Approaches to Develop Sustainable, Climate Adapted Buildings for Japan as a Subtropical Climate Case

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Abstract

The study addresses the need to develop overall designs and concept for houses that are tailored to culture and climate in order to sustainably reduce emissions from the building stock. It focuses on subtropical climates and Japan as an example for such conditions. The general method used is balancing initial ecological and economical costs (such as CO2e emissions or aggregated indicators) with running costs to assess the lifetime performance of concepts also taking into account frame conditions like users’ acceptance and culture. The method is applied in a project in Japan from which the first preliminary experience values and results stem from. Calculations for the Japan case show that the optimal balances for economical and ecological costs match quite well for this country. Concepts concentrating on the envelope in order to cover and reduce the energy demand by passive means are tending to show lower environmental costs while concepts concentrating on the heating-cooling system tend to show lower economical costs. A sensible compromise can be found between these two aspects optimum. The reason is to be seen in the low interest on the one hand and the lack of alternative energy generation measures on the other. The necessary make-ups for the wall from the building physical viewpoint also match quite well with the evaluated concepts. The concepts that are now realized in Japan by far surpass any currently established efficiency and therefore are met with scepticism at the moment. In the first discussions with local building companies and customers the increased comfort and the provided healthy living prove to be far superior arguments that the original focus on an overall minimum of environmental and ecological costs. Barriers to be overcome in the next years are mainly to be seen in the current focus on initial investments on part of the customers, neglecting the life time costs and therefore resulting in concepts that are not optimal when evaluated over the complete lifetime. Also many concepts still have a very strict viewpoint on how a house has to look like, often being inspired by concepts that come from completely different cultural and climatic conditions.

Keywords: sustainable building concepts, Japan, subtropical climate, life cycle balances, climate adapted concepts
1. Background

1.1 General

The challenges of reducing their overall CO₂ emissions confront many countries with the need to reduce the emissions from their building stock, as emissions from this source often equals about a third of the overall amount. (Lomas 2009) Contrary to other areas where savings often come hand in hand with demands for sufficiency which would reduce the living standard and comfort of the people in question, the building stock can be seen as one of the rare cases where saving of emissions and a raise in health and comfort accompany and complement each other. The reason for this is that many countries with poor quality houses suffer from sick building syndrome due to mould and condensation phenomena in the buildings. Increases in the quality of the building envelope also result in more comfortable inside conditions by creating surface temperatures. (United Nations Environment Programme UNEP 2007)

Because of the reasons above the field of energy efficient building technology is understood by many companies as a very promising export market. In several countries there are solid experience values with energy efficient houses and the required technology. These obviously qualify for export and have the potential to have a huge impact on the energy consumption of buildings in the receiving countries and therefore the emissions.

However many such approaches in potential markets are met with failure. There are two main reasons for this:

- There are often no solid evaluation of the local needs and demands. This would include knowledge of the local living style, the culture, the acceptance of a technology as well as taking into account the necessary infrastructure to run a technology. Many frame conditions that are existent in the source country are taken for granted in the approached country as well. The result of such mistakes is often a technology that is not accepted, used incorrectly, cannot be supported or implemented into the local conditions.

- The technology to be exported is introduced without the necessary overall concept that is required by it to perform well. The results are often damages to the technology or severe reductions in its performance and efficiency up to the point where it loses its emission reducing value completely.

Out of the many countries that emit huge amounts of CO₂ emissions due to their consumption in buildings some are of special scientific interest as they have very challenging demands for a low emission buildings and implementing a new technology is most difficult. These countries have climates that are summed up under the overall term subtropical climates by meteorology. From the viewpoint of architects they have heating as well as cooling demand. From the viewpoint of building physics the humidity stream inside the outer walls changes direction in the course of the year. From
the viewpoint of the social scientist many of these countries have customs and a lifestyle that completely differs from the western one. It has to be noted that some of the countries with the fastest growth of CO2 emissions are in subtropical climates. (Raupach, Marland et al. 2007)

The following map gives an overview of the countries addressed:

![Map of countries with subtropical characteristics]

Picture 1: Relevance of the subtropical characteristics for the housing design (Based on Köppen-Geiger climate definitions) / from relevant (dark) to irrelevant (bright)

1.2 Japan

Besides the challenges of the local climate Japan offers some conditions that make it ideally suited as a starting point to test and optimize methodological approaches as well as technologies and concepts for subtropical climates.

