Study of Chiang Mai Health Care Center

SUGGESTED MEASURES FOR ENERGY EFFICIENCY IMPROVEMENT / SIMULATION RESULTS

Final Report for Chiang Mai Municipality, Building Department,

January 2017

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EXECUTIVE SUMMARY

Chiang Mai, Thailand, is one of the Nexus partner cities within the “Integrated Resource Management in Asian Cities: The Urban Nexus” Project, financed by the German Federal Ministry of Economic Cooperation and Development (BMZ) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The Chiang Mai Municipality has requested technical assistance from GIZ Urban Nexus Project to conduct an energy efficiency study on the new building design for the Chiang Mai Health Care Center (CMHCC) in the Nong-Hoi district of Chiang Mai.

The objective of this study is the examination of the existing design to improve its anticipated energy performance by identifying possible application of feasible measures with reduced energy related Life Cycle Cost and viable payback periods. An inquiry and analysis of the existing building design in terms of function, building operation, selection of construction materials and building system based on provided planning documents and meetings with project owners and building operators was conducted. Based on the provided information, a suggestion of probable energy efficiency measures was made and a simulation of the current design’s baseline performance realized. Moreover, a selection of suggested energy efficiency measures was then simulated to determine their predicted energy savings.

In combination with the estimation of necessary capital costs for implementation, and the projection of anticipated life-cycle periods and calculated payback periods are identified for comparing their specific economic viability.

Results indicate that effective energy savings with acceptable payback periods can be achieved when investing in LED lighting, Roof insulation and AC systems with inverter technology as energy efficiency measures. Other suggested measures, such as the installation of photovoltaic panels, suggest being uneconomical due to high investment costs, long payback periods or limited energy savings capacity.

INTRODUCTION

The “Integrated Resource Management in Asian Cities: The Urban Nexus” implemented by GIZ is consulting a new building project for a Health Care Center in Chiang Mai (CMHCC), Thailand. The project owner is the Chiang Mai municipality, with its building department as design and planning team of the project. At the beginning of the consultation in October 2016, the project was in the final phase of design with the drawing set for building approval almost complete. Unexpected Co., Ltd. was asked to assess and propose possible energy efficiency measures in coordination and inclusion of respective building performance simulations of an energy engineering office (EGS plan Bangkok).

The execution of the study foresees the project analysis of existing building design, combined with a project inquiry of the project owners, and building operators. An energy performance simulation of the existing building design is carried out, followed by a suggestion of probable energy saving measures that are presented to the project stakeholders. Agreed measures are selected and a performance simulation carried by the energy engineer. The performance simulation includes the building simulation for energy consumption, and calculation of yield of a suggested PV system, followed by a profitability analysis in regards to investment costs, annual energy savings, payback time and energy related life cycle costs.

The finally the presented results will be commented including a recommendation for project implementation of well performing energy saving measures.

CONTEXT

The Chiang Mai Health Care Centre, or CMHCC, is situated in the Ban Nong-Hoi District in Chiang Mai, located alongside Kan Kaha Road between Soi 19 and 21. The following map in figure 1 illustrate the geographic location.
The location can be found with the google map application under the geographic coordinates of 18°45'47.2"North / 99°00'40.9"East.

![Google Map Image](image-url)

*Figure 1: Geographic location (see star) of building site*

The property of the building site is currently unbuilt and used by the surrounding neighbors as a parking space. All buildings in the close vicinity are not more than one or two floor levels and do not cast shadows on to the site during the day.

The current design, provided by the Building Department of the Chiang Mai municipality, foresees about 2670 sqm of total usable floor area that are distributed over three floor levels.

The ground floor level constitutes of an entrance lobby, a water therapy area, and an outdoor parking area that is covered by upper floor areas. The second-floor areas contain a corridor area, a multipurpose area that functions as canteen and event area, a nursing ward, separated into a female and a male section and combined via a nursing and doctor station. The third-floor level contains an herbal and massage healthcare center, comprising several massage and treatment rooms, changing rooms and bathrooms and sauna. All floor levels are separately accessible via elevators, a main stair connected to the lobby and an escape stair connected to the corridor areas.

