-two eco-houses name and location in different climate area of the country. Area climate classification was based on Japan's Institute for Building Environment and Energy Conservation.

7-2-1. Shimokawa Eco-house

Shimokawa eco-house is located in the northern of Japan which has the coldest climate area. It is aimed at zero carbon by the aggressive use of biomass. The detail overview of Shimokawa Eco House was summarized in **Table 7-2-1**.

Table 7-2-1 Shimokawa eco-house overview

Structure and floor	Wooden, two-story, solid foundation	
Site area	916.42 m²	
Construction area	177.42 m²	
Total floor area	249.3 m²	
Power generation equipment	Solar power generation capacity 0.56 kW	
Heat source equipment	Geothermal heat HP (heating capacity 10kW: COP = 3.7) Pellet stove (5.6kW)	
Heating system	Earthen floor heating by hot water circulation of geothermal heat HP, and auxiliary heating system by fan coil vector at the time of the supplying the air from under the floor: pellet stove	
Ventilation system	Ventilation type 1* Under floor fan to supply air by (outside air preheating by circulating the hot water), natural exhaust system	
Hot-water supply equipment	Pellets hot water boilers (14.9 kW, hot water tank 500 L) used as the primary heat source for hot water supply Hot water supply boilers (7 kW) Auxiliary heat source for hot water supply	
Hot-water supply system	Hot water supply system that combines the pellet boiler and hot water tank 500 L. Hot water supply system to be used by switching to hot water boilers	

7-2-2 Bihoro Eco-house

Bihoro Eco House is also located in the northern part of Japan in Hokkaido Island. The overview of Bihoro Eco-house is described in Table 7-2.

Table 7-2 Overview of Bihoro Eco House

	
Structure and rank	Wooden, two-story, solid foundation
Site area	4809.79 m^2
Construction area	198.74 m^2
Total floor area	252.96 m^2
Power generation facilities	Installed solar power generation capacity 0.126kW roof surface
Heat source equipment	Geothermal Heat HP (heating capacity 10kW: COP = 3.7) Pellet stove (5.4kW) Electric heater
Heating system	Earthen floor heating and the heating system in the main room by a pellet stove heating system by hot water circulation of geothermal heat HP Auxiliary heating: private room of the panel heating by electric heater
General ventilation system	Ventilation type 2*
Hot-water supply equipment	Air heat source HP water heater (hot water tank 460L) Pellet boiler (hot water tank 460L)
Hot-water supply system	The hot water supply system by air source heat HP water heater and pellet boilers

7-2-3 Iitate Eco House

Iitate Eco House is constructed for two-family lived by two generation of family. It is located in the northern part of Honsyu Island. The overview of Iitate Eco-house is shown in **Table 7-2-2**.

Table 7-2-3 Iitate Eco House

Structure and rank	Wooden, 2-story, solid foundation
Site area	2630.36m^2
Construction area	201.06m^2
Total floor area	221.99m^2
Power generation facilities	Installed solar power generation capacity 1kW roof surface
Heat source equipment	Roof solution heat collecting formula solar system (solar thermal collector panel 3.76 m^2-hot water tank 200L) - Firewood kerosene boilers (51.1kW, visceral hot water tank 60L)
Heating system	Hot water circulation radiator heating system due to roof solution heat collection type solar system and firewood kerosene boilers
General ventilation system	The first kind ventilation (total heat exchanger)
Hot-water supply equipment	Roof solution heat collecting formula solar system (solar thermal collector panel 3.76 m^2-hot water tank 200L) - Firewood kerosene boilers (51.1kW, built-in hot water tank 60L)
Hot-water supply system	Roof solution heat collecting type solar system and the hot water supply system by firewood kerosene boilers

7-2-4 Takayama Eco House

Takayama Eco House is a house made with a traditional method is characterized structure with a large blow to the center of the house. Unlike the other Japanese Eco-house model Takayama Eco-house has simple equipment. The features of the house are shown in **Table 7-2-4.**

Table 7-2-4 Takayama Eco House

Structure and rank	Wooden, two-story, solid foundation
Site area	1801.722 m^2
Construction area	193.87 m^2
Total floor area	240.83 m^2
Power generation facilities	Installed solar power generation capacity 2.6kW roof surface
Heat source equipment	Pellet stove capacity 11kW
Heating system	The entire heating by pellet stove
Cooling system	None
General ventilation system	The first kind ventilation
Hot-water supply equipment	Pellet boilers capacity 30kW
Hot-water supply system	Hot water supply system that combines the pellet boiler and hot water tank 150L

7-2-5 Iida Eco-house

Iida Eco-house is lived eco-house of two different household, each divided into the south and the north buildings. An overview of Iida Eco House is shown in **Table 7-2-5**.

Table 7-2-5 Iida Eco-house overview

Structure and rank	Wooden, 2-story, solid foundation	
Site area	211.40 m^2	
Construction area	127.28 m^2	
Total floor area	188.57 m^2	
Power generation facilities	Installed solar power generation capacity 3.12 kW roof surface	
Heat source equipment	Roof air collector thermal solar system (the entire surface roof heat installed collecting-air heat source HP water heaters and hot water supply for the hot water storage tank 420 L) Pellet stove two capacity 7.5 kW and 3 kW	
Heating system	North building: The air heat collector type solar heating by the roof air collector thermal solar system South building: 7.5kW Heating auxiliary heating by pellet stove: 3kW of pellet stove	
General ventilation system	North Building: is switched in the first kind ventilation (at the time of the heat collection of the solar system) and the three ventilation (during non-thermal collector of the solar system) South tower: the first kind ventilation	
Hot-water supply equipment	Roof air collector thermal solar system (roof over the entire surface heat collecting-air heat source HP water heaters and hot water supply for the hot water storage tank 420L)	
Hot-water supply system	Roof air collector thermal solar system	

7-2-6 Yamagata Eco House

Yamagata Eco House by the leverage of the rich forests of the northeastern Japan, the use of wood for material from the neighborhood. The roof and walls adopts glass wool, and polystyrene foam heat-insulating material is used to the foundation. It overview of equipment is shown in **Table 7-2-6** Overview of Yamagata Eco House.

Table 7- 6 Yamagata Eco House

Structure and rank	Wooden, 2-story, solid foundation	
Site area	567.83m^2	
Construction area	149.54m^2	
Total floor area	208.15m^2	
Power generation facilities	Installed solar power generation capacity 5kW roof surface	
Heat source equipment	Roof solution heat collector solar system (solar thermal collector panel 6m^2 · hot water tank 650 L), Pellet boiler capacity 7 kW, Pellet stove Air conditioner upstairs (cooling capacity 4kW: COP = 4.5, heating capacity 5kW: COP = 5.1), Exhibition room (cooling capacity 2.2kW: COP = 5.4, heating capacity 2.5kW: COP = 6)	
Heating system	Circulate the hot water stored in the hot water storage tank by the roof-liquid heat collector type solar system and pellet boilers, heat dissipation from under the floor of the radiator Auxiliary heating: pellet stove	
Cooling system	The cooling by electric air conditioner	
ventilation system	Ventilation type 1* (sensible heat exchange)	
Hot-water supply equipment	Roof solution heat collector solar system (solar thermal collector panel 6m^2 · hot water tank 650 L) Pellet boiler capacity 7 kW	
Hot-water supply system	Hot-water supply system roof liquid heat collecting type solar system (the solar thermal collector panel 6m^2 · hot water storage tank 650 L) a combination of pellet boilers	

7-2-7 Yaita Eco house

Yaita is located in the northeastern part of Tochigi Prefecture. Summer is hot and humid, while winter is dry low temperature, so there is big difference of highest and lowest temperature in a year. Amount of sunlight radiation throughout the year is relatively large. The features of Yaita Eco-house described in **Table 7-2-7**.