Japan has severe problems with its building stock. The complete traditional knowledge of designing climate tailored buildings was lost in the Second World War. Afterwards influences by western oriented construction methods dominated traditional knowledge. These imported and new building systems where never adapted to the cultural and climate conditions and therefore suffer from building physical problems of all kinds. Especially the residential buildings and one family houses, mostly wooden structures are problematic in this regard. The average lifespan of such a Japanese dormitory is about 20 years, afterwards it is torn down and a new one is built. About one million Japanese are currently registered by the Ministry of Health, Labour and Welfare as having illnesses that are the direct result of their living conditions. The economic demand for solutions to these problems by designing buildings that are free of mould and condensation and therefore also have a lifespan of much more than the currently accepted 20 years is huge. The necessary knowledge to design and build such houses is not existent in Japan at the moment. While there are often several chairs that are conducting research on earthquake resistance measures at a Japanese university, the field of building
physics while existent so far has no influence on the building industry. The potential for a simple know how transfer seems to be enormous.

On the downside Japan has a very restrictive market. This shows in the complex and time consuming steps necessary for getting a license for a technology in Japan in the first place and later in a general scepticism of the customers concerning foreign products.

While being liberal in many markets, especially those with direct international competition, the housing sector is especially conservative. The reason for this is to be seen in the market structure of the Japanese building sector. It is dominated by several big housing companies, sometimes building several thousand houses every year, in contrast to the more individual oriented system using small architects’ offices that is common in Europe. The big Japanese companies have a huge infrastructure, including prefab branches, material producing branches and engineers. As a result they are slow to change their houses concepts, as it would include massive changes in their infrastructure as well. With most of the job training taking place within the companies and not at the universities a huge effort for schooling the employers would also be necessary, resulting in enormous costs.

Middle sized companies on the other hand would have the ability to change more quickly. They are however at a severe disadvantage on the market, as the customers give huge advance of trust to big corporate groups. In times of the economic crisis the same is true for their chances to get funding for initializing own and innovative projects. From the viewpoint of the funding organizations they are often simply not competent enough to conduct such projects. As the big corporate groups are not willing to move the market the change however can only come from these middle sized actors.

Concerning the problems listed above the Japanese market is a prime example. Because of its attractiveness many companies have tried to introduce building material or technologies without adapting the concept/technology and doing solid research on culture and local needs. All of the approaches focussing on the envelope failed, resulting in low quality building hulls with a sophisticated heating and cooling system without a sound overall concept. These two fields of technologies do not complement each other but work against each other in many cases, resulting in mould and low comfort. As another result running consumption and initial effort are not balanced. This creates a situation where the vast majority of buildings are wasting energy due to unnecessary large running consumption. On the other side there is a minority of buildings introducing concepts from abroad that have low running consumption but levels of insulation and therefore initial environmental costs that are not sensible in subtropical climates or window fractions that are oversized for reducing heating demand due to solar gains instead creating more cooling demand in summer.

From the scientific viewpoint Japan offers a unique opportunity: because of its extreme shape, stretching from north to south, Japan encompasses several climate zones in one country and therefore one legal condition and culture. Therefore concepts for climate tailored designs can be evaluated for several climate conditions with in one country and culture. The following picture shows the distribution of the climate zone in Japan from cool temperate Hokkaido to the subtropical climate of central Japan and Kyushu:
1.3 Holistic approaches

The current state of knowledge concerning sustainable approaches to counter climate change names three important aspects to ensure a truly holistic solution: social sustainability, economical sustainability and ecological sustainability. Such an approach would also prevent a technology from failing in a given country due to the under background given reasons. To implement technologies for reducing emissions in Japan it is necessary to first design a truly sustainable overall concept implementing promising technology and tailoring it to the local needs. Such a demand for a concept that is climate adapted and fit for the future, combining new technology with design issues, however is leading to a lot of questions:

- In a country where a new concept is to be introduced there are no experience values with the user behaviour yet. While certain guesses can be made a huge uncertainty has to be seen here. A solid evaluation of the impact the concept has on the way of living is surely mandatory.

- The general acceptance for technological solutions is often unclear. In some cases it affects mainly active technologies; in some cases it mainly affects passive technologies. For both cases there are cultures and cultural subgroups that are extremely hesitant to employ a certain solution because it does not feel right for them. Solid exchange with the people in question is mandatory.

- Regional problems that are only indirectly connected to the building often of fer huge potential for acquiring local acceptance and improving the environmental performance of concepts. A solid research on the local problems beyond the core building industry is often extremely valuable.
When starting the design process the order by which the measures are applied has a great impact on the result. When the design is started from small to big measures (controls to design) the outcome is most often a building that is centred on flexible application of the housing services and movable elements at the facade. When the design is started from big measures to small measures (from design to controls) the result is often a traditional inspired design where the heating and cooling system is focussing on covering the peak demands. Both design strategies surely have their potentials and advantages, to be reflected in front of the local situation.