The CMHCC is to be operated during weekdays from 8.30 am – 6 pm. Throughout the CMHCC, a maximum occupation of 110 people is anticipated. Yet, with the building being operated exclusively during the day, about 1600 sqm of the buildings 2600 sqm total floor area are to be air-conditioned and the remaining 1000 sqm are non-air-conditioned. The definition of thermal zones of the building, identifying areas where air conditioning is foreseen or not foreseen, is described in the boundary conditions for the energy simulation chapter of this report.

**EXAMINEND OPTIONS FOR ENERGY EFFICIENCY IMPROVEMENT**

**PROJECT INQUIRY**

Before the undertaking of suggesting architectural and engineering measures for improving the buildings energy performance, a meeting between the building department of Chiang Mai municipality, GIZ and Unexpected was realized to deliberate the existing building design its inherent thinking processes involved. The project inquiry with members of the Chiang Mai building department led to the understanding that changes to the existing building design are likely not possible or wanted, mainly due to the advanced stage of the design, but also due
to the large amount of constraints originating from various stakeholders. Earlier made design decisions such as building orientation or the arrangement of rooms and spaces must thus be considered given, leaving possible measures for energy efficiency improvement mostly to planning issues such as material selection, shading and insulation, or the improvement of technical equipment for lighting and building climatization.

**SUGGESTED MEASURES**

Accordingly, several measures for improving the buildings energy performance have been suggested and discussed prior to their selection for further energy performance simulation. Referring to their energy saving effect on the building, the suggested measures are divided in active measures that involve technical equipment, and passive measures that involve material and design improvement. Thus, the active and passive measures define as follows:

**Active Measures**
- Installation of PV system
- HVAC split type evaporator with inverter technology
- LED lighting
- Lighting control system

**Passive Measures**
- Exterior shading for east façade openings
- Improvement of façade openings
- Reflective coating of roof surfaces
- Insulation of ceiling below roof surfaces
- Insulation of exterior walls
- Operating cooling temperature adjustment

The suggested measures were scrutinized per their expected impact, effort of implementation, as well as expected capital cost. Altogether, seven of the suggested measures were selected as measures to be simulated for further evaluation.

Then non-selected measures (as highlighted via cursive writing) disqualified for the following reasons:

**Lighting Control system**

A sensor base lighting control system can detect the presence of occupants in a defined area and thus control on / off conditions of the foreseen lighting. In public building zones, such as corridors, stairways or restrooms can reduce their electricity demand up to 70%. Still, an estimate on capital cost and electricity cost savings did not result positively, mostly due to the high number of sensors needed and the low-cost savings results due to low electricity costs.

**Reflective Coating**

Per comments made by the CM Building Department after suggestion, a reflective roof coating is already foreseen.

**Insulation of exterior walls**

The insulation of exterior walls was neglected due to the high amount of wall areas and the estimation of additional capital costs needed.

**SELECTED MEASURES**

The selected measures that qualified for simulation describe as follows:
OPTION 1 LED LIGHTING

In the current design, more than 98% of the foreseen lamps are fluorescent. As shown in figure 2, their replacement into LED lighting fixtures will help reducing the electricity demand.

For the current design lighting power density (LPD) is calculated as $\text{LPD} = 5.35 \, \text{W/m}^2_{\text{GFA}}$.

With the recommended replacement of fluorescent lamps the reduced LPP is calculated as $\text{LPD} = 3.08 \, \text{W/m}^2_{\text{GFA}}$.

![Designed lighting](image1.png)  ![Recommended lighting](image2.png)

*Figure 2: Option 1 suggesting LED lighting*

OPTION 2 GLAZING

The improvement of window glazing is considering two options; both of them focusing on the glazing only (no frame or air tightness improvement). The window properties of the window glazing in the current building design have a solar heat gain coefficient (SHGC) of 0.81, and a U-Value of 5.7 W/m²K.

Option 2.1 foresees the use of green tinted glazing, with an improved SHGC = 0.59, and a remaining U-value of $U = 5.7 \, \text{W/m}^2\text{K}$

Option 2.2 foresees a double pane Low-E Glazing with an improved SHGC = 0.34, and a U-value of $U = 2.5 \, \text{W/m}^2\text{K}$.

OPTION 3 INSULATION

Since most sunlight exposure is onto the building’s roof surfaces, insulation of ceiling areas below the roof are supportive in reducing the heat transfer in these areas. The estimate based on material (SCG Stay cool) and labor for installation is estimated as 230 THB/m². The designated roof areas to have insulation installed underneath are indicated in figure 3.
The current design of the roof indicates a total thermal resistance \( R = 0.44 \, \text{m}^2\text{k/W} \), or a \( U \)-value of \( U = 2.28 \, \text{W/m}^2\text{k} \).