Table 7-2-7 Yaita Eco-house

Structure and rank	Wooden, two-story, solid foundation	
Site area	500.05 m^2	
Construction area	208.52 m^2	
Total floor area	264.02 m^2	
Power generation facilities	Installed solar power generation capacity 4.8 kW roof surface	
Heat source equipment	Roof solution heat collecting formula solar system (solar thermal collector panel 11.5 m^2 · air-source HP water heaters and hot water supply for the hot water storage tank 420 L Heating water storage tank 200 L) Wood stove capacity 13.9 kW	
Heating system	Roof solution heat collecting type solar system and wood-burning stove	
General ventilation system	Ventilation type 1*(total heat exchanger)	
Hot-water supply equipment	Roof solution heat collecting type solar system (solar thermal collector panel 11.5 m^2 · air-source HP water heaters and hot water supply for the hot water storage tank 420 L · Heating hot water storage tank 200 L)	

7-2-8 Tsuru Eco House

It is located in the eastern part of Yamanashi Prefecture, with clean water source as the impact of Mounth Fuji. South-facing roof of a large area is one of the features appearance of Tsuru Eco House. The overview of Tsuru Eco-house described in **Table 7-2-8**.

Table 7-2-8 Overview of Tsuru Eco House

Structure and rank	Wooden, two-story, solid foundation	
Site area	593.89m^2	
Construction area	122.55m^2	
Total floor area	191.42m^2	
Power generation facilities	Solar power generation capacity 1.13kW roof surface installation, Small hydroelectric power 20kVA (geothermal heat)	
Heat source equipment	Roof air collector thermal solar system (roof over the entire surface heat collecting-air heat source HP water heaters and hot water supply for the hot water storage tank 460 L) Wood stove; Air conditioner the first floor living room: cooling capacity 5kW: COP = 3.71 and 2.5kW: COP = 6.3	
Heating system	Combination of air heat collector type solar heating and air conditioning heating and wood-burning stove heating by roof air collector thermal solar system	
Cooling system	Electric air conditioner	
General ventilation system	It is switched in the ventilation type 1 (at the time of the heat collection of the solar system) and ventilation type 3(during non-thermal collector of the solar system)	
Hot-water supply equipment	Roof air collector thermal solar system (roof over the entire surface heat collecting-air heat source HP water heaters and hot water supply for the hot water storage tank 460 L)	
Hot-water supply system	The hot water supply system by the roof air collector thermal solar system	

7-2-9 Yamanashi Eco House

Yamanashi Eco House is a relatively small scale detached house located near the volcano in Yamanashi Prefecture. The detail features about this house was summarized in Table 7-2-9.

Table 7-2-9 Overview of Yamanashi Eco-house.

Structure and rank	Wooden, 2-story, solid foundation	
Site area	408.720m^2	
Construction area	101.38m^2	
Total floor area	160.94m^2	
Power generation facilities	Installed solar power generation capacity 2.2kW roof surface	
Heat source equipment	Pellet stove capacity up to 9.3kW Air Conditioning Family Room: cooling capacity 4kW: COP = 3.7, heating capacity 5kW: COP = 4.3 Living: cooling capacity 5kW: COP = 3.1, heating capacity 6.3kW: COP = 3.9	
Heating system	The combination of air conditioning and pellet stove	
General ventilation system	The first kind ventilation (total heat exchanger)	
Hot-water supply equipment	Roof solution heat collecting type solar system (solar thermal collector panel 2m^2 · air-source HP water heaters and hot water supply for the hot water storage tank 460L)	
Hot-water supply system	The hot water supply system by the roof-liquid heat collector type solar system	

7-2-10 Omihachiman Eco House

Omihachiman Eco-house was constructed to promote communication with the neighboring called *Omi pavilion*. The features of Omihachiman Eco-house are shown in Table 7-2-10.

Table 7-2-10 Omihachiman Eco-house overview

Structure and floor level	Wooden, two-story, solid foundation
Site area	487.13 m^2
Construction area	178.52 m^2
Total floor area	183.36 m^2
Power generation facilities	Installed solar power generation capacity 3.89 kW roof surface
Heat source equipment	Air-conditioned first floor kitchen: cooling capacity 5 kW: COP = 3.7, heating capacity 6.7kW: COP = 4.6 First floor living room: cooling capacity 3.6kW: COP = 2.8, heating capacity 4.2kW: COP = 3.7
Heating system	The heating system due to air conditioning
Cooling system	The cooling system of the air conditioning
General ventilation system	Third kind ventilation
Hot-water supply equipment	Roof solution heat collecting type solar system (solar thermal collector panel 4m^2 · air-source HP water heater, hot water tank 420 L)
Hot-water supply system	The hot water supply system by the roof-liquid heat collector type solar system

7-2-11 Toyoka Eco House

In summer season receive strong sunlight, blocking the afternoon sun, and incorporating the warm light of winter to the back of the room, for the purpose of heat storage in the soil wall. Toyoka Eco-house. The overview of Toyoka Eco-house is shown in **Table 7-2-11**.

Table 7-2-11 Toyoka eco-house overview

<table>
<tr><td>Structure and floor level</td><td>Wooden, 2-story, solid foundation</td><td rowspan="4"></td></tr>
<tr><td>Site area</td><td>1282.72m^2</td></tr>
<tr><td>Construction area</td><td>109.49m^2</td></tr>
<tr><td>Total floor area</td><td>168.4m^2</td></tr>
<tr><td>Power generation facilities</td><td colspan="2">Solar Power: capacity 1.76kW roof surface installation
Household fuel cell: propane gas use and power generation capacity 700W ·hot water tank 200 L</td></tr>
<tr><td>Heat source equipment</td><td colspan="2">Multi air conditioning: cooling capacity 14kW: COP = 3.2, heating capacity 16kW: COP = 4.1
Air-conditioning blowing Floors: cooling capacity 3.2kW: COP = 3.8, heating capacity 4.5kW: COP = 4.1
Pellet stove: 14kW</td></tr>
<tr><td>Heating system</td><td colspan="2">Under floor heating and the combination of the pellet stove by each room heating and floor blowing air conditioner with multi air conditioning</td></tr>
<tr><td>Cooling system</td><td colspan="2">The cooling system of the air conditioning</td></tr>
<tr><td>ventilation system</td><td colspan="2">Ventilation type 3*</td></tr>
<tr><td>Hot-water supply equipment</td><td colspan="2">Air-source heat HP water heater</td></tr>
<tr><td>Hot-water supply system</td><td colspan="2">Although it is not a main hot water supply system may be switched to a hot water system for home use fuel cells with air heat source HP water heater</td></tr>
</table>

7-2-12 Bizen Eco House

Bizen eco-house was applying a simple large roof which equipped with solar panel. The features of Bizen Eco-house are summarized in Table 7-2-12.