Most important the evaluation of a solution should not be reduced to the usage phase, though it is often dominant (Sartori and Hestnes 2007). When designing houses that come close to fulfilling the requirements of international targets like 1 ton CO₂ per capita and person or the derived 2000 Watt Society the initial effort needed to produce the building materials contributes an important part of the lifetime emissions. The current state of knowledge allows the calculation of this part if the associated companies provide in formation on the related production procedures. The increasing availability of this data in combination with more and more reliable calculation tools for the running consumption allow for the calculation of overall life cycle performances and therefore the possibility of balancing measures to archive and optimum overall performance. (Spreng 1995)

2. Method

Basically a building can achieve a comfortable inner room climate by passive (internal and solar gains in combination with a well designed envelope) and active means (heating or cooling system):

![Graph 1: Combinations of active and passive systems to cover comfort](image)

While in theory comfort can be created by either approach alone, almost all concepts use a combination of active and passive means to reach an overall sound solution. The reason for this is that the effort for active and passive measures increases disproportionately in concepts that rely mostly on one of them. Approaches solely relying only on one of them (a campfire) can also fail to provide comfort. The basic dependency is shown in the graph below:
Graph 2: Accumulated costs of active and passive systems to cover comfort

When comprehending a house as a combination of active and passive measures, the main question when developing a house for a certain climate is which combination is resulting in the optimal overall lifetime performance. Such an optimal solution is described in the graph below:

Graph 3: Optimal solution for a given Indicator and reasonable solutions based on optimal solution

Of course the results will differ based on the frame scenarios (development of scarcity, interest and resulting costs) and the indicator chosen (CO2, money, energy, UBP). Together with information on the user acceptance concerning passive and active measures in between the optimal solutions for one given indicator sound overall concepts can be developed.
The regional energy generation (both for the running consumption and the creation of the materials in the first place) and the interest for investment money for financing the building of a given project are the main factors for influencing the optimal combinations. Lessening the interest on investments allows for more initial investment in efficient heating or cooling systems and the envelope, therefore reducing running consumption. An adapted, ecological energy generation or energy mix can counter individual ecological costs in terms of life cycle assessed indicators such as above.

Besides helping to decide on a sound combination of active and passive measures, the method can be a tool to develop proposals for the local decision makers where to create the biggest impact when investing money in the local infrastructure to decrease environmental damages.

3. The first project in Japan

3.1 General information

The University of Tokyo, the EMPA and the ETH Zürich are currently working on a project to develop sustainable houses in Japan and start an ongoing know-how transfer between Switzerland and Japan. The project is funded by the Swiss government due to the Commission for Technological Innovation (CTI/ KTI) as an export opportunity for Swiss building technology is seen based on the results of the cooperation.

On the business side of the project Japanese building companies will cooperate with partners to bring the concepts to the Japanese market. The Japanese companies will be schooled in the technologies and concepts in the coming year in theoretical workshops and on the building site. This process, during which also the concepts are further fleshed out based on the feedback of the cooperating Japanese building companies, the first test buildings will be constructed in Sendai, Tokyo, Kyoto, Nagoya and Kanazawa. These buildings will be evaluated on their performance and used for promotion measures.
First buildings using some of the materials used in the overall concept have already been realized during the last years. As acquiring the licence especially for structural elements is extremely hazardous in Japan it made sense to separate the single components during the licensing phase.

![Picture 3: Pictures from the building sites necessary for acquiring the license for the employed structural elements in Japan]

Besides a focus on the hygro-thermal modelling of the materials used in the building envelope and accompanied testing of promising solutions in climate chamber tests to avoid any humidity damages in the first test buildings the design approach is covered by the method above. For the frame conditions in Japan there are therefore first preliminary results concerning the feasibility of the approach as well as practical experience values.

After the evaluation of the performance of the first test houses, there will also be data on the correctness of the assumptions made during the calculations.

### 3.2 Preliminary results

#### 3.2.1 Feasibility and results

The approach of balancing initial effort with running consumption is in many cases met with an overwhelming acceptance. The architects and building companies are relieved to be approached with concepts that are made for their market instead of just being proposed a copy from another country, climate and culture. Their very Japanese viewpoint of seeing Japan and its frame conditions as something very special, not comparable to other situations in the world also supports the approach chosen in the project.

While the argumentation that buildings look different, depending among other factors on the climate conditions and culture, is understandable at once, there is currently no calculation approach to apply this knowledge and implement it into the design process. Balancing the initial costs and resulting running costs of the most influential active and passive parts of a building to archive an optimized overall performance is in this regard a promising first step.
Problems arise from the fact that especially the data on Japanese building materials is insufficient. Japanese production companies often fear that the information they would have to provide will lead competitors to copy their production methods. This kind of thinking has lead to the situation that the environmental impact of the production of Japanese building materials is difficult to assess and very often (because of lack of interest and competition) very inferior to international competitors. Considering the global market of building products this makes importing building materials an alternative for the short term. Improvements could surely be created by establishing more sustainable local production processes of course. As a side aspect the calculation model gets increasingly complex the sources of energy generation are to be included. The creation of insulation material with a very efficient energy production in one place, while using a very environmental damaging means of covering the running consumption is an example that can lead to very extreme results, especially concerning the environmental indicators.