The improvement using the glass wool insulation designates a total thermal resistance \( R = 2.40 \, \text{m}^2\text{k/W} \), or a \( U \)-value of \( U = 0.41 \, \text{W/m}^2\text{k} \).

**OPTION 4 SHADING AND OPENINGS**

For the North, South and East orientation of the building, shading structures are already foreseen, modifications are suggested to improve the visual comfort and are not expected to improve the buildings energy saving performance. However, shading elements on the east façade can further reduces the impact of solar radiation onto the building envelope and its openings. The estimation is based on covering openings of the façade only.

Additionally, the openings on the east façade have been modified to improve visual comfort in the wards.

The visualizations in figures 3 and 4 indicate the changes made to the building facades. Modified openings and shadings are shown in red.
OPTION 5 AC SYSTEM

As commented by the design team of the Chiang Mai municipality that the currently foreseen use of a single split type AC units should remain, the suggestion on using multi type VRV systems have been neglected. Instead, the suggestion of improving the current AC system is based on the upgrading of its evaporator units with inverter technology. The estimation is based on price difference between currently foreseen ‘non-inverter’ unit types and comparable types with inverters.
The mentioned inverter type evaporators reduce temperature fluctuations of the AC’s set point temperature, as illustrated in figure 6.

![Inverter Type Evaporators](image)

*Figure 6: Option 5 suggesting AC units with inverter technology*

**OPTION 6 PHOTOVOLTAIC SYSTEM**

Option 6 suggests the installation of a Photovoltaic (PV) System of 16 kWp onto unutilized roof top areas. With feed in of generated electricity into the public grid currently and the use of electricity storage devices not foreseen, the PV system aims for direct electricity usage during daytime only. Current payback periods for PV systems in Thailand are estimated to be around 10 years due to low electricity costs. Due the condition that the generated electricity can only be utilized during the week the payback time further increases above 14 years. Figure 7 illustrates location and extent of the PV system installation on the roof top.

![Photovoltaic System](image)

*Figure 7: Option 6 suggesting Photovoltaic System*

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**Important remark:**
- Currently no feed in available
- Maximum estimated electric power demand of building: 85 kW
- Maximum estimated power output of PV: 16 kWp
  - On week days PV energy can be consumed onsite
  - But not during weekend → increased payback time!
OPTION 7 OPERATIVE TEMPERATURE

With building functions having such as the nursery station, the massage rooms, and waiting areas foreseeing limited human activity, (elderly resting in beds) the currently set operative temperatures can be higher to respond per these non-active zones. As shown in figure 8 the operative temperature has been raised to 26 degree Celsius.

![Figure 8: Option 7 suggestion increased operative temperatures](image)

BOUNDARY CONDITIONS FOR ENERGY SIMULATION

To comprehend the anticipated energy demand for the CMHCC, a baseline simulation was realized. Accordingly, the existing design provided by the Chiang Mai Building department was used for simulating the buildings overall energy demand based on cooling demand, artificial lighting and use of general appliances foreseen for the building.

Considering the baseline simulation of the building, boundary conditions were defined as follows

CLIMATE / BUILDING ENVELOPE

In respect to the building’s location, an hourly weather data for Chiang Mai was used. For the building envelope of the existing design, the necessary boundary conditions were defined as:

- External Wall: Traditional concrete block (no insulation): 100 mm (U= 2.85 W/m²K)
- Roof: Traditional concrete slab (no insulation) 100 mm (U= 4.3 W/m²K)
- Window: Single glazing 6 mm (U= 5.91 W/m²K, SHGC = 0.8)
- Infiltration (air-leakage): 0.7 h-1
- Gross floor area: 2,670 m²GFA

THERMAL ZONES

For the cooling demand, one non-air-conditioned and three types of air conditioned zones (Zone A, B, and C) were defined, such as:

- Zone A: Active room (e.g. meeting room, therapy room, reception)
- Zone B: Non-Active room (e.g. nursing room)
- Zone C: Corridors

The definition of the thermal zones of floor levels 1, 2 and 3 are shown in the following figures 9-11.
Figure 9: Thermal Zones, 1st Floor