Table 7-2-12 Bizen Eco-house overview

Structure and floor level	Wooden, two-story, solid foundation
Site area	1231.72 m^2
Construction area	148.17 m^2
Total floor area	177.8 m^2
Power generation facilities	Solar Power: capacity 5.12kW roof surface installation
Heat source equipment	Multi air conditioning: cooling capacity 14kW: COP = 3.2, heating capacity 16kW: COP = 4.3 Air supply of preheated air conditioning: cooling capacity 2.8kW: COP = 4.3, heating capacity 4.2kW: COP = 3.9
Heating system	The heating by multi air conditioning
Cooling system	The cooling by multi air conditioning
General ventilation system	The first kind ventilation
Hot-water supply equipment	Roof solution heat collecting type solar system (solar collector thermal panel 4 ㎡
Hot-water supply system	The hot water supply system by the roof

7-2-13 Ishikawa Eco House

Ishikawa eco-house is located in big land area in the northeastern of Honsyu Island. The overview of Ishikawa Eco-house was presented in **Table 7-2-13**.

Table 7-2-13 Ishikawa Eco House overview

Structure and rank	Wooden, 2-story, solid foundation
Site area	835m^2
Construction area	307.61m^2
Total floor area	258.91m^2
Power generation facilities	And solar power generation: capacity 8.068kW roof surface installation And small wind power generation capacity 1kW
Heat source equipment	Air conditioner, First floor Japanese-style room, second floor children room, flexible space: the cooling capacity 2.2kW: COP = 5.5, heating capacity 2.5kW: COP = 6.3 First floor dining: cooling capacity 2.8kW: COP = 4.8, heating capacity 3.2kW: COP = 6 First floor common living, parent households Bedrooms: cooling capacity 2.2kW: COP = 5.6, heating capacity 2.5kW: COP = 6.9-Air heat source hot water HP heat source: Heating capacity 6kW: COP = 4
Heating system	The heating system due to air conditioning, Auxiliary heating: hot water floor heating by air-source heat hot water HP heat source
Cooling system	The cooling system from air conditioning
General ventilation system	The first kind ventilation (total heat exchanger), further outside air preheating by geothermal heat pipe
Hot-water supply equipment	Roof solution heat collecting type solar system (solar thermal collector panel 4.2m2 · air-source HP water heater, hot water tank 370L)
Hot-water supply system	The hot water supply system by the roof-liquid heat collector type solar system

7-2-14 Hamamatsu Eco House

Hamamatsu Eco House are using and taking advantage of pillars and beams made from local material, outer wall mixed with red clay, sand plaster in combination with solid wood on the inner wall. The summary of Hamamatsu eco-house are presented below.

Table 7-2-14 Hamamatsu Eco House summary

Structure and level	Wooden, two-story, solid foundation	
Site area	596.02m²	
Construction area	113m²	
Total floor area	147.5m²	
Power generation facilities	Solar Power: capacity 3.29 kW roof surface installation	
Heat source equipment	Roof solution heat collecting type solar system (solar thermal collector panel 6m² · air-source HP water heater, hot water tank 420 L) Air conditioner, Second floor open space: the cooling capacity 7.1kW: COP = 2.6, heating capacity 7.5 kW: COP = 3.8, First floor dining: cooling capacity 2.8 kW: COP = 4.8, heating capacity 3.2 kW: COP = 6 1st floor office: cooling capacity 2.2kW: COP = 5.4, heating capacity 2.5kW: COP = 6, Pellet boilers up to 9.5 kW	
Heating system	Floor blowing heating system from the roof liquid heat collector type solar system and pellet boiler circulating the hot water under the floor fan coil unit	
Cooling system	The cooling system of the air conditioning	
General ventilation system	Third kind ventilation	
Hot-water supply equipment	Roof solution heat collecting type solar system (solar thermal collector panel 6m² · air-source HP water heater, hot water tank 420 L)	
Hot-water supply system	The hot water supply system by the roof-liquid heat collector type solar system	

7-2-15　Bungotakada Eco House

Bungotakada eco-house located in northern part of Kyushu. It is divided in two different area under the same prefecture (Oita). The overview of Bungotakada eco-house 1 and 2 are shown in Table 7-2-15-a and b.

Table 7-2-15a　Bungotakada eco-house 1 overview

Structure and floor	Wooden, one-story, solid foundation	
Site area	377m^2	
Construction area	123.22m^2	
Total floor area	117.04m^2	
Power generation facilities	Solar power solar heat collector panel 4m2 No connection	
Heat source equipment	Wood stove：14.6kW	
Heating system	The heating system by wood-burning stove	
General ventilation system	Ventilation type 3	
Hot-water supply equipment	Electric water heater 4.7kW, hot water tank 370 L	
Hot-water supply system	The hot water supply system by the electric water heater	

Table 7-2-15b　Bungotakada eco-house 2 overview

Structure and floor	Wooden, two-story, solid foundation	
Site area	851.63m^2	
Construction area	113.95m^2	
Total floor area	148m^2	
Heat source equipment	And electric stove -Open type oil stove	
Heating system	The heating system by an electric stove and an open type oil stove	
General ventilation system	Ventilation type 3	
Hot-water supply equipment	Conventional gas water heater (propane gas used)	
Hot-water supply system	The hot water supply system by conventional gas water heater	

7-2-17 Kochi Eco House

Kochi Eco House located in Shikoku Island and it is the only one eco-house in the island. The detail features of Kochi eco-house are summarized in Table 2-1-17.

Table 7-2-17 Kochi Eco-house overview

Structure and level	Wooden, two-story, solid foundation	
Site area	500.01m²	
Construction area	158.09m²	
Total floor area	202.7m²	
Power generation facilities	Solar Power: Capacity 2.6kW roof surface installation	
Heat source equipment	Roof air collector thermal solar system (roof over the entire surface heat collecting-air heat source HP water heater And hot water supply for the hot water storage tank 460L) -Air heat source hot water HP heat source (heating capacity 6.3kW: COP = 4.1), Pellet stove up to 6.5kW	
Heating system	Solar Building: roof air collector thermal solar system heating system by the (at the time of bad weather, heating by hot water with air heat source hot water HP heat source is circulated in the near-vector that has been installed in the duct of the solar system)	
General ventilation system	Biomass building: third-class ventilation Solar Building: the first kind and ventilation (heat collection at the time the roof air collector thermal solar system) (roof air collector thermal solar system non-heat collection during) the third type ventilation is switched.	
Hot-water supply equipment	Roof air collector thermal solar system (roof over the entire surface heat collecting-air heat source HP water heater And hot water supply for the hot water storage tank 460L) Pellet boilers (30kW · hot water tank 200L)	
Hot-water supply system	Solar Building: roof air heat collector type solar system by a hot-water supply system, Biomass building: The hot water supply system by pellet boilers	

7-2-18 Minamata Eco House

Minamata Eco House is located in the southern part of Kyushu Island, Kagoshima Prefecture. The southern Kyushu has warmer climate rather than area in Honsyu Island. The features is also simpler than other eco-house model. The detail features of Minamata eco house summarized in Table 7-2-18.

