SUSTAINABLE DESIGN FOR THE ELDERLY:

SENIOR HOUSING DESIGN GUIDELINES

By

Kezhen Chen

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ABSTRACT

Currently there is rapid aging and huge demand for elderly housing. Buildings for senior living must be of a particular type. The sustainable methods in those buildings are special in some respects. To meet the theory of sustainable design, it is necessary to evaluate the suitability of sustainable designs of buildings for senior living.

This paper has researched literature of senior living to discover the differences from normal architectural designs. Afterwards, this paper presented three case studies on well-designed senior housing, including a nursing home, a complex nursing community and a senior apartment. After those studies, this paper recommends some effective sustainable designs in senior housing, including: Building Shape Coefficient, Energy-efficient HVAC system, Space optimization for efficient operation, Healing Garden Rain Garden, Three-dimensional green, Rainwater collection system, and solar arrays.

Keywords： Senior housing， Sustainable design

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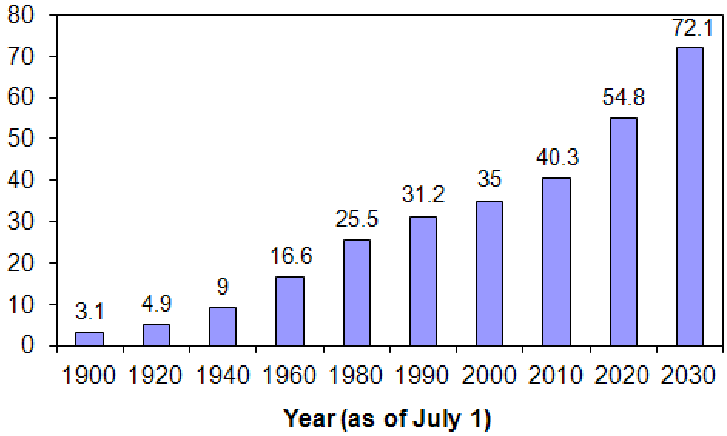
INTRODUCTION

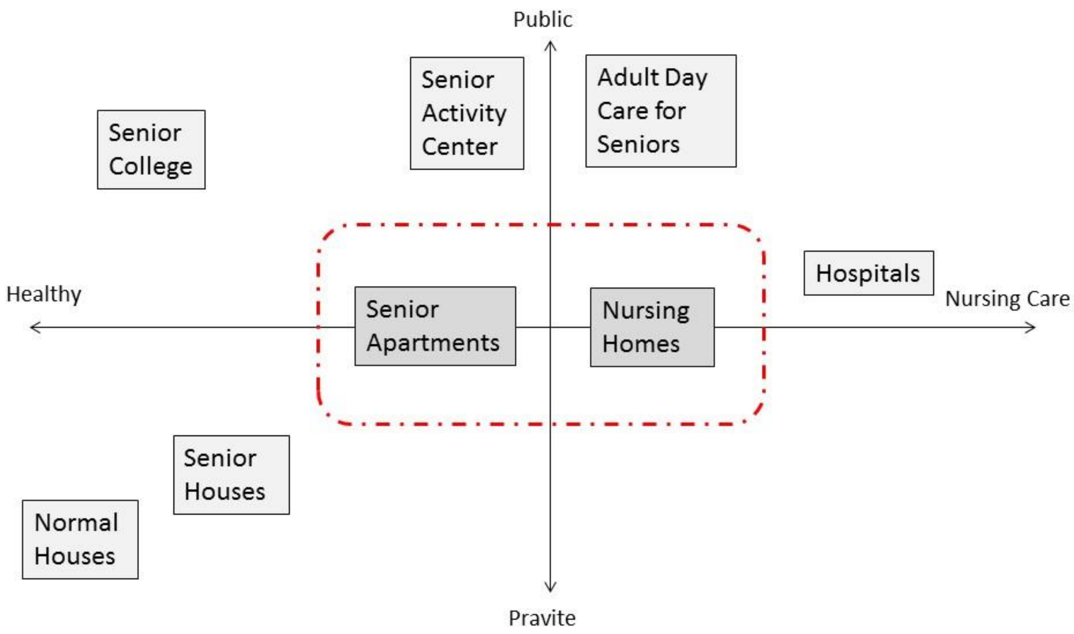
Figure 1.1 Number of Persons 65+, 1900-2030 (numbers in millions)



Source: (Administration for Community Living, 2011)

Currently there is a rapidly aging population and huge demand for senior housing (Roth,2016). Buildings for senior living are of a particular type. The sustainable methods utilized in those buildings are special in some respects. To complete the theory of sustainable design, it is necessary to evaluate the suitability of sustainable designs of buildings for senior living. Some sustainable designs, such as indoor environment management, may be suitable for keeping health of seniors. The elderly not only need a shelter space, but also housing that allows them to live near children and a community that gives them love. The research is aimed at the design of rehabilitation space that is both sustainable and comfortable for the elderly. The senior apartments and nursing homes were selected as objects of study (Figure1.2).

Figure 1.2 Research range



Source: The author organized and draw.

The topic of this paper is the sustainability of residential buildings for the elderly. This research is formulated to find out what kind of sustainable design in senior housing is suitable for the elderly. The research questions include:

RQ1: What kind of sustainable design in senior housing is used in well-designed cases for the elderly?

Sub question 1: What sustainable designs currently exist in those senior housing cases?

Sub question 2: How can those sustainable designs help the elderly?

RQ4: What is the elderly’s attitudes toward those sustainable designs?

This paper researches sustainable designs used in senior housing and how those sustainable designs can help the elderly or the environment. This paper studied three cases of elderly residential buildings with sustainable designs: a nursing home and a senior apartment in the U.S. with LEED Gold Certification, and an energy self-sufficient nursing home in Germany. This paper also researches the elderly's attitude toward those sustainable designs. The research involved a thorough search of existing data and included multiple buildings as case studies. Design recommendations of senior housing were concluded after the stated research.

This paper studied some of these designs to find out the answers to the above questions. Differing designs show the importance of different factors, such as access to nature and surrounding, views, greenery, fresh air, impressions of life, seasons changing, sensual pleasures of nature, safety and security and familiarity (Bengtsson, A.2013). Some sustainable designs are more suitable for residential buildings for the elderly.

CHAPTER 2

LETERATURE REVIEW

The need for build sustainable senior housing

Creating good living environment for the survival and the development of humans is imperative, especially for the elderly. Because of their age, physiological functions decline, adaptability of the surrounding environment decreases, and the need for more public love and affection increases. Therefore, senior housing should not only meet the basic requirements of the elderly necessities, but also meet the spiritual and cultural needs for the elderly to provide appropriate leisure and entertainment and promote elderly exchanges(Roth,2016). However, there are still many problems in the elderly apartments, such as unsuitable site planning, single function, backward facilities and lack of multi-level communication space. Those buildings face difficultly in meeting the standards for high quality apartments and meeting their diverse needs. Therefore, we should focus on the architectural design and sustainable technology applications of the senior housing research (Perkins, 2013).

Senior living

The world's population aged 65 and over is expected to increase from 6.9 to 16.4 percent, or approximately 1.53 billion people, by 2050 (United Nations Department of Economic and Social Affairs, 2010). The increasing number of the aging is creating requirements for new care and housing options. There are also some changes wherein these senior citizens want to live out their later years in comfort and their expectations of a high-quality life remain (Perkins, 2013). Different from other buildings, the buildings for senior must serve special function.

These buildings need to provide several functions. First, the function of living is the core function of senior housing. It depends on the situations of the elderly (e.g. short or long time living, need medical care or not), to provide corresponding rooms. Secondly, the most significant attention of the elderly is their health. Medical care function is one reason these people choose a nurse house. Thirdly, the living serving functions are based on the requirements of the elderly, such as housekeeping, shopping and psychological comfort. Moreover, there are some special architectural needs for these building including where there is enough available sunlight and convenient traffic patterns for the buildings.

Regarding site selection, good environment quality is a benefit for the health of senior citizens. Convenient traffic patterns allow senior citizens to venture out and visit friends or welcome visitors into their homes (Wang, 2014).

Sustainable design

With the rapid development of the world economy and society, people's energy needs have had an effect on climate change. Building energy is one of the largest forms of energy consumption. Energy efficiency and sustainable development of buildings has become one of the most discussed construction industry topics around the world.

A genuinely sustainable project is a project that should be conceived and defined as such before site selection (Perkins, 2013). Traffic and parking are major issues facing senior living projects (Perkins, 2013). Every site has unique positive features—a particular view, a heritage tree, a favorable solar orientation, an ecosystem of flowers and animals in a supportive habitat (Perkins, 2013).

To save water, it is important that leaking faucets and other plumbing connections are repaired. It is also important to install low-flow devices for showers and sinks and low-water-use toilet fixtures, design and utilize low-water-use landscaping and apply rainwater previously captured in cisterns (Perkins, 2013).

In order to reduce the use of fossil fuels, building orientation and domestic hot water usage should be considered (Perkins, 2013). Other factors, such as heating, heating, ventilation, air-conditioning, lighting, day lighting and smart usage of materials resources, also should be considered (Perkins, 2013).

Indoor functions and environment

When analyzing senior housing interiors, we understand that some senior citizens want to live alone while others need additional services such as meals, rest or nursing care. Drawing rooms and bedrooms important areas of concern for these seniors. Kitchens and bathrooms are areas which require specialized features for these seniors and a balcony offers a transition from the inside to outside (Wang, 2014). Public space is an important contribution to those residents living in nursing homes. The function of public space usually includes a game room, reading room, fitness room, painting room and classrooms (Lin, 2014).