AC Zone A:
- Operative Temperature: 25°C
- Number of people: 25

Figure 10: Thermal Zones, 2nd Floor

AC Zone B:
- Operative Temperature: 25°C
- Number of people: 40

AC Zone C:
- Operative Temperature: 25°C
USE PATTERN OF THE BUILDING

Further, to simulate building use during operation, the following assumptions were made:

- Number of occupants: 110 persons per day (see slide no. 6,7,8 for details)
- Density: 0.041 persons/m²GFA
- Building operation hours: 8.30-18.00
- Lighting (5.35 W/m²GFA) in all areas is switched on from 8.30-18.00

EQUIPMENT

The in the planning foreseen electrical equipment was identified as follows:

- TV & Devices: On 8.30-18.00: 3 W/m²GFA
- Refrigerator (10 W): always on
- WLAN (5.3 W): always on: (10x10) + (5.3x10)/2670 m² = 0.057 W/m²GFA

COOLING

- AC split type (follow Technical Drawing E03)
- COP: 3.2 (EER: 11)
- Set Operative Temperature: 25°C

ECONOMIC BOUNDARY FOR LIFE CYCLE CALCULATION (LCC)

Regarding financial aspects of the design the following assumptions were made:

- **Energy Price**: 4.5 THB/kWh
- **Interest Rate**: 5 %

LIFE TIME OF EQUIPMENT FOR LCC ANALYSIS

Based on the Association of German Engineers Standard (VDI 2067), the life time of electric equipment used is defined as:
### SIMULATION RESULTS

**PRE-SIMULATION AND COMPARISON OF OPTIONS**

With the boundary conditions for the energy simulation defined, a pre-simulation was realized to retrieve the baseline results of the exiting design concept. The following figure shows the building’s monthly energy demand, indicating peak demand in the month of May, and the lowest demand during December.

![Figure 12: Baseline simulation results of energy demand per month](image)

**FLOOR AREA RELATED ENERGY DEMAND**

In addition to the baseline simulation, a simulation considering the implementation of the selected measures was realized. The simulated results for the building’s energy intensity (in KWH/m² GFA) were separated into energy demands for cooling, lighting, and foreseen electrical equipment. Moreover, the suggested energy saving options were simulated with their individual energy savings recorded.

As shown under figure 13, the respective energy saving options simulated energy consumptions for cooling, lighting and equipment are assembled next to the baseline results on the far-left column.
The achieved simulation results can be grouped into ‘considerable savings’ with results above 5%, and ‘inconsiderable savings’ with results below 5%. Considerable savings can be achieved by:

- Option 1 LED Lighting with 13.5%,
- Option 3 Roof Insulation 17.3%,
- Option 5 AC System 20.8 %,
- Option 6 PV System with 12.8%, and
- Option 7 Operation settings with 3.5%

Inconsiderable savings can be listed as:

- Option 2 with 0.9 – 3.1 % of simulated savings
- Option 4 with negative energy savings, however, as discussed later the redesign of openings and shadings should be considered when concerning the visual comfort of the building’s occupants.

Since the improvement of glazing did not yield any significant energy saving, its further consideration seems not necessary. Especially, since the measures for improving the glazing is known to be investment intensive. It should be noted that a reason for the small improvement is likely to be the already provided shading design along the South, West and North façades, which protects the openings from direct solar insolation. In this regard, an additional shading of the openings on the East façade should be considered.

When compared to the baseline design, the negative saving effect under Option 4 occurred primarily due to the increased size of the openings along the East façade. Here the wider openings lead to higher energy demand, even though additional shading protections were provided for.

To further understand the effect of saving floor related energy demand, the considerable options have been aligned with the baseline result in figure 14, along with an assembly of three combinatory options (‘Combi’ 1-3). Combination 1 combines the option of LED Lighting and Roof insulation, combination 2 adds the option of using AC inverter technology, and combination 3 adds the photovoltaic system option.
The results show that significant energy savings between 31.1 – 57.6 % are possible when combining considerable options. Here most of the savings are achieved by reducing the buildings cooling and lighting demand. Savings considering the usage of electrical equipment only appear indirectly through the utilization of renewable energy that is generated by the PV system.