Table 7-2-18 Minamata Eco house overview

	
Structure and level	Wooden, two-story, solid foundation
Site area	361.69 m^2
Construction area	96.58 m^2
Total floor area	130.61 m^2
Power generation facilities	Solar Power: Capacity 1.874kW ground mount installation
Heat source equipment	Wood Stove: 15.2kW
Heating system	The heating system by wood-burning stove
Cooling system	None
General ventilation system	Without mechanical ventilation
Hot-water supply equipment	Ground-air heat collector type solar system (solar thermal collector panel 4 m^2-latent heat recovery type gas water heater, hot water tank 200L)
Hot-water supply system	The hot water supply system by the ground-based air heat collector type solar system

7-2-19 Miyakojima Eco House

Miyakojima is consist of six small islands, located under administration of Okinawa Prefecture which belongs to the subtropical climate of hot and humid, average temperature 23,3 ℃ a year, annual average humidity of 79%, average annual rainfall greater than about 2,019 mm. **Table 7-2-19a** and **b** summarized the features of Miyakojima eco-house 1 and 2 respectively.

Table 7-2-19 Miyakojima Eco-house 1

<table>
<tr><td>Structure and level</td><td>Mixed structure, one-story Ken solid foundation</td><td rowspan="6"></td></tr>
<tr><td>Site area</td><td>426m²</td></tr>
<tr><td>Construction area</td><td>187.84m²</td></tr>
<tr><td>Total floor area</td><td>168.84m²</td></tr>
<tr><td>Power generation</td><td>None</td></tr>
<tr><td>Heat source equipment</td><td>None</td></tr>
<tr><td>ventilation system</td><td colspan="2">Third kind ventilation</td></tr>
<tr><td>Hot-water equipment</td><td colspan="2">Latent heat recovery type gas water heater (propane gas use · 33.3kW)</td></tr>
<tr><td>Hot-water system</td><td colspan="2">The hot water supply system by the latent heat recovery type gas water heater</td></tr>
</table>

Table 7-2-20 Miyakojima Eco-house 2

<table>
<tr><td>Structure and level</td><td>Wooden, 2-story, solid foundation</td><td rowspan="6"></td></tr>
<tr><td>Site area</td><td>173.35m²</td></tr>
<tr><td>Construction area</td><td>111.16m²</td></tr>
<tr><td>Total floor area</td><td>191.27m²</td></tr>
<tr><td>Power generation</td><td>none</td></tr>
<tr><td>ventilation system</td><td>Third kind ventilation</td></tr>
<tr><td>Hot-water supply equipment</td><td colspan="2">Solar water heater (heat collection panel 3m2 · hot water tank 227L) - Latent heat recovery type gas water heater (propane gas use · 33.3kW)</td></tr>
<tr><td>Hot-water supply system</td><td colspan="2">The hot water supply system by solar water heater and latent heat recovery type gas water heater</td></tr>
</table>

7-2-21 Kitakyushu Eco-house

Kitakyushu Eco House is a pioneer of various passive techniques which have been introduced in Japanese eco-house. Fuel cells in power generation, photovoltaic solar cells, are equipped with power generation equipment due to hydrogen automobile. The features of Kitakyushu eco-house is shown in **Table 7-2-21** an overview of the Kitakyushu Eco House.

Table 7-2-21 Kitakyushu Eco-house

Structure and floor	Wooden, two story, solid foundation
Site area	4100.03m²
Construction area	130.83m²
Total floor area	183.43m²
Power generation facilities	Solar Power: capacity 3.29kW roof surface installation Household fuel cell: hydrogen gas use and power generation capacity 700W · hot water tank 200L Roof air collector thermal solar system (roof over the entire surface heat collecting-air heat source HP water heaters and hot water supply for the hot water storage tank 460L) Gas engine cogeneration (city gas use and power generation capacity 1000W · hot water tank 200L) - Second floor loft air conditioning 1: cooling capacity 5.5kW: COP = 3.3, heating capacity 4.1kW: COP = 3.7 - Second floor loft air conditioning 2: cooling capacity 6.6kW: COP = 3.1, heating capacity 5.7kW: COP = 4.1
Heating system	Air conditioning heating and gas engine cogeneration air collection by roof air collector thermal solar system thermal solar heating and by the second floor loft air conditioning, the combination of hot water floor heating by household fuel cell
Cooling system	The cooling system according to the second floor loft air conditioning
Hot-water supply equipment	The first kind and ventilation (at the time of the heat collection of roof air collector thermal solar system)
Hot-water supply system	It is switched in the type 1 to 3 ventilation (during non-thermal collector of roof air collector thermal solar system) Gas engine cogeneration (city gas use and power generation capacity 1000W · hot water tank 200L) Household fuel cell (hydrogen gas use and power generation capacity 700W · hot water tank 200L)

7-3. Building energy simulation on Japanese eco-house models

7-3-1 Study method and assumption

The energy loads simulation was conducted using *Energy-Plus* as the simulator engine with *Design-Builder* as the interface software. The *Energy-Plus* was chosen because of its use world-wide and the numerous validation studies it has been subject to **[8]**. All the building models were reconstructed in *Design-Builder ver.3* by including detail information such as envelope materials, openings, building direction collected from literature book **[2]**.

7-3-2 Validation

Validation studies have sought to test the adequacy of the core computational engine. For that reason, the experimental researches were conducted in Eco-House Model of Kitakyushu City by including the local homes appliances and nuclear family as the respondents to measure the energy demand and house performances **[9]**. **Fig.7-2** shows the high correlation score between the results of measured energy use and the results of simulation during a day in winter season.

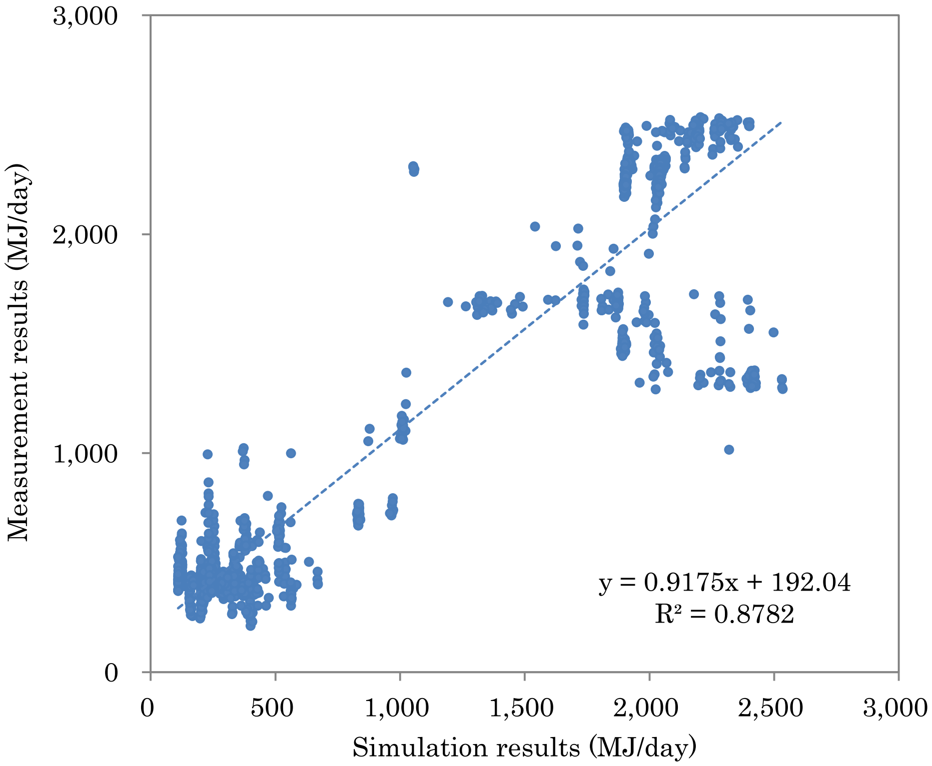


Figure 7-2 correlation of measured data and simulation results

7-3-3 Simulation

7-3-3-1 Setting and assumption

In the end of 2012 the questionnaire survey was conducted to better understand actual occupant behaviors of younger nuclear households in Kitakyushu City. The survey collected some information about family characteristics, building characteristics, behavior on heating-cooling practices, and appliances ownerships through more than 4,450 households. The results of the survey were previously reported [7].