Interior air quality is particularly important for frail seniors, who spend long periods of the day indoors (Perkins, 2013). Avoiding toxic material and efficient ventilation is necessary.

We need to recognize the loss of the physiological capacity in all design considerations. Specific requirements can be summarized as the following:

1. Privacy: the elderly need a space of their own. In the design of senior housing, we must respect resident living habits, preferences, and privacy. Even in most household types, track curtains can serve as needed privacy

partitions.

2. Social interaction: a lonely life is very harmful to the physical and mental health of the elderly as they themselves have the need for social interaction. Therefore, when considering the residents there should be space for social interaction space and exchanges between residents.

3. Clear direction and logo system: the elderly, because of identification problems and memory recession, require that their environment offers clear direction and a legible marking system guiding them to event locations.

4. Security and comfort: all designs for the elderly need to provide a safe indoor environment which provides a sense of security and meets their physical and psychological comfort requirements.

5. Disability design: indoor spaces for elderly activities require good accessibility.

6. Familiarity and continuity: the design of senior housing should contain certain local tradition and offer the residents self-decoration spaces for the placement of familiar personal items, such as photos, which serve as reminders of earlier days.

Outdoor environment

Bengtsson concludes the principles of the outdoor environment as “1. The sense of control and access to privacy. 2. Social support. 3. Physical movement and exercise. 4. Access to nature and other positive distractions”. (Bengtsson, 2013)

Building communities should remain accessible and offer viable walking spaces: sidewalks and parking lots should be designed and sloped not to exceed 5 ° so that residents either walking or in wheelchairs can explore the community alone. Outdoor environments should create a sense of security so that frail, aging adults can feel very comfortable. Vegetation, soft furnishings, and even building sidewalls can be used to create a sense of enclosure or shade. Venues for public gatherings, planting ponds, pavilions, terraces, and other public spaces create opportunities for networking and meaningful activities. Blocking the sun is a way to access nature. The use of the natural characteristics of trees, flower racks, green corridors can contribute to preventing sun exposure.

Zhang (2009)'s research showed that sustainable urban landscape designs should follow principles such as land efficiency, energy efficiency, ecologic plant arrangement, preservation and utilization of natural community and efficient use and conservation of water resources.

Three-dimensional greening

Three-dimensional greening can maximize the use of building space and can include both interior and exterior building surfaces including any balconies and roofing areas. It is one of the most effective ways to expand the amount of urban greening and reduce the urban heat island effect. At present, a widely used three-dimensional green building offers green walls and a green roof. (Cui, 2016)

Wall greening mainly refers to placing plants on the inside and outside of the building surface. There are two commonly used wall greening methods: traction climbing wall greening and modular facilities wall greening. Early wall greening systems generally use traction climbing plants. This method causes some damage to the wall, takes a long time to cover the entire wall slowly. Modular vertical wall greening is a plant placed in a container and fixed on the keel on the wall surface. Modular vertical greening methods generally require a separate drip irrigation system.

Balcony green is the most common and easy method of implementation. The balcony is an important part of building facade modeling and is usually for people to relax, remain cool and dry, but also to connect the indoor and outdoor environments. Balcony greening used in the form of potted plants which can be hanging, flat or wall-hanging.

Roof greening is one of the most widely used three-dimensional greening methods for urban greening. Roof greening offers the best insulation cooling effect of the three three-dimensional greenways, but the cost is also the highest. Urban construction roofing covers 1/5 to 1/10 of the city area. If the roof can be a green building it will contribute to a rapid increase in urban greening. (Cui, 2016)

CHAPTER 3

CASE STUDIES

Case Study 1: Clyde E. Lassen State Veterans' Nursing Home

The Clyde E. Lassen State Veterans' Nursing Home was designed by Harvard Jolly Architecture and is located in St. Augustine, Florida. It is the first nursing home in Florida to achieve LEED Gold Certification (figure 3.1.1). The Harvard Jolly Architecture make sustainable design decisions in the beginning of the design and tries to apply them throughout the building process. This case study offers analysis of how this nursing home complies with the principles of social, economic, and ecological sustainability.

Figure 3.1.1 Clyde E. Lassen State Veterans' Nursing Home LEED Facts

LEED Facts

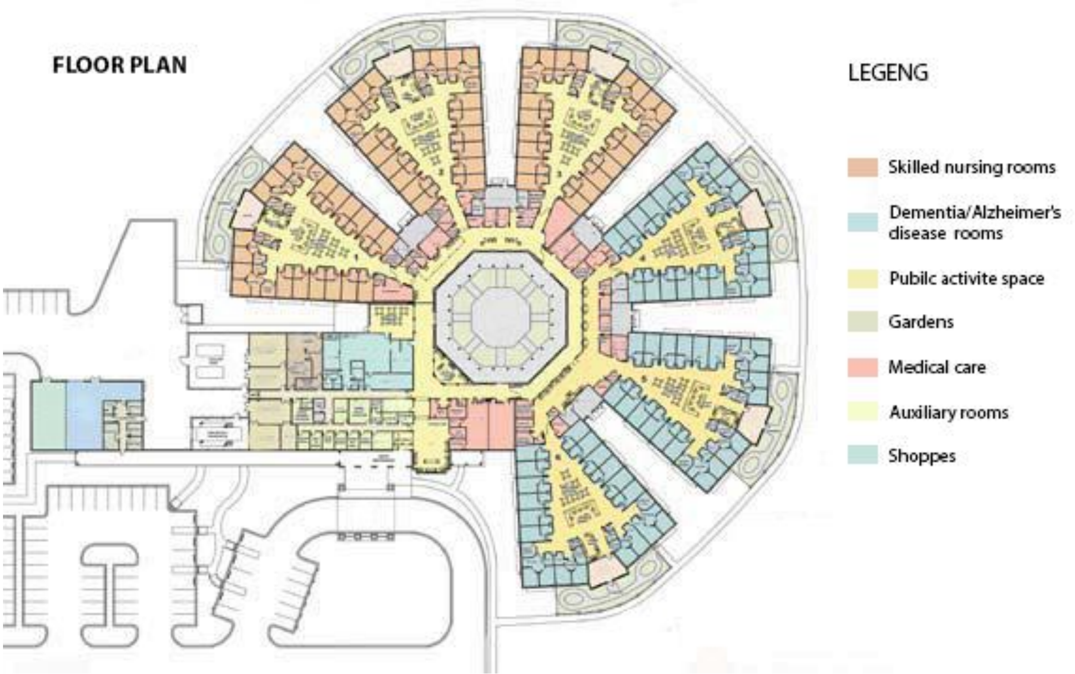
for LEED BD+C: New Construction (v2.2)

Certification awarded Mar 2011	
Gold	**40**
Sustainable sites	8/14
Water efficiency	3/5
Energy & atmosphere	5/17
Material & resources	6/13
Indoor environmental quality	13/15
Innovation	5/5

Source: © 2017 U.S. Green Building Council

There are 96 patient rooms with a 120- bed capacity in one pinwheel layout building (figure 3.1.2). All the residents are long time living veterans. Indoor environmental quality is one of the most important influencing factors to the physical health of the elderly. In the ratings of this project, the score of indoor environmental quality (11 of 13) is the highest. It shows the priority of offering high indoor environmental quality in nursing home design. The following information was gathered from LEED and Harvard Jolly's website. First, this project developed and implemented an Indoor Air Quality (IAQ) Management Plan for construction and pre-occupancy (U.S. Green Building Council, 2017). Second, all adhesives, sealants, paints, coatings, composite woods, and carpet systems are low-emitting materials to reduce odor, irritation and harmful air contaminants. Third, high-performance heating, ventilating, and air conditioning (HVAC systems) provide thermal comfort and increased ventilation. The climate in the building location is humid subtropical. It is necessary to keep temperature and humidity at a comfortable level. In addition, there are outdoor air delivery monitoring and control of lighting systems and thermal comfort system. Shortcomings may be the lack of daylight and views in some rooms.

Figure 3.1.2 Clyde E. Lassen State Veterans' Nursing Home Floor Plan

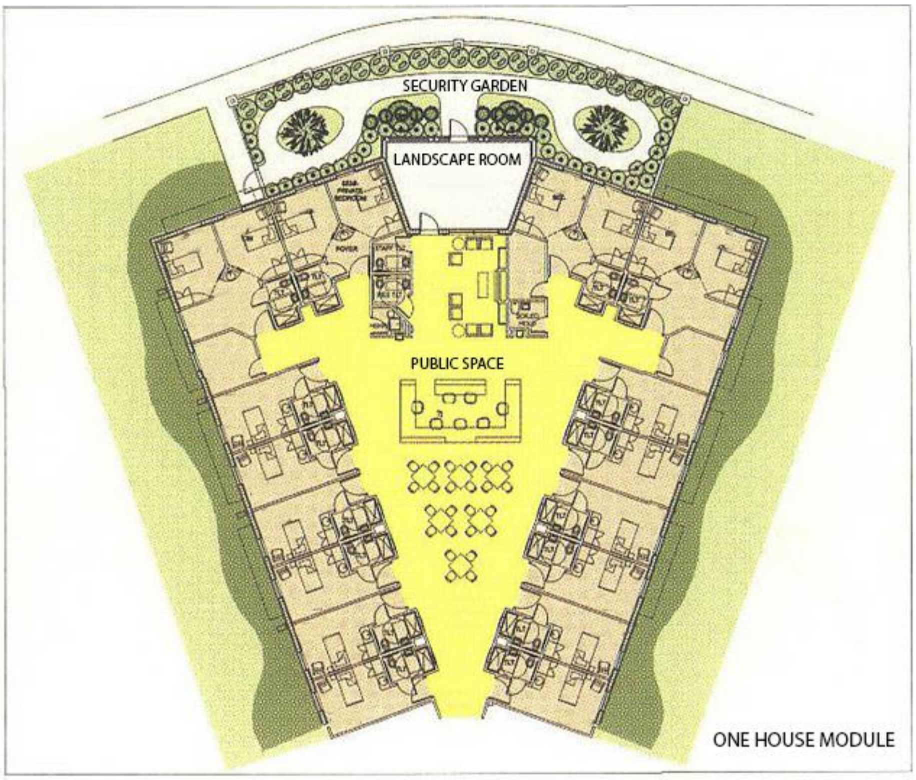


Source: Harvard Jolly Architecture (floor plan)

Good mental health is other aspect that contributes to social sustainability.