As a result of importing many building materials (for the envelope) the optimal combination of passive and active components moves towards a more active concept. For central Japan, differing based on frame conditions an local energy generation, sound insulation thicknesses are in the area of 10 to 14 cm in combination with extremely sophisticated air based heat pump systems from Japanese Manufacturers. While ecologically optimal concepts (with local production lines) are in the range on 20 cm, the short term solutions are within 25% of the optimal ones. In all current concepts sophisticated two layered glazing performs better than three layered glazing in central Japan, especially when combined with adaptive shading measures.

A general problem is that for calculating the running consumption a certain user behaviour has to be assumed. As there are only experience values with the Japanese user behaviour in very low insulated houses without wind tightness, these assumptions are more or less good guesses based on experience values in other cultures and climate. Derivations from the assumptions made of course change the results of the calculations.

When comparing the optimal concepts for different indicators the difference is surprisingly small. In contrast to calculations for Switzerland and Germany, where economical indicators tend strongly to low initial investments and higher running consumption while ecological indicators show an opposite demand, Japan shows a much smaller difference. The reason for this is to be seen in the nearly not existent interest from sides of the banks for funding building projects especially for building companies and private customers. The constant demand of sustainable technology in Europe to compete with the possible earning by putting the money at the local bank, respectively the money consumed by paying off the interest from a credit taken does nearly not exist in Japan. This should lead to very ecological solutions and concepts; however this is not the case. The roots for this situation are however to be seen in social conditions, for the possible application of the method the situation is a strong point.

### 3.2.2 First field experience values

Besides the scientific feasibility of the approach and the creation of acceptance on the Japanese part, the method has been found to be absolutely no selling point. This is even though the proposed
concepts beat the established concepts by factors in the associated life cycle costs. Japanese customers tend to view their home as a consumption product. The initial investment is all they look at. The main selling points were proven to be in the field of health (as the concepts can be proven to be free of mould due to dynamic modelling) and comfort (as a well designed and insulated/ wind tight house offers comfortable inner climate).

As a surprise during the building process of the first buildings for licensing the single materials to be employed came the complete lack of communication and understanding between the craftsmen responsible for different tasks of the building processes. As a result the interchange between the employed building technologies is not looked at or even realized. The culture practically forbids talking a professional into his business unless specifically asked. As the respective professional does not know what questions to ask some irrational solutions are never solved. One of the key reasons for this situation is the near complete lack of building physics in the Japanese building industry. Most damages arise in situations where a building physician would be the responsible expert. Due to him being not existent the problem persists. Examples for this are condensation phenomenon and aspects of wind and air tightness that would lead to a demand for modified detail solutions.

The interchange between performance and detail solutions generally is on a low level. That a concept demands a resourceful planning and realization is only applied to earthquake safety where highest standards are met. Where energy savings and emission reduction comes from is not realized. The general quality on Japanese building sites and the exactness of their building processes is on an extremely high level though. Even solutions that were thought to be difficult to apply on site due to building site conditions where easily realized with overwhelming exactness. What is lacking is the realization of what factors are important and why they are.

The above mentioned focus on concepts that only use 10 to 14 cm of insulation is often an advantage when talking to Japanese customers. As the established homes often have no or only 4 cm of insulation, convincing them of using 20 cm is difficult. 10 to 14 cm is for them the limit of rationality.

A great advantage is the focus on building materials that can in middle terms be produced using local regenerative resources. As there is need to utilize a large amount of small sized woods which come from forest improvement and are regarded as not strong enough for applying as structural elements of buildings, any use for this resource is appreciated. The Japanese building industry, currently suffering from the economical crisis, is also much more attracted to concepts that provide long chains of value generation and employment within Japan.

### 4. Outlook

Besides the outstanding evaluation of the first test buildings, allowing for a sharpening of the assumptions made especially on the user behaviour, two points are to be optimized in the next years:

- Although the approach is promising, the calculation process is hazardous at the moment. Contrary to the smooth graphs shown under method, the process currently consist of
calculating several concepts (some focussing more on active and others focussing of passive means). Afterward the fine-tuning is done by changing insulation values and other building physical characteristics. A software based tool that would allow to easily model the effect of changes and different scenarios is under development.

- Even when first evaluation of the test buildings provide a clearer picture of the Japanese user behaviour and is changes in better buildings the findings will hardly be representative. The first customers under related circumstances in other countries are mainly people with a high awareness for ecological issues and are not main stream customers (Steemers and Manchanda 2010). In the next years when the cooperating Japanese companies will start diffusing the market, broader studies on the user behaviour will be mandatory.

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