Based on the survey results some assumptions to run the simulation were presented in **Table 7-2**. The weather data made by the JMA (*Japan Meteorological Agency*) [8]was converted to *TMY2* format which is one of the Energy-Plus weather data types. There are eight distinct climatic zones in Japan, each location of Eco-House Model was classified refers to **Table 7-1**. In the other hand, the daily pattern of household was decided based on *IBEC 2000* [7].

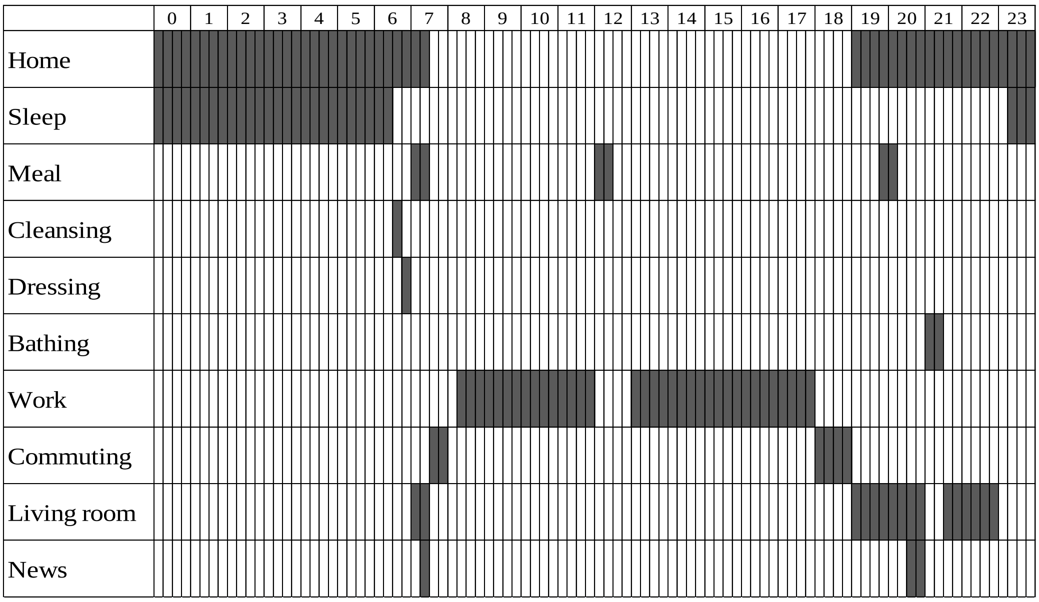
In the other hand the basic data for building the models were presented in **Table 3**. Further, all the building characteristics were used to conduct the analysis on influential factors on Eco-House Model energy use in ***section 5*** of this paper.

[7] Novianto, D., Gao, W. Analysis on residential lifestyle and energy consumption of Japanese family group in Kitakyushu City. 10th AIUE Chino, Japan (2012).

[8] http://www.ibec.or.jp. Institute for Building Environment and Energy Conservation.

Table 7-23 Assumption and simulation setting

	Climate data	*Energy plus(TMY2)*	
	Heating-Cooling period [11]		
	Area	HDD	CDD
Climate site	Ia	4665	0
	Ib	3983	1
	II	3157	22
	III	2682	46
	IVa	2179	113
	IVb	1689	188
	V	1229	213
	VI	144	502
Operation occupancy	Number of occupants	4 person	
	Family structure	Parent-two children	
	Temperature control		
	Heating: 22℃	Cooling: 26℃	
Daily pattern (householder)			



Internal heat (W)	Person	Latent:70; Sensible:45
	Equipment	314
	Lighting	68

Table 7-24 Basic information and some physical characteristics of Eco-House models

No	Name	Land area	Built area	Floor area	Envelope size	Main Structure	Floor number	Building direction	WWR	WFR	Air ventilation	AC number
1	Shimokawa	916	177	249	541	wooden	2	E-SE	13.30%	42.10%	Type 1	central
2	Bihoro	4,810	199	253	660	wooden	2	S	10.0%	30.9%	Type 2	central
3	Itate	2,630	201	222	688	wooden	2	S	12.70%	23.20%	Type 1	central
4	Takayama	1,802	194	241	589	wooden	2	W-NW	16.60%	30.60%	Type 1	central
5	Ida	211	127	189	518	wooden	2	E-SE	19.20%	33.80%	Type 1 & Type 3	1 unit
6	Yamagata	568	150	208	526	wooden	2	S	8.40%	17.80%	Type 1	central
7	Yaita	500	209	264	593	wooden	2	S-SE	25.90%	30.90%	Type 1	1 unit
8	Tsuru	594	123	191	573	wooden	2	S-SE	21.60%	37.30%	Type 1	3 units
9	Ota	180,724	260	234	822	wooden	1		16.80%	24.90%	Type 2	4 units
10	Yamanashi	409	101	161	422	wooden	2	S-SE	16.50%	34.90%	Type 1	2 units
11	Omihachiman	487	179	183	441	wooden	2	NW	31.40%	36.80%	Type 3	2 units
12	Toyoka	1,283	109	168	419	wooden	2	SW	20.6%	36.3%	Type 3	2 units
13	Bizen	1,231	148	178	477	wooden	2	SW	22.9%	44.7%	Type 1	2 units
14	Ishikawa	835	259	308	713	wooden	2	S	11.50%	22.10%	Type 1	6 units
15	Hamamatsu	596	113	148	502	wooden	2	S-SE	33.20%	35.50%	Type 3	2 units
16	Kitakyushu	4,100	131	183	563	wooden	2	S	12.90%	37.00%	Type 1 & Type 3	central (loft AC)
17	Bungotakada I	377	123	117	299	wooden	1	SSW	40.30%	45.90%	Type 3	central
18	Bungotakada II	852	114	148	505	wooden	2	E-NE	15.90%	31.80%	Type 3	central
19	Kochi	500	158	203	563	wooden	2	E	22.80%	35.90%	Type 1 & Type 3	central
20	Minamata	362	97	131	349	wooden	2	W-NW	16.10%	23.10%	Type 1	central
21	Miyakojima I	173	111	191	404	RC	2	SSW	24.50%	53.70%	Type 3	central
22	Miyakojima II	426	188	169	550	RC	1	S	27.70%	52.10%	Type 3	central