Harvard Jolly Architecture said:” Communication is encouraged within a therapeutic and safe environment.” (Harvard, 2012) The pinwheel layout grouped rooms in six houses: 60 skilled nursing residents in three houses and 60 residents with dementia/Alzheimer's disease in three houses. Every house model is functional and homelike. Each provides a central living room where residents can talk with and visit each other. The interim administrator remembered that residents with amnesia started talking about their impressive memories when school children visited the location (Gustafson, 2011). Every house model provides a private walking garden which uses natural and native plantings that offer an appealing environment for residents, their families, visitors and staff. (Figure 3.1.3)

Figure 3.1.3 Clyde E. Lassen State Veterans’ Nursing Home House Model



Source: Harvard Jolly Architecture (floor plan)

First of all, for economic sustainability, the project’s pinwheel layout provides enhanced staff efficiency in that the staff's daily travel distances are reduced

(Figure 3.1.2). High quality and low impact construction methods require additional funding but Gustafson (2011) found “choosing higher-cost sustainable products can save money in the long run” in this project. The high-performance HVAC systems also reduce the economic impact in the long term. The building cost were estimated at $227.21 per square foot in June, 2012. This project had high evaluation and many recommends in Facebook. Although good service also contributed to the results, design can make business better and sustainable.

This project also offered a lot in ecological sustainability. It considered alternative transportation with bicycles, low-emitting vehicles, fuel-efficient vehicles, and offered carpool parking capacity. The project manages storm water runoff and on-site infiltration to limit disruption of natural water hydrology. The landscaping method offered 50% potable water consumption for irrigation and saved 30% in total water consumption by using dual-flush water closets and water-saving faucets throughout the building. The proposed building performance rating is 21% lower than the baseline building performance rating. The high-performance HVAC systems and led lights contributed most to that performance. Regional building materials were used in construction to reduce energy use during transportation. Rapidly renewable materials and certified wood products were used in the project.

This subject shows a high level of sustainable sense from the overall attention to details. The pinwheel layout is compact for indoor transfer and service. Designers made the goal of LEED certification in the beginning so that building construction could follow most guidelines. They especially focused on improving indoor environment quality with lower energy use. The main sustainable designs are high-performance HVAC systems, IAQ management, LED lighting, low-emitting materials, renewable materials, non-portable irrigation, dual-flush water closets and water-saving faucets. The residents most care about their indoor environment, gardens and public areas. In posted feedback, the indoor environment, gardens, and public conversation spaces were the most discussed topics. On the contrary, on-site renewable energy and building reuse were not concerns of this project as the cost is too high and the overall effect is insufficient. In conclusion, the key sustainable features are the pinwheel layout, high-performance HVAC systems, IAQ management, low-emitting and renewable materials.

Case Study 2: Riedlen Nursing Home

Riedlen Nursing Home (Figure 3.2.1) is located in Balingen, a small town in the southwest corner of Germany. It includes residential, resort, nursing and other functions. As a good example of the advanced nursing home model in Germany, it abandoned the traditional mode where the elderly were completely isolated from society and creatively combined rehabilitation, nursing care and home care together, thereby combining daily life and healthcare together. “Dwelling is Life” (German: “Wohnen ist Leben”) is the motto of this integrative residential model (WFP ARCHITEKTEN, 2016).

Figure 3.2.1 Riedlen Nursing Home (Seniorenpflegeheim Riedlen) Aerial View

Source: © 2016 WFP ARCHITEKTEN

Riedlen Nursing Home is composed of two "L" shaped single buildings. The building located in the north is a sanatorium, while the one located in the south is an accessible senior apartment. They both revolve around an atrium garden. (Figure 3.2.2). The community illustrates the concept of exchange and integration in many aspects: it does not have a fence and the historical town streets are directly linked to the residential unit. The roof and color of the building are taken from the town’s style. On each floor, balconies supported by steel columns provide residents with a platform for daily resting and makes more connection of the indoor and outside. The eaves and balconies protect the walls from the strong sun exposure and rain (figure 3.2.3). Green climbing plants are attached to the steel columns and fences. They not only adjust the micro climate, but also beautify the building, bringing people a pleasant feeling (figure 3.2.4).

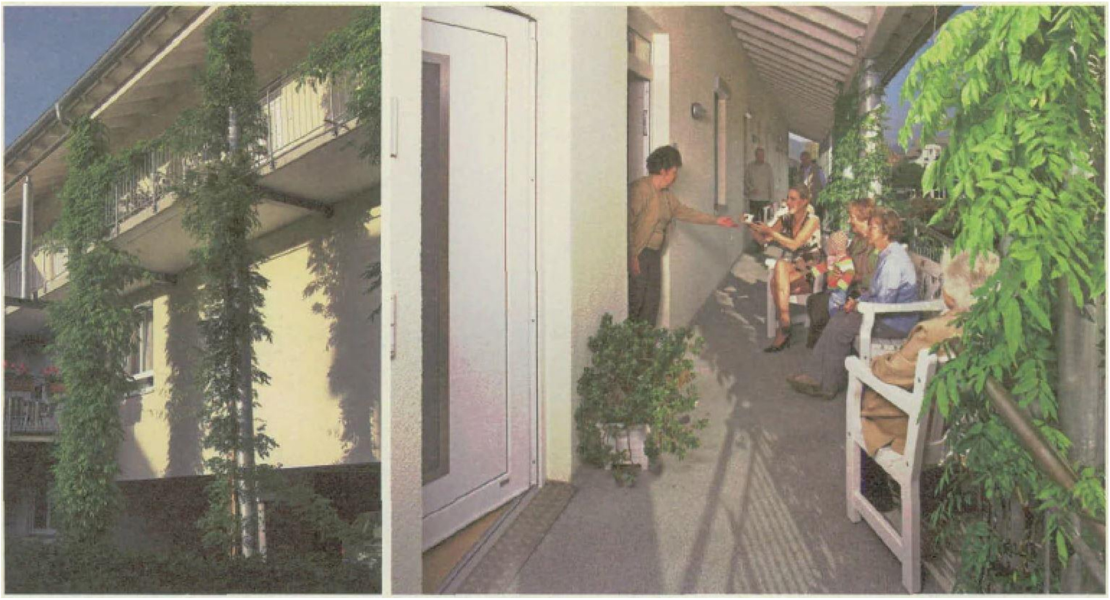
Figure 3.2.2 Riedlen Nursing Home (Seniorenpflegeheim Riedlen) Site

Source: © 2017 GoeBasis-DE/BKG (©2009), Google

Figure 3.2.3 Steel Self-Supporting Balcony

Source: © 2016 WFP ARCHITEKTEN

Figure 3.2.4 The Vines Climb Along the Steel Columns



Source: © 2016 WFP ARCHITEKTEN

This project consists of 28 nursing care residential units, 53 sets of accessible senior apartments and a community center, with a total floor area of 62000ft² (5760m²) for living in a variety of backgrounds and health levels. Twenty-eight residents who need special care live in the ground floor of the sanatorium. There are 19 sets of accessible apartments on the first and top floors of the sanatorium for the elderly or disabled people who have limited self-care ability. There are 34 sets of accessible senior apartments which provide a variety of different room types. Some units are only simple single rooms, some come with bathroom and living room, and some are 2 ~ 4 rooms units. Both buildings are equipped with public kitchens and public spaces on each floor, and are equipped with different medical staff members as needed.

With the support of the local Aid Association, Arbeiter-Samariter-Bund, the entire community is equipped with nursing facilities providing the most advanced nursing concept, making the senior community highly acclaimed in the local area. The project is designed according to the German design standards for senior housing. The rooms are compact and connected so that each resident can enjoy comfortable private space and care for their neighbors while also facilitated systematic medical care. Each household has an independent bathroom and there are public dining spaces and kitchens. Considering health and safety, kitchens only are equipped for simple functions as daily meals are mainly supplied by external catering enterprises. Other rooms are divided into many types according to function, such as emergency room, gym and functional treatment room.

Each level has an observation nursing point at the junction to observe the situation of all groups. Each floor has a large activity room for resident leisure, party and entertainment activities with their family and neighbors. The spacious balconies or terraces are convenient for outdoor activities and social activities.