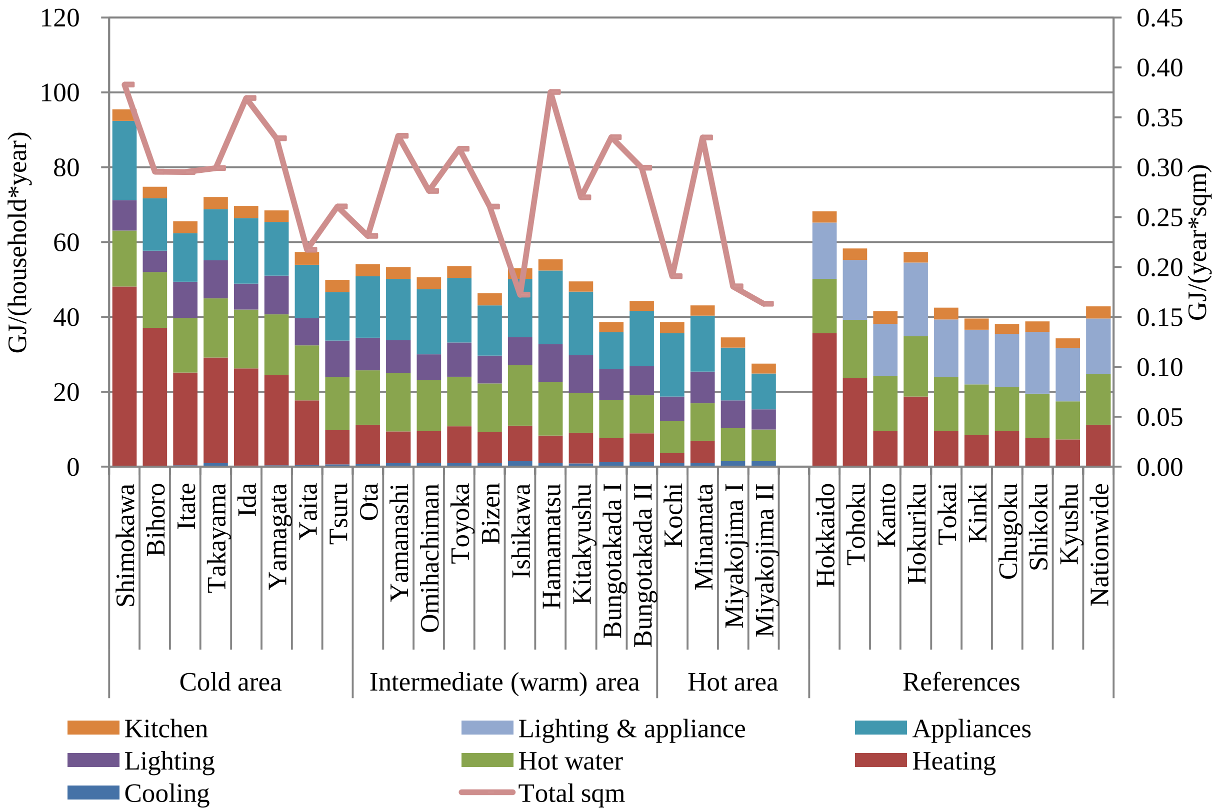


Figure 7-25. Results of energy load simulation

**Reference: Jyukankyo Institute "Household Energy Statistics Annual Report (2012)"*

7-3-4 Simulation result

Figure 7-25 shows the simulation results on twenty-two Eco-Houses from the coldest area to the hottest area in Japan. As for the annual total energy use, *Shimokawa Eco-House* has the highest energy use per household (95.4 GJ/year) and per square meter (0.38 GJ/year). While *Miyakojima II Eco-House* has the lowest energy use among all Eco-Houses, amounted 27.5 GJ/year as the total per household and 0.163 GJ/year as the total for per square meter.

The simulation results also can be evaluated with average energy use data of common house in some regions of Japan. Compared to the *Hokkaido* average, some Eco-Houses consumed more energy. Probably this is due to the bigger floor area of the house model than the average floor area of common houses in Japan. In the other hand, there are some areas such in Hot Area, have much lower energy use than average references (*Kyushu*). From this result, the significant factors on contributing the total energy load of each house are the heating-cooling load.

7-3-5 Influential factors on energy load

Multiple Regression Analysis with *Quantification Theory 1* was used to weigh the contribution of independent variables (Eco-House attributes) to the dependent variables (heating and cooling load per households). A series of linear regressions were performed using *Stepwise* procedure. R^2 represents the square of the correlation between the predicted value and actual simulation value. A comparison of Energy-Plus simulation results and the regression models is shown in **Figure 7-26** and **Fig 7-26**. As results of multi-regression analyses, a mathematical model illustrated the relationship between variables and energy load is significant. The empirical equation could be described as follows:

Heating Load ***(Eq.1)***

y = -25.159 + 4.312 [*climate area*] + 7.404 [*floor number*] + 7.143 [*envelope material*]

Cooling Load ***(Eq.2)***

y = 15.795 - 5.928 [*climate area*] + 6.804 [*glass type*] + 3.543 [*floor area*]

The influence extent of the factors on heating and cooling can be established. Those are the important factors on heating and cooling load based on the values of *Significant*

Probability. On the other words, the colder climatic area, the more floor number, and the less performance of envelope material, can result in the larger heating energy load of Eco-House model.