According to local conditions, the HVAC system of the senior apartment makes full use of local natural resources. The HVAC system does not use fossil fuels. Room heating heat is totally geothermal supported in the winter with heat transfer indoors by floor radiation. The quiet floor radiating system keeps the indoor temperature uniform and stable to ensure indoor comfort. In the summer, groundwater with a lower temperature is pumped directly into floor coil tubes. With the heat exchange cycle, there is no need to use air conditioning to ensure cooler indoor temperatures. The heat for hot water is derived from wood pellet fuel, which is usually made of sawdust, with high burning efficiency and low harmful gas emissions. These devices work together to ensure a comfortable indoor environment, while also greatly reducing building energy consumption (WFP ARCHITEKTEN, 2016).

It achieves a complete self-sufficiency in the building energy consumption. The roof of the building is equipped with 70kW solar photovoltaic panels for the equipment. The nominal power output of the photovoltaic system is higher than the building's total electricity grid connection level (WFP ARCHITEKTEN, 2016).

With the improvement of living standards, the daily needs of the elderly are no longer simply material needs but meet the comprehensive needs of physical care, psychological changes, living habits and ergonomic factors. German experts believe that the elderly are less lonely when their need health care needs are provided by a nursing home that is different from their normal living habit and familiar social environment. Therefore, the question becomes how to challenge the traditional pension model. To fully realize the wishes of the elderly becomes an important issue at this stage. In this regard, the German designers suggest that: a new isolated nursing home cannot meet senior citizen needs; community nursing care, self-responsibility and local help become stronger; social infrastructure must be dominated by locally responsible communities and cannot be the result of speculative investment. Riedlen Nursing Home follows the above principles. The residents live here in common communities. Other citizens can come enter the courtyard and join activities as these areas are open to the public. Various public activities lead senior citizens to become members of these intimate groups. In order to create a comfortable and relaxing atmosphere for the elderly, the program has also introduced the concept of "pet zoo". The zoo has docile animals, such as goats, sheep, rabbits and hamsters.

As the physical and psychological needs of the elderly, in the new pension model, family members, friends and charitable organizations can provide more support for resident care and these overall costs are greatly reduced. According to the survey for German traditional pension care institutions, for a household to provide full-time care and medical services the costs are usually about 3000-4000 euros per month. While Riedlen Nursing Home has cancelled full-time care model, residents only pay regular rent and fees. According to different actual needs, the apartment management agencies provide the appropriate care and medical services along with the corresponding billing (WFP ARCHITEKTEN, 2016). They are the on-demand care fee is in addition to the monthly cost (usually divided into several charges), the apartment area rent, plus the sum of the complex rates (heating, electricity, etc.). This amount is much lower than conventional nursing home fees. For developers, if the nursing costs and inputs could be reduced, elderly apartment rents could improve but still lower than current nursing home market prices. So, it could obtain greater market competitiveness and influence.

In the design of the living environment, the atrium garden and green balconies provide an enjoyable benefit but also adjust the building micro climate, pet zoo active living atmosphere, and enhance the exchange of people and nature. In the green building technology, this project also has a distinctive feature: the building's heating and cooling use underground water; wood pellet fuel combustion supplies hot water; solar photovoltaic panels cover the roof; can fully realize the energy self-sufficiency. These are the results of local environment and German grid accessing solar photovoltaic systems. In conclusion, the key sustainable features in this project are the atrium garden, green balconies, geothermal heating and the photovoltaic system.

Case Study 3: Armstrong Place Senior Housing

Armstrong Place Senior Housing was designed by David Baker＆Partners and is located in San Francisco, CA, United States. This senior apartment complex is adjacent to family housing to prevent seniors from living in isolation. There are many designs involved with sustainable consciousness. The building achieved LEED Gold Certification in 2011. This case study analyses how this nursing home complies with the principles of social, economic, and ecological sustainability.

Figure 3.3.1 Armstrong Place Senior Housing LEED Facts

LEED Facts

for LEED BD+C: New Construction (v2.2)

Certification awarded Sep 2011	
Gold	**48**
Sustainable sites	12/14
Water efficiency	3/5
Energy & atmosphere	11/17
Material & resources	6/13
Indoor environmental quality	11/15
Innovation	5/5

Source: © 2017 U.S. Green Building Council

This project is located in a formerly industrial city and provides the elderly with the ability to take care of themselves. An appropriate site of a senior housing should be surrounded with existing infrastructures, communities, and people of all ages, public parks, and convenient public transport. This site selection avoided inappropriate sites and channeled development to urban areas with existing infrastructure. The architect David (2011) described this project as an innovative housing mix: “Affordable urban townhomes to keep growing families in the city and family housing adjacent to senior apartments to prevent seniors from living in isolation.” (Figure 3.3.2) The main commercial corridor project is transit-oriented and is only one block away from the new LRT line, parks and medical centers. There are 116 apartments for the elderly in economical rental units. The major project development offers community services, and retail space (Figure 3.3.3 & 3.3.4). A flag tower located at the corner gives the project a sense of place. The central courtyard, side garden and roof provide vegetated open space (over 25% of property area) does double-duty, adding green areas and creating miniature wetlands. These selections and design made a sustainable site with social and ecological sustainability.

Figure 3.3.2 Armstrong Place Senior Housing and Family Housing Plan

Source: the architect © David Baker & Partners

Figure 3.3.3 Armstrong Place Senior Housing ground floor Plan

Source: the architect © David Baker & Partners

Figure 3.3.3 Armstrong Place Senior Housing standard floor Plan

Source: the architect © David Baker & Partners

It features some green strategies of indoor environment. For good air quality, this project implemented an Indoor Air Quality (IAQ) Management Plan in the construction and pre-occupancy phases (U.S. Green Building Council, 2017). All adhesives, sealants, paints, coatings, composite woods, and carpet systems are low-emitting materials to reduce odorous, irritating and harmful air contaminants. This project's architectural type and layout provide daylight in 75% of spaces and outside views for 90% of the spaces (Figure 3.3.5). High daylight and nice views provide a connection between indoor spaces and the outdoors, which is good for seniors' physical and mental health.

Figure 3.3.5 Armstrong Place Senior Housing indoor

Source: © Brian Rose from http://www.archdaily.com

For the economic sustainability, this project put forward a way to keep growing population in this formerly industrial city block with affordable and easy-access urban townhouses. The major benefit from these senior apartments is that they are lively and community accessible. Based on income, the rents in the senior housing range from $0 to $635/month, with qualifying income levels below 50% AMI. Government subsidies for the elderly provide a better living environment. Sustainable products cost higher, but they can save money in the long term use in this project.

This project features many complementary green strategies, including alternative transportation, storm water management, solar arrays, and water efficient landscaping. It considered alternative transportation with bicycles, low-emitting vehicles, fuel-efficient vehicles, carpool parking capacity, and LRT system (Figure 3.3.6). This project manages storm water runoff and on-site infiltration to limit the disruption of natural water hydrology. Solar arrays on the roof heat domestic water and light the common spaces and provide 13% of energy needs (Figure 3.3.7). The proposed building energy performance rating is 28% lower than the baseline building performance rating. The solar arrays and led lights contribute most of the performance. The landscape reduced 50% potable water consumption for irrigation with a courtyard rain garden (Figure 3.3.8) and saved 30% water by using dual-flush water closets and water-saving faucets in the building.

Figure 3.3.6 Armstrong Place Senior Housing LRT Station

Source: © Brian Rose from http://www.archdaily.com

Figure 3.3.7 Armstrong Place Senior Housing Aerial View

Source: © Brian Rose from http://www.archdaily.com

Figure 3.3.8 Armstrong Place Senior Housing Garden

Source: © Brian Rose from http://www.archdaily.com

In conclusion, the key sustainable features of this design are solar arrays, storm water management, and water-saving landscape and healthy interiors and materials.

CHAPTER 4

FINDINGS

Findings for Case 1

This case shows a high level of sustainable sense from the overall attention to details. The pinwheel layout is compact for indoor transfer and service. Designers made the goal of LEED certification in the beginning so that building construction could follow most guidelines. They especially focused on improving indoor environment quality with lower energy use. The main sustainable designs are high-performance HVAC systems, IAQ management, LED lighting, low-emitting materials, renewable materials, non-portable irrigation, dual-flush water closets and water-saving faucets. The residents most care about their indoor environment, gardens and public areas. In posted feedback, the indoor environment, gardens, and public conversation spaces were the most discussed topics. On the contrary, on-site renewable energy and building reuse were not concerns of this project as the cost is too high and the overall effect is insufficient. In conclusion, the key sustainable features are the pinwheel layout, high-performance HVAC systems, IAQ management, low-emitting and renewable materials.

Findings for Case 2

As a building not in the US, this building is not follow the LEED and has features of German. In the green building technology, this project also has a distinctive feature: the building's heating and cooling use underground water; wood pellet fuel combustion supplies hot water; solar photovoltaic panels cover the roof; can fully realize the energy self-sufficiency. These are the results of local environment and German grid accessing solar photovoltaic systems. In the design of the living environment, the atrium garden and green balconies provide an enjoyable benefit but also adjust the building micro climate, pet zoo active living atmosphere, and enhance the exchange of people and nature. In conclusion, the key sustainable features in this project are the atrium garden, green balconies, geothermal heating and the photovoltaic system. This case focusses more on energy saving, outdoor environment and economic nursing model than other two cases.

Findings for Case 3

This case also followed the requirements of LEED. It has a high score in indoor environment quality, too. However, it is located in a city, and focused more about the energy saving and land saving. The key sustainable features of this design are solar arrays, storm water management, and water-saving landscape and healthy interiors and materials. It also showed a recommended way to select senior housing location: family housing adjacent to senior apartments to prevent seniors from living in isolation and nearly hospital to provide medical service

Synthesis of findings from three cases

Recording to above case studies, the sustainable designs which benefit to the elderly's physical and psychological health were suitable for the elderly. In addition, the elderly tended to save daily spending on electricity and water. In these cases, existing sustainable designs are pinwheel layout, high-performance HVAC systems, IAQ management, atrium garden, green balconies, soil heat, solar arrays, storm-water management, water saving landscape, low-emitting and renewable materials. The operating efficiency of senior housing (pinwheel layout and other shape), and reducing operating costs, were inherent requirements of sustainable development. The elderly's requirements on indoor environmental quality caused high energy consumption, which restricts energy saving. In this condition, HVAC systems were necessary and energy-efficient HVAC systems can save significant energy and reduced impact. IAQ management and low-emitting materials helped he elderly's physical health. Beautiful green landscapes (atrium garden, green balconies, etc.) could enable senior more contact with natural environment, and increase the frequency of outdoor activities. Rainwater collection system saved water and solar arrays save energy.

Marketing data collected by Gerontological Services, Inc., consultants specializing in market feasibility (2010), 71 percent senior respondents said that energy-saving and recycling programs are very important to them (Perkins, 2013). younger cohorts were more likely to think sustainability were "very important" than older ones. (Figure 4.1) In the Facebook comments of above three cases, good garden, good environment was the most concerned. In conclusion, the majority of senior people concerned about energy-saving, recycling, and the surrounding environment.

Figure 4.1 Sustainable Concern, by Age

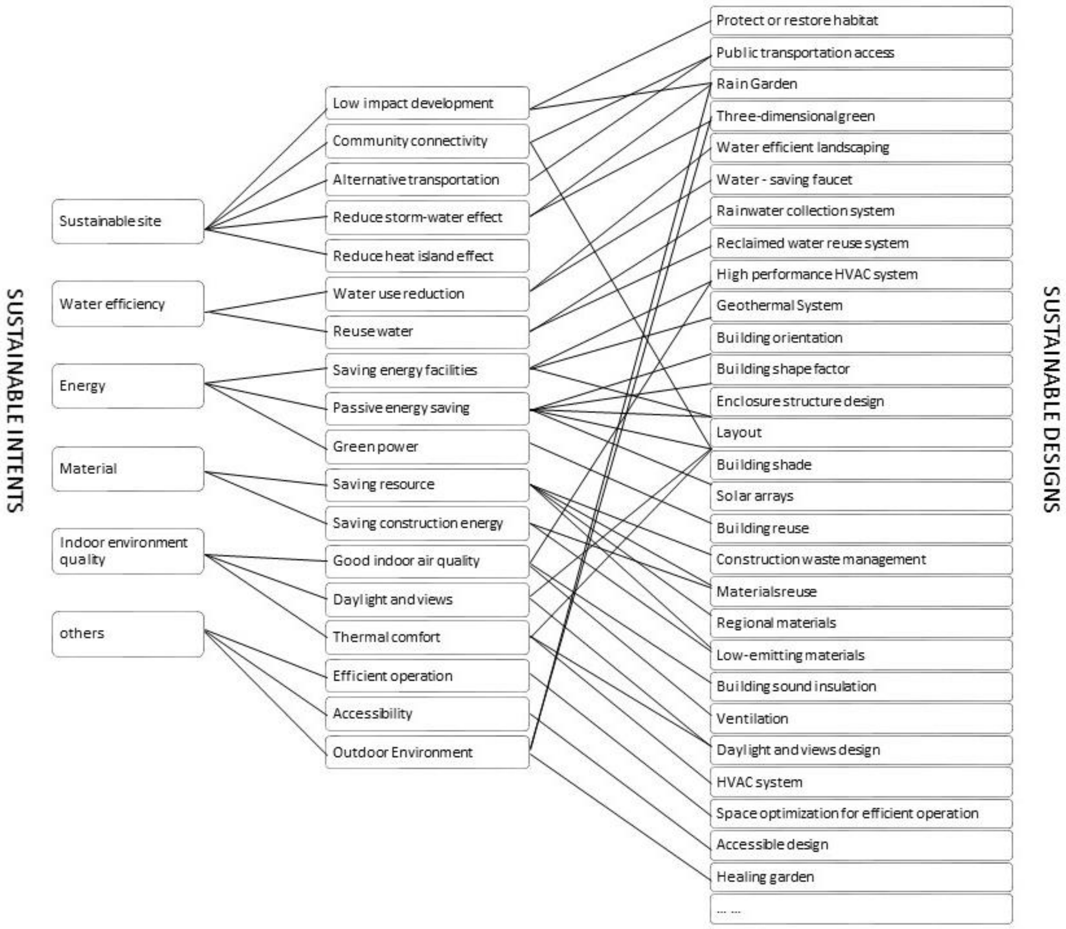
Age	Rate energy saving and recycling "very important" (%)
Under 65	82
65–69	74
70–74	71
75+	63

Maria Dwight and Karen Adams

CHAPTER 5
RECOMMEDATION

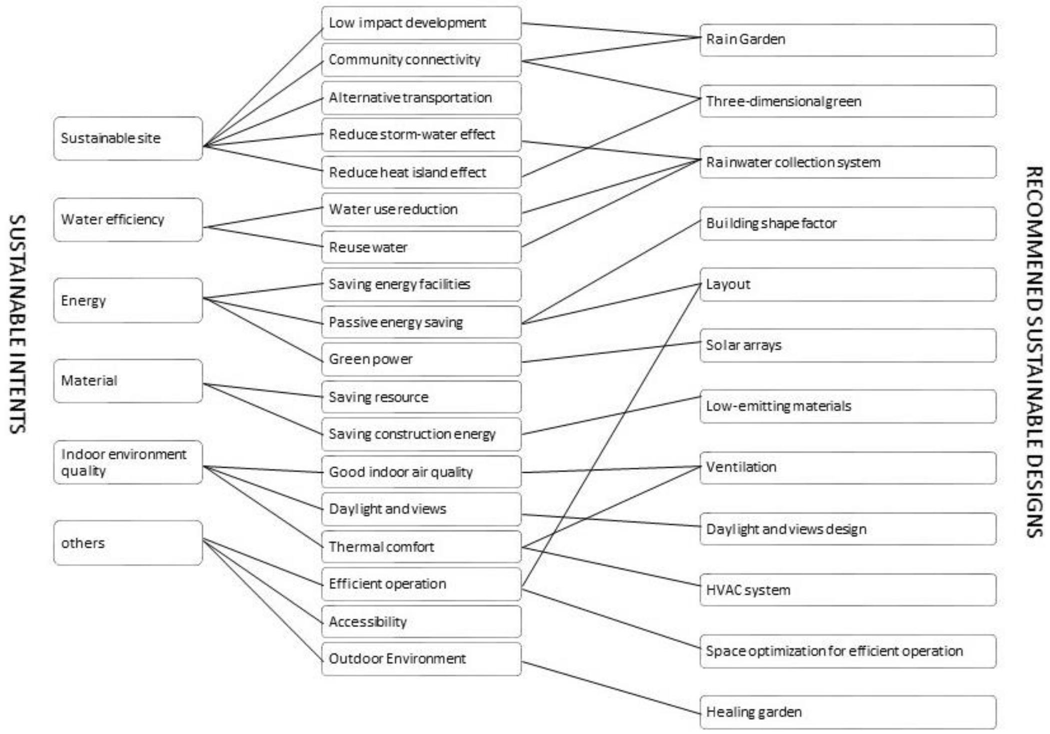
In the U.S., projects with sustainable goals usually follow the LEED. However, some *new construction* requirements in LEED are important in senior housing while some ignore the different actual situation. There are designs should be considered but that are not included in LEED. According to analysis of building design characteristics of senior housing and studies on superior cases in the U.S. and Europe, this research concluded the sustainable intents with related strategies and designs (Figure 5.1), and recommend some more efficient strategies in architecture design (Figure 5.2).

Figure 5.1 sustainable intents and designs



Source: The author organized and draw.

Figure 5.2 recommended sustainable designs



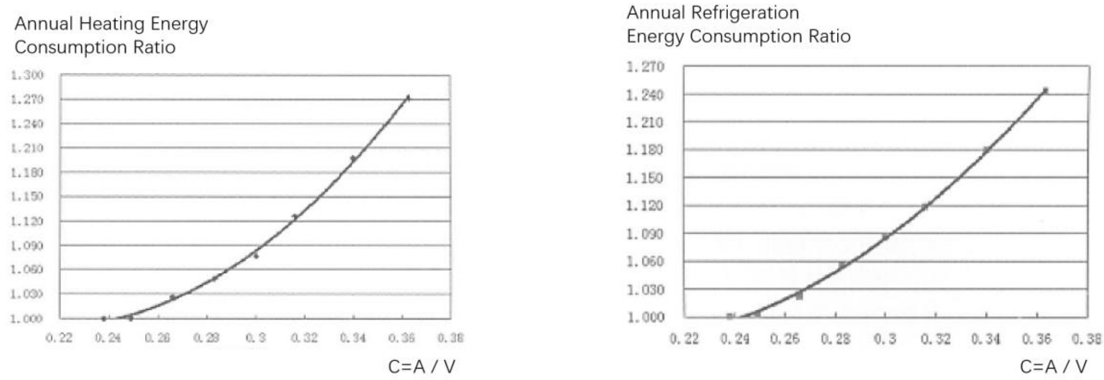
Source: The author organized and draw.