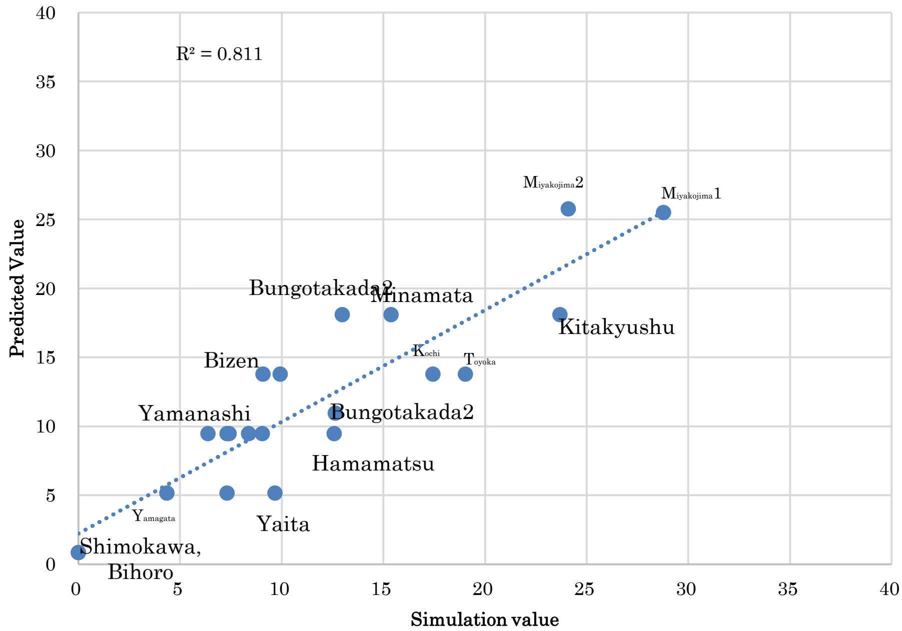


Figure 7-26.Analysis of cooling load

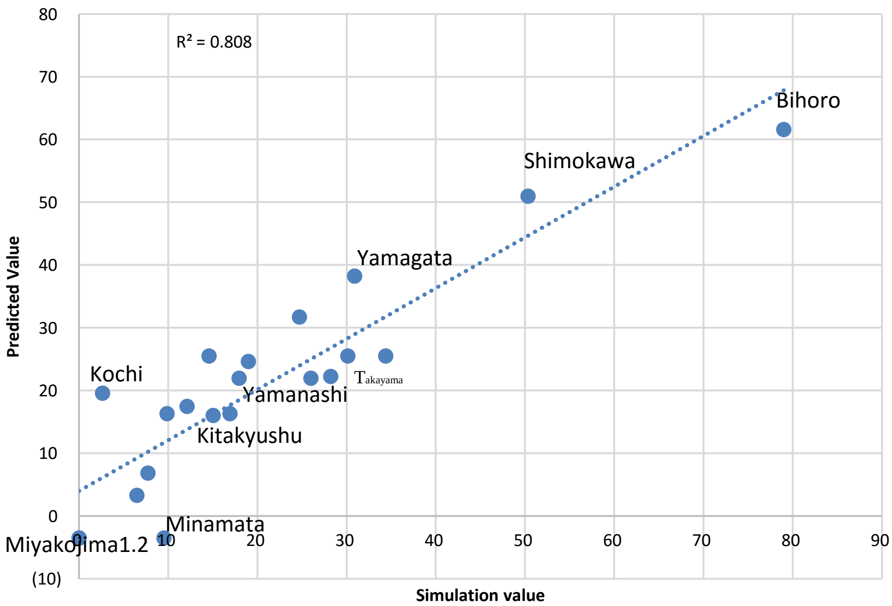


Figure 7-27.Analysis of heating load

7-5 Potential analysis of eco-house practice in other Asian cities

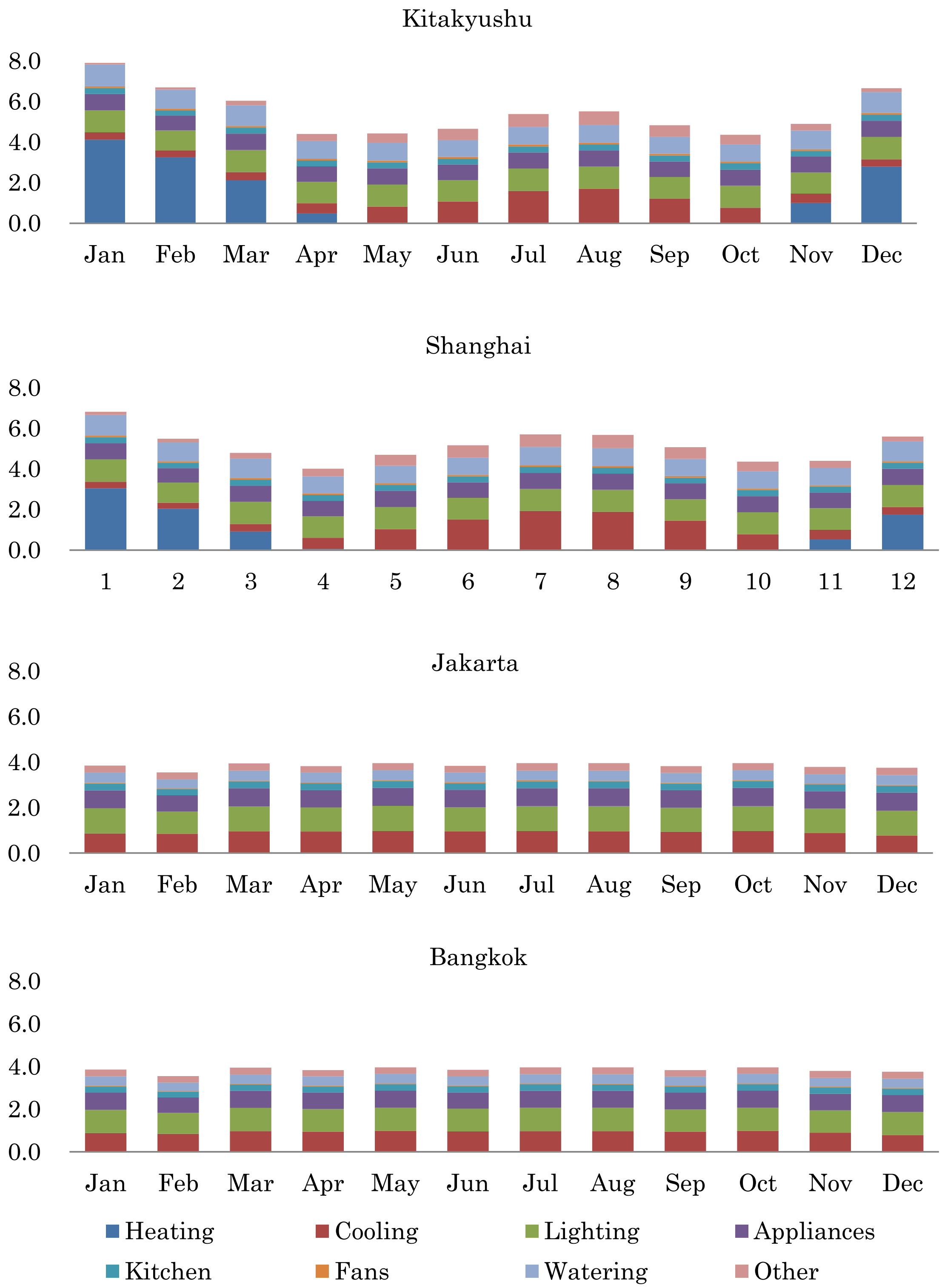


Figure 7-28 Energy simulation results of if Kitakyushu eco-house built in other cities

Validation studies have sought to test the adequacy of the core computational engine. For that reason, the experimental researches were conducted in Eco-House model of Kitakyushu by including the local homes appliances and nuclear family as the respondents to measure the energy demand and house performances. In these simulations, the family number was decided (four person) and the building characteristics (direction, equipment, architectural design, and physical preferences) were not changed from the original model. However, the household lifestyle such as occupancy rate, and number of the heating-cooling days were adjusted to follow the climate characteristics of each country.

Figure 7-28 shows the results of Eco-house monthly energy use when the same buildings (Kitakyushu Eco-house) are built in three different Asian cities, Jakarta, Bangkok, and Shanghai. In another word, these results only showed the impact of different climate and occupancy rate to Eco-house energy use. Based on the results, the design of Kitakyushu Eco-house can maximize the performance of practicing the energy saving in Jakarta, amount 46.1 GJ/year, and followed by Bangkok 48.5 GJ/year. These two models show similarity in the energy use results although the occupancy rate in Bangkok is more similar to Kitakyushu. On the other hand, the results of energy use simulation in Shanghai, showed slightly different with Kitakyushu, although the occupancy pattern of household member are different. It is also showed that the daily occupancy rate did not strongly impact the yearly energy use.

In this simulation, the rooms were set to be fully air conditioned during a year. With the total floor area of 183.4 m2, this eco-house needs bigger energy for the heating system in the winter. For that reason, the results in Jakarta and Bangkok have advantages for not using the heating system due to hot and humid climate of tropical area. The simulation also did not consider about lifestyle in terms of moving air by open and close the windows that may have big influences on reducing energy use. In the future, the research will conduct the analysis of factors that influence the energy use in eco-house model in order to find the sustainable house in tropical countries by including variable related to housing attributes and changing characteristics follow the local conditions.