Some sustainable methods are more dependent on machines rather than architectural designs, such as water - saving faucets, high-performance HVAC system, geothermal system and low-emitting materials. They are all worth considering during the design and construction phases according to the particular situation of a senior housing location. The recommended sustainable designs are more relevant to architectural design, and focus on both sustainability and aging.

Building Shape Coefficient

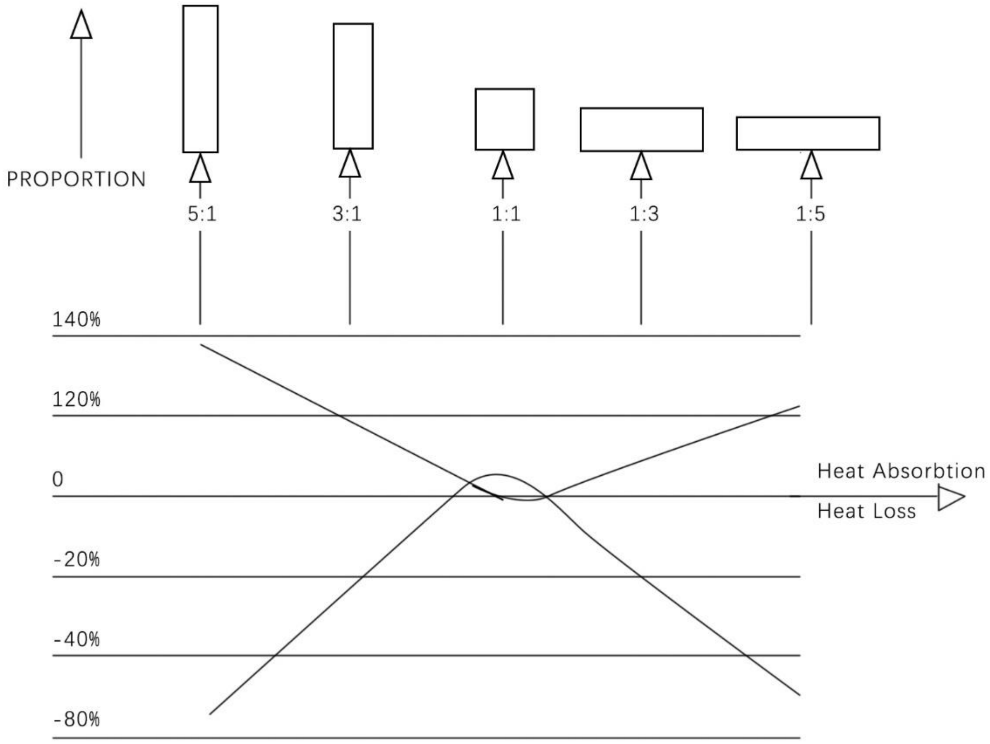
First of all, the building Shape Coefficient has a great impact on the building's ability of endothermic and heat dissipation. In general, the regular plane, simple shape with less ratio of length to width contribute to the building insulation but are not conducive to loss heat. Studies have shown that with body shape increase （Building Shape Coefficient(C)= Surface area(A) / Inner volume(V) ） of 0.01%, the HAVC consumption index increased by about 2.5 percentage points (Zhou, 2007)(Figure 5.1). Because, compared with the same volume of the building, the buildings larger surface area has more winds, window opportunities, and ventilation better, but the heat loss is also larger than unfavorable insulation (Figure 5.2)

Figure 5.1 Building Shape Coefficient influence energy consumption.



Source: Zhou, Y. Yan, C. Yao, Jian.(2007) *Effects of Body Shape Coefficient on Building Energy Consumption in Buildings*. Huazhong Architecture. 25 (5): 115-116.

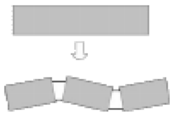
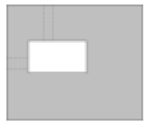
Figure 5.2 Heat absorption and heat losses with different forms of plan



Source: Klaus Daniels, *Through Integral Planning to Advance the Performance of Building*

Therefore, in the design of senior housing, designers should take full account of the building shape design, by adjusting the building body balance heat dissipation and insulation performance. The building shape design of senior housing is generally advantageous in the regular form, a high level and a large body shape, a well-ventilated, and shady design. Several common architectural details are more suitable for the body. Table 5.1 lists several common architectural shapes that are more suitable for senior housing.

Table 5.1 common suitable architectural shapes of senior housing

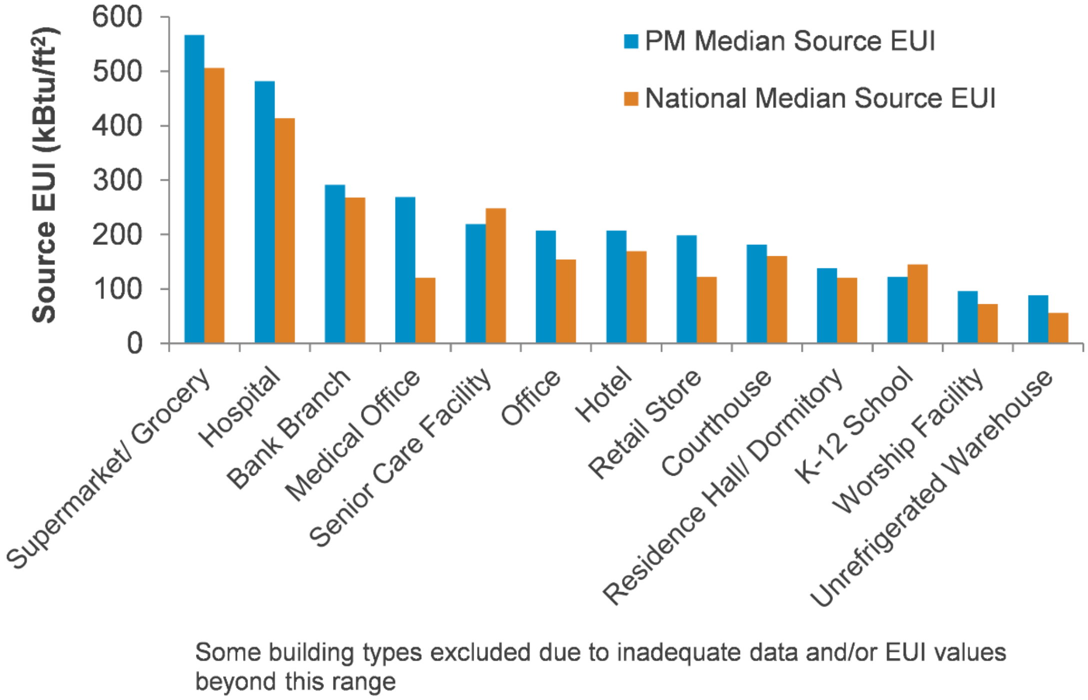
	“_____” Form	“L” Form	“U” Form	Hollow Square
Diagram				
Feature	The more traditional form of senior housing, can have more communication space through variants	It should strengthen the insulation measures at the corner	It forms a half-enclosed courtyard. Reasonable design the direction of the opening of the courtyard, to avoid the wind vortex	It is suitable for the limited site, forms closed activities of the courtyard. It should be connected to the outdoor overhead layer or wind tunnel in the bottom

Source: The author organized and draw.

Energy-efficient HVAC system

The energy consumption of the senior housing is usually higher than that of ordinary residential buildings but lower than supermarkets, hospitals and office buildings. A study by U.S. Environmental Protection Agency (Figure 5.3) investigates the average energy consumption per unit area of different building types. The survey found that the building area of the senior care facility was about twice as much as residence hall / dormitory, but about half of the Hospital.

Figure 5.3 Typical Energy Use Intensity （EUI） for selected buildings.



Source: U.S. Environmental Protection Agency

Aging people usually need higher room temperature, humidity, lighting, ventilation than young people. For senior housing complexes which offer health care service, there is the need to consider the operation of medical equipment, energy consumption and intelligent integrated management of the special needs. In summary, the elderly’s requirements on indoor environmental quality cause high energy consumption, which restricts energy saving. In this condition, HVAC systems are necessary and energy-efficient HVAC systems can save significant energy and reduce impact.

Low-emitting materials

Materials effect the indoor air quality a lot. Low-emitting materials can reduce the quantity of indoor air contaminants that are odorous, irritating or harmful to the comfort and well-being of installers and occupants (LEED). Low-emitting materials usually be used in adhesives, sealants, paints, coatings, carpet systems, composite wood, and agriculture fiber products. It is related to using more nature material to saving energy. But in senior housing, indoor environment quality is more important. Low-emitting materials improves indoor air quality, improves worker safety and health, reduces incidents of eye and respiratory irritation, headaches, fatigue and other symptoms of “sick building syndrome”, healthier environment for seniors who are sensitive to certain products, and reduces pollution of natural waterways.

Space optimization for efficient operation

To improve the operating efficiency of senior housing and reduce operating costs is one of the inherent requirements of sustainable development. The architectural designs are mainly based on the needs of the elderly and the service needs of the staff. A reasonable division to reduce the cross-collision of the streamline is needed so that buildings can have the shortest service path.

From the needs of the elderly, the elderly cognitive map may become fuzzy, and unreasonable space design will cause the elderly to possibly become lost, posing security risks. Therefore, it is vital to improve the efficiency of space use by reducing flow line crossover, easing the functional attributes of the centralized activities / dining area, improving the medical package and improving the identification of the elderly walk route.