7-6. Summary

The research intends to investigate the performances of Japan's Ecological Houses which in reality there is no household's occupancy and home appliances load. The simulations were conducted and following conclusions were drawn:

1. New method on evaluating the Ecological Houses performance was developed by combining the field measurement data, questionnaire survey, and building computational model with integrated climate information. As the results, the eco-house models located in the northern area of Japan were predicted to have higher energy use than other area. Shimokawa in Hokkaido spend about 95.5 GJ/year, it is 40% higher than average residential energy use in Hokkaido and 4 times higher than energy use in southern area.
2. The energy loads of twenty-two Eco-House Models can be predicted and the result revealed the high share on hot water supply. . The results vary between 14 to 16 GJ/year in the cold area, 10 to 16 GJ/year in intermediate area, and 8 to 10 GJ/year in warmer area. Even so the heating and cooling load contribute total energy use changes among households.
3. Through multiple regression analysis (with R-square results higher than 0.8 mean the model is valid to predict the load) the main factors influencing heating and cooling load could be revealed, which both factor of climate area and building area are included. Therefore, planners and architects must be attentive to the location, insulation material, and heated floor area in designing energy conscious housings because most of the Eco-House models seem to be considerably larger than average Japanese houses.

Generally, the projects were successfully realized even most of the Eco-Houses are built in rural locations and only few of many technological solutions adopted in Eco-houses were installed in Japanese apartment blocks. Further, the study on the behavior in Eco-house will be also conducted to find the best way on lowering residential energy use in the future.

第八章

結論

Chapter eight: Conclusions

8-1 Conclusion

8-2 Prospect

8-1. Conclusion

The influential factors affect household energy use were investigated through questionnaire surveys distributed to more than 4,000 households, in China, Thailand, Indonesia, and Japan. The field measurement on Japanese ecological house model energy use was also conducted to understand the performances of passive and active technology related with the lifestyle of the occupants. Further, the residential building energy use simulation was also conducted in order to study various cases in practicing the ecological house for sustainable development in Asian countries. The conclusions of this research are summarized as follow.

In **chapter two** (THEORY AND RESEARCH METHOD OF RESIDENTIAL LIFESTYLE AND ENERGY), we found that questionnaire survey could grasp more information of lifestyle pattern but low in accuracy. Field measurement could collect detailed data of energy use which are needed to perform a validation from questionnaire result. Data logging period has become limitations of field measurement. However, by combining with the building simulation software this small number of measurement still can be useful input. GIS (geographical information system) were also combined with statistical data in order to provide map/spatial analysis which easier to understand.

In **chapter three** (FUNDAMENTAL SURVEY ON LIFESTYLE AND HOUSEHOLD ENERGY USE IN ASIAN COUNTRIES), the conclusion can be drawn follow: The AC appliances are very important factor influencing the energy use in three countries. In China and Thailand houses, AC ownership is 99% and 89% respectively, while Indonesia only 32% households use the AC. Occupancy rate in tropical (Indonesia, Thailand) is lower than subtropical (China, Japan) this may explain the difference in yearly energy use pattern. Household lifestyle related the use of home electronic appliances is dominating the influential factors of energy use. If the standard of life is increasing, the energy use can be predicted to increase follows the appliance ownership. The use of electric fan showed the negative impact to energy use in tropical countries. It is important to design spaces for effective ventilation, to reduce the use of AC in the future.

In **chapter four** (SURVEY AND ANALYSIS ON HOUSEHOLD LIFESTYLE IN RELATION WITH ENERGY USE IN JAPAN), the conclusion can be drawn below: Building characteristics, it was found that about 65% of respondents are living in multi-dwelling house type. The multi-dwelling house type consumed 35% less energy yearly than the detached houses. Only 11% of households are using electric-only energy sources while 89% use a combination of gas and electricity. Averagely, the electric-only house consumed more energy (in primary energy sector) than combined gas and electric house even the annual consumption cost is lower. Unlikely electricity use which almost constant every month, the use of gas in the winter were almost three times than in summer. The influential factor analyses show that the house size, AC use and ownership, residential year, cooking period, and family size greatly affect the annual energy use of residential housing in Kitakyushu City.

In **chapter five** (STATISTICAL AND GEOGRAPHICAL ANALYSIS ON THE IMPACT OF RESIDENTIAL ENVIRONMENT QUALITY TO THE HOUSEHOLD LIFESTYLE), the conclusion can be drawn as follow: The study on model fitness shows that the evaluation system developed in this study captured most attributes that underlie residential environment and can offer a promising and valuable theoretical framework for the evaluation of residential environmental quality. By comparing the results of 2003 and 2013, the increase of satisfaction levels of city facilities and environment qualities during ten years can be described. It was found that more than half of total respondents comprehensive wish on living condition are realized to the largest extent, which mean the target of ideal residential environment plan and design nearly to achieve.

In **chapter six** (FIELD EXPERIMENT ON HOUSEHOLD BEHAVIOR IN KITAKYUSHU ECO-HOUSE MODEL), the conclusion can be drawn below: The comparison analysis between the measured value of each consumer electronics appliances and the measured value of the whole of the electricity of waste type of house lifestyle pattern were conducted. It is found that Eco-house can effectively operate if the practice on the energy conservation lifestyle performed. By scenario of Case 1 as the energy conservation type, the yearly energy use can be reduced 34.8% from Case 2 which is the ordinary lifestyle type. While, by the scenario in Case 3, the yearly energy use increased 182%, almost 3 times of Case 2. Based on questionnaire survey in Chapter 4, and intensive literature research, the main factors affecting energy use reduction were selected. It is found that both heating and cooling loads are influenced by wall material, WWR, and temperature setting. These R-square results show high numbers which mean the model is valid to predict the cooling and heating load. According to the Orthogonal Arrays it is possible to reduce the 531,441 number of simulation to be 81 (depends on number of factors included).By using orthogonal arrays the development on the method to evaluate the eco-house design can be preformed. This method can reduce the simulations number for the early design stage.

In **chapter seven** (BUILDING ENERGY USE AND LIFESTYLE SIMULATION OF VARIOUS JAPANESE HOUSING MODELS), the conclusion can be drawn follow: New method on evaluating the Ecological Houses performance was developed by combining the field measurement data, questionnaire survey, and building computational model with integrated climate information. As the results, the eco-house models located in the northern area of Japan were predicted to have higher energy use than other area. Shimokawa in Hokkaido spend about 95.5 GJ/year, it is 40% higher than average residential energy use in Hokkaido and 4 times higher than energy use in southern area. The energy loads of twenty-two Eco-House Models can be predicted and the result revealed the high share on hot water supply. The results vary between 14 to 16 GJ/year in the cold area, 10 to 16 GJ/year in the intermediate area, and 8 to 10 GJ/year in warmer area. Even so the heating and cooling load contribute total energy use changes among households. By multiple regression analysis the main factors influencing heating and cooling load were revealed. Planners and architects must be attentive to the location, insulation material, and heated floor area in designing energy conscious housings because most of the Eco-House models seem to be considerably larger than average Japanese houses.

8-2. Prospect

In the future, deeper and wider research on residential behavior and its relationship with residential environment satisfaction in terms of commuting should be performed to develop and improve the city compactness. In the other hand, Japan is facing the aging populations which affected by many factors such as social and economic, therefore, research on different types of family groups are also needed to propose the sustainable city and community development in the futures. A study on the behavior in Eco-house will be also conducted to find the best way on lowering residential energy use in the future. The study on investigating and measuring the real residential house includes of appliances, space cooling-heating and design performance in order to understand the major sources on residential energy use in other Asian countries.

Further, the study on energy use monitoring system also need more attention since it will affect the householder perspective on using home appliances and changing their way of life related with sustainable energy use.

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