Senior housing should be managed in different area zonings, based on the health of the service, such as horizontal division, vertical division and group partition, and should be set up in the first floor of the entrance.

Exploiting the centralized public space with a small, decentralized dining / activity space avoids the security risks caused by crowds in the centralized restaurant / activity area. At the same time, the small dining / activity area is in contact with the elderly living area more closely, the scale is more cordial and can promote neighborhood communication. The service staff will become more familiar with the elderly, improving work efficiency and service quality.

Color and logo design can deepen the elderly's understanding of the spatial map. In the turning point of traffic (such as staircase, elevator hall, corridor corner, etc.), designers should set and identify color and pattern.

When making floor plans for senior housing, the traffic lines to areas offering foodstuffs, food and beverage, clean clothing should be separated from the traffic lines leading to garbage disposal and service areas.

Office, logistics and other service spaces should have independent external entrances and exits and be apart from resident living space.

Three-dimensional green

Beautiful green landscape can promote contact with a more natural environment and increase the frequency of outdoor activities for the elderly. Faced with the uncertain status of urban land, the combination of three-dimensional greening (the surrounding greening, the site greening, green roof, balcony / terrace greening) not only provides an all-round green feel for these seniors, but also saves land and reduces the heat island effect (Table 5.2).

Table 5.2 the three-dimensional greening in senior housing

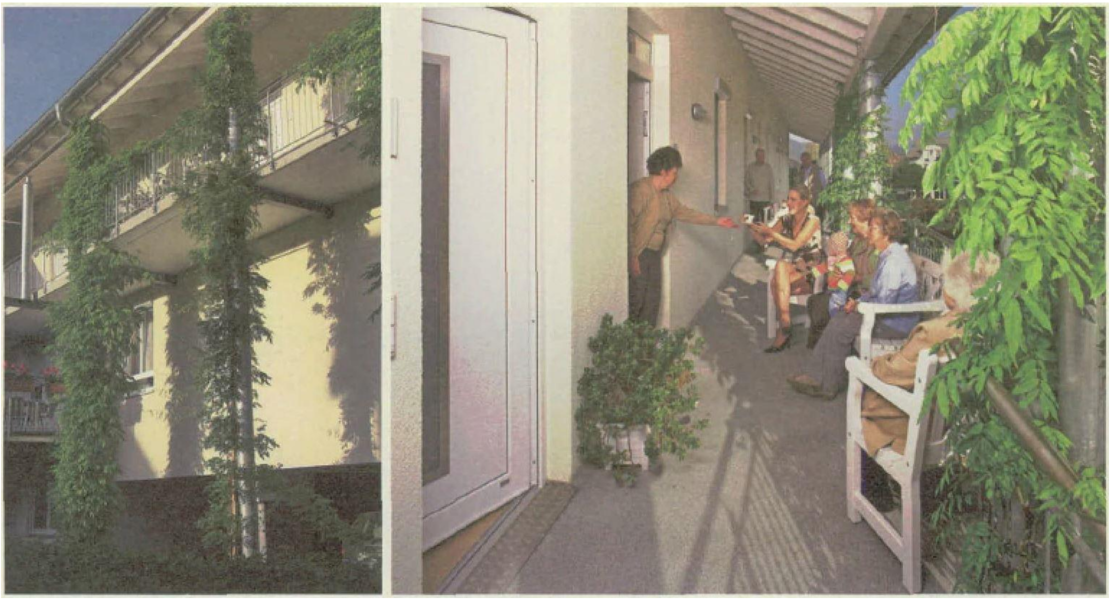
Type	Features	Designs
Surrounding greening	Self-care old people like to have activities in green open space in the city, a good surrounding green environment will help to enhance the attractiveness of senior housing.	The planning and selection of the senior housing should take the surrounding greening environment into account, such as parks, green belts, floodplains, etc. Architectural design should take full account of the elderly living room

		orientation to take advantage of green design.
Site greening	The main green method, can effectively reduce the outdoor heat island strength and isolate noise	Consider the proportion of shrubs and trees to plant, set up a reasonable water pavement, plant street trees to isolate traffic noise. Control plant height to meet the visual accessibility of the staff to protect the safety of outdoor activities.
Green roof.	Auxiliary green way, can improve the green rating.	Usually to cultivate lawn and shrub. Accessible green roof should have security and accessible design.
Balcony / terrace greening	Auxiliary green way.	Usually planted with potted plants, or rattan plants climbing column and railing
Wall greening	Auxiliary green way, enriched the facade effect.	Planted climbing rattan. Local wall design into a plant wall.
Atrium / patio greening	Auxiliary green way, can allow green into the room, and enhance green feelings of the elderly, and improve IAQ. The transpiration of plants can form a temperature difference with hot air and drive hot ventilation.	Usually potted plant or climbing; soil covers the ground layer in the atrium or patio

Source: The author organized and draw.

In addition, the rational design of the construction interface can penetrate the outdoor environment and move it indoors. The introduction of an external natural environment through the building inside and outside can enhance resident perception of the natural environment and help them to relax, to regain the love of life and interest in the surroundings. A large number of studies have shown that the natural landscape visible through a living room window can make the resident feel happy, and lead to a good mental association. Therefore, in the architectural design of senior housing, it is necessary to design ornamental windows that fill a green frame with visual beauty(Dahlkvist,2014).

Figure 5.4 The Vines Climb Along the Steel Columns (Balcony / terrace greening)



Source: © 2016 WFP ARCHITEKTEN

Healing garden & rain garden

Gardens play a significant role in comfortable senior living. While physiological function might be degrading, outdoor exercise can help the residents maintain a strong physique. As people age, the psychological needs of social recognition and communication gradually increase. In addition, older people like to rest in a sunny place. When designing senior housing, landscape architects need to consider the following needs (Rosen, 2014):

1) Establish a walkable or barrier-free community:

The design and location of sidewalks and parking lots should not exceed 5 ° so that residents can visit the community alone;

2) Create a sense of security:

For the elderly who are weak, it is very uncomfortable to be completely exposed to the outdoor environment. Vegetation, soft decoration, and even the building side walls can be used to create a feeling of enclosure or shade;

3) Provide meeting activities place:

Planting ponds, pavilions, terraces and other gatherings create opportunities for interpersonal and meaningful activities;

4) Block the sun:

Trees, the construction of flower racks and green corridors prevent sun exposure;

5) Strengthen the characteristics of existing places:

Understand the advantages and disadvantages of the natural environment and demonstrate the ideal natural features of the site by design;

6) Memory care walk garden:

For residents with memory impairment, provide a specially designed safe walkway garden as part of the memory barrier care apartment group.

It is a water-saving method to design the healing garden as a rain garden. Rainwater management is one of the important contents of landscape design through the use of wetlands, plant communities and rainwater treatment facilities. They can be used to design and landscape waterways, ponds, low potential green land, natural terrain and other rainwater resources. It can achieve the purpose of rainwater use, but also obtain a good landscape and ecological effect.

Figure 5.5 Closeness and easy access. Outdoor environment close at hand and clearly visible from inside the building.

Source: Anna Bengtsson, Patrik Grahn 2014

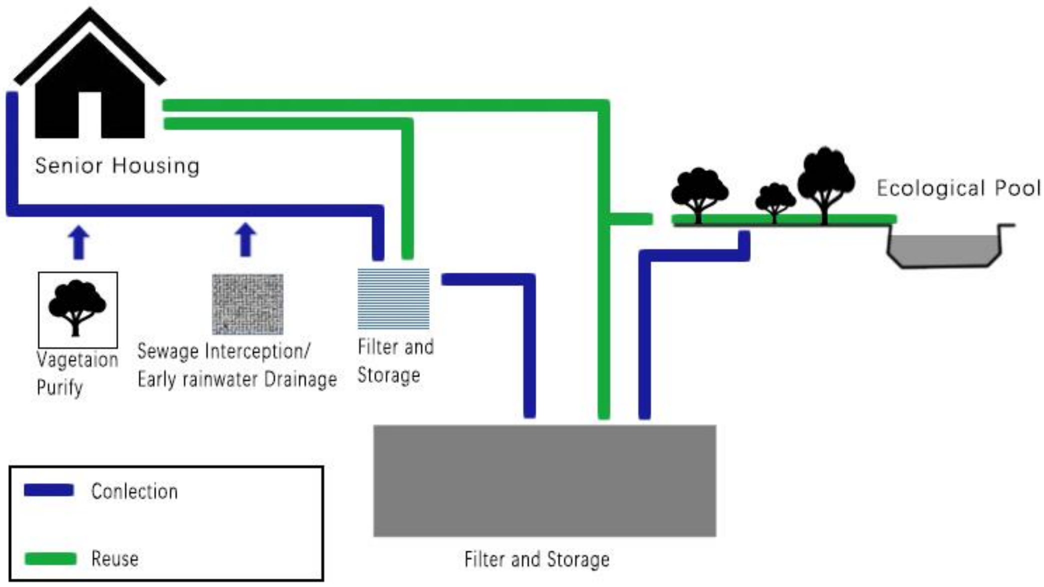
Figure 5.6 Rain garden and healing garden

Source: Anna Bengtsson, Patrik Grahn 2014

Rainwater collection systems include roofing rainwater and ground runoff.

The roof is the most suitable and common rainwater harvesting surface. For the sake of resident water safety, the roof rainwater harvesting system should be equipped with sewage interception or an early rainwater drainage device. The use of surface vegetation can purify rain, and improve the quality of rain water collection. Activity squares, lanes and green areas can take full advantage of the terrain. When it is difficult to produce large terrain height, a rainwater ditch can be used to collect rainwater within the rational design of natural drainage slope. The best rainwater usage is for landscape replenishment and ecological pool water. Ecological pools not only improve the rainwater conservation capacity of the earth, but also for the elderly to provide a refreshing landscape environment (Figure 5.).

Figure 5.7 Rainwater recycling system

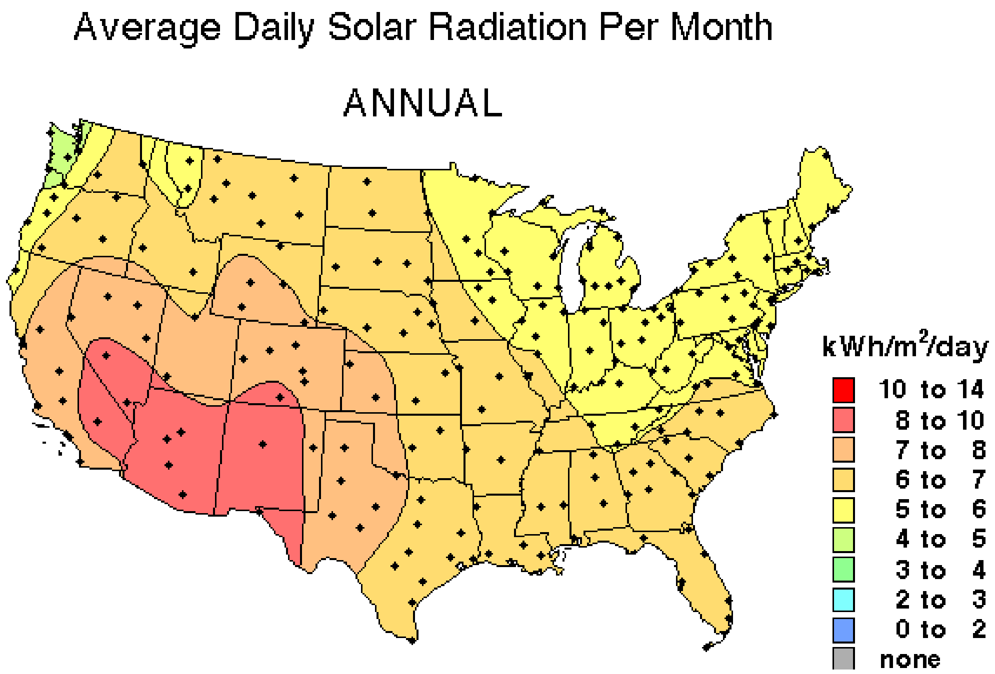


Source: The author organized and draw.

Solar arrays

Currently, a solar hot water system is the most economic solar energy utilization form. It is the most widely used, most mature technology, and the fastest industrialization utilizing solar energy. Due to their age, these senior citizens need all-day hot water, and water temperature remaining as stable as possible. Solar collectors are arranged on the roof, and walls, and with an auxiliary heating device, provide users with 24-hour domestic hot water.

Figure 5.8 The continental United States with a legend including units of kilowatt hours per square meter per day



Source: © Oliver Seely

A centralized hot water system is generally for multi-users with a set circulating heating system. Each system has a separate water tank with heating terminal and metering devices (each household has a meter to indicate the amount of hot water). This system can save overall pipeline settings, makes it easier to charge hot water circulation, and offers saving investment. For the senior apartments and nursing home, this system offers high integration and offers a more beautiful building appearance than a household solar hot water system.

Integration of solar energy and buildings requires using solar energy, a clean and pollution-free energy, to supply hot water to meet the daily needs of the elderly, but also save energy. However, in architectural design, designers need to consider two aspects of the problem. One is the impact of the application of solar energy in buildings, including the use of buildings, the structure of the envelope, building size and facade changes. Another one is to consider the selection of solar energy system, a creative combination of solar energy products and architectural form. To achieve integration of solar energy and the building, the solar hot water system components are used as building components and considered in the facade, structure, water supply and drainage design to make the solar heating system an integral part of the building as a whole. (Figure 5.).

Figure 5.9 Armstrong Place Senior Housing with Solar Array

Source: © Brian Rose from http://www.archdaily.com

CHAPTER 6

CONCLUSION

This study provides a basic analysis and practical research on sustainable designs for senior housing. The study is divided into three parts. The first part addresses how the characteristics of senior living serve as a basis for developing sustainable designs, this part also includes a critical interpretation of LEED to provide operability cognition for senior housing. The second part of this study analyzes well-designed senior housing and summarizes the advantages and disadvantages of the research objects (pinwheel layout, high-performance HVAC systems, IAQ management, atrium garden, green balconies, soil heat, storm-water management, water saving landscape, low-emitting and renewable materials) of the three case-studies in order to lay the empirical foundation for this paper. The third part applies the theoretical approach to real-world designs. Based on this this study's theoretical research and case studies, the following specific designs for senior housing are recommended: Building Shape Coefficient, Energy-efficient HVAC system, Low-emitting materials, Rain Garden, Three-dimensional green, Rainwater collection system, Solar arrays, Ventilation, Daylight and views design, , Space optimization for efficient operation, Healing garden.

These sustainable designs will be both comfortable and low-impact. The most effective designs improve the quality of indoor environments. Building shape coefficient have a great impact on the building's ability of endothermic and heat dissipation. Furthermore, improving the operating efficiency of senior housing, and reducing operating costs, are inherent requirements of sustainable development. Beautiful green landscapes can enable senior more contact with natural environment, and increase the frequency of outdoor activities. Rainwater collection system save water and solar arrays save energy.

Due to the limitation of this study including time and the length of the paper, this study has included only a select few recommend designs and there remains a lack of depth and breadth regarding sustainable designs for senior living. Different climate and geographical environments must make a great difference of the building design; each type of climate and geographical environment is worthy of further study.

BIBLIOGRAPHY

United Nations Department of Economic and Social Affairs, Population Division, *World Population Ageing 1950–2050 (2010)*, ch.2, “Magnitude and Speed of Population Ageing,”

Roth, E., Eckert, J., & Morgan, L. (2016). Stigma and discontinuity in multilevel senior housing's continuum of care. *Gerontologist, 56*(5), 868-876. doi:10.1093/geront/gnv055

Perkins, L. B. (2013). *Building type basics for senior living* (Second ed.). Hoboken: Wiley.

Wang, R., & Sun, Y. F. (2014). *The research on environment design of senile apartments*. Applied Mechanics and Materials, 584-586

Lin, W. J., Song, N. N., & Yang, Y. J. (2014). *Study on the design of the reading room in nursing-home-based on the needs of seniors*. Applied Mechanics and Materials, 584-586

Kwon, S., & Kim, K. (2005). *Architectural types of residential unit in nursing homes*. Journal of Asian Architecture and Building Engineering, 4(1), 105-112.

Bengtsson, A., Carlsson, G., & Aktivtoch, M. (2013). *Outdoor environments at three nursing homes-qualitative interviews with residents and next of kin*. Urban Forestry & Urban Greening, 12(3), 393-400.

Cui, Y., & Zheng, H. (2016). *The impact of the three-dimensional greening of buildings in cold regions in China on urban cooling effect*. Procedia Engineering, 169, 297-302.

Xu, J. X., & Xue, Y. B. (2014). *Strategies of three-dimensional greening design in building sectors*. Applied Mechanics and Materials, 507, 119-123.

Harvard, W. B. Jr (2012) *Clyde E. lassen state veterans' nursing home*. Design Cost Data, 56(3), 36.

Gustafson, M. (2011). *Future and past in the plan: The clyde E. lassen state veterans' nursing home honors residents by respecting and promoting their past, and protecting their future*. Vol. 32 Haymarket Media, Inc.

U.S. Green Building Council. (2017). *FDVA Nursing Home*. Retrieved from http://www.usgbc.org/projects/fdva-nursing-home

WFP ARCHITEKTEN (2016). *Riedlen Nursing Home*. Design Community, 2016(05),66-71.

WFP ARCHITEKTEN (2016). *Riedlen Nursing Home*. Retrieved from http://wfp-architekten.com/english/index.php/Product/showproduct/id/31/flag/2

U.S. Green Building Council. (2017). *Armstrong Senior Housing*. Retrieved from http://www.usgbc.org/projects/armstrong-senior-housing

Baker, D. (2011). *Armstrong Place Senior Housing / David Baker & Partners*. Archdaily. Retrieved from http://www.archdaily.com/153359/armstrong-place-senior-housing-david-baker-partners

Dahlkvist, E., Nilsson, A., Skovdahl, K., & Engstrom, M. (2014). *Is there a caring perspective in Garden/Patio design in elderly care? A description and a comparison of residents' and staff members' perceptions of these outdoor spaces.* Journal of Housing for the Elderly, 28(1), 85-106.

Gratia, E., De Herde, A. (2003) *Design of low energy office buildings*. Energy & Buildings, Vol. 35, 473-491.

Rosen, R, S (2014) Landscape Design of Senior Living Communities. Chinese Landscape Architecture, 2015(1), 35-40

Zhou, Y. Yan, C. Yao, Jian.(2007) *Effects of Body Shape Coefficient on Building Energy Consumption in Buildings*. Huazhong Architecture. 25 (5): 115-116.