**ADDITIONAL INVESTMENT COSTS & ANNUAL ENERGY COST SAVINGS**

To understand the cost saving effects of the suggested energy saving measures, individual investment costs have been estimated. In the following, the investment cost of considerable measures and their combinations are documented in figure 15.
Here, considering the estimated investment costs, especially option 1 (LED lighting), and option 2 (Roof Insulation) appear low and thus attractive for implementation. In numbers, options 1 and 2 necessitate additional investments of 100,000 THB and 225,000 THB, respectively. Contrarily, AC units with inverter technology, or the PV system implementation appear to require significantly higher investment costs with around 1 Million THB each. To remain attractive as an investment for improving the buildings energy efficiency, achieved cost savings of option 5 and 6 need to be high to cover the covered capital costs quickly. As shown in figure 16, this may be the case for the AC units with inverter technology, but less for the PV system.

![Figure 16: Annual energy cost savings](image)

Annual energy cost savings indicate that PV, even though a 1 MTHB investment cost, savings are lower than LED lighting, roof insulation or the inverter technology utilization for the split type AC units. The largest saving amount of a single option is achieved when using inverter technology. Combined options are likely to increase with the amount of combined options having the highest savings when combining LED lighting, roof insulation, inverter technology and PV technology under option 3.

**PAYBACK PERIOD**

The calculated payback period shows the anticipated breakeven points of the energy savings with the investment cost of the suggested measures. In general, it can be said that short payback periods below 5 years may be considerate measures for implementation as there is less risk involved. Contrariwise, medium, or long payback periods may not be considered economically viable, as costs for maintenance, repair or short life-time expectancy of technical equipment can easily conflict such. Figure 17 shows the results of the calculated payback periods.

The calculated results indicate that the payback period for LED lighting and roof insulation are very short, thus suggesting their implementation into the design as an energy saving measure. This can also be said for the utilization of AC units using inverter technology as their estimated payback time seems feasible, indicating that cost savings can be still be achieved for more than half of their normal lifetime.

Considering the possible use of a photovoltaic system, the expected payback time of 14.5 years appears too long as they require three quarter of the PV systems lifetime. It should be noted that the long-time span is also influenced by the need for direct use and the inability to utilize generated electricity during the weekend as the building is not operated on Saturdays and Sundays. In case that building operation would be maintained for seven days in a week, the payback period is reduced to an approximate period of 10.5 years.
COMPARISON OF LIFE CYCLE COSTS

The comparison of Life Cycle Costs (LCC) enables to incorporate costs and benefits that occur over the entire life cycle of a building into procurement decisions - rather than considering the initial capital cost only. To compare the effect of short term initial cost with long term operation cost is considered helpful to reduce the effect of costs occurring during a suggested lifetime of 50 years. The most cost effective solution is seen in achieving minimal life cycle costs. In Figure 18, the LCC of energy costs illustrated by adding up energy cost of suggested energy saving measures with the additional capital for their implementation, and comparing them to the baseline result.

![Figure 18: Life Cycle Costs (LCC)](image_url)
Accordingly, it can be said that LED lighting, roof insulation, and the implementation of inverter technology for the AC units help reducing the buildings energy related LCC, whereas PV system utilization are expected to not reach breakeven with the baseline design concept.

Considering the combination of options, combination option 1 indicates the best result with lowest energy LCC yield of 446,121 THB/a, followed by option 2 with 496,589 THB/a. Option 3, with 517,606 THB/a is already higher than the roof insulation option alone, making the increased effort become unnecessary.

SUMMARY AND RECOMMENDATION

SIMULATION RESULTS SUMMARY

EXAMINED OPTIONS

- **OPTION 1**: The suggested replacement of fluorescent lamps with LED lamps lead to additional investment costs of less than 200,000 THB and significantly reduce the energy demand for lighting. The estimated payback period below 2 years justifies implementation as an energy saving measure.

- **OPTION 2**: The simulated results for improving the existing windows with tinted glazing, or alternatively, double glazing with low-e coating, do not lead to significant energy saving due already efficient shadings in front of the façade. Yet, to prevent insufficient daylight utilization for interior spaces, the shadings should be revised in terms of using horizontal light shelves in south orientation and vertical wall extensions surrounding the windows on the east and west façade. A suggestion on the shading design can be found in the suggested façade design displayed in figure x and x.

- **OPTION 3**: The thermal insulation in areas under the roof indicate low investment cost below 200,000 THB and significantly reduction of the energy demand of the building. The estimated payback period below 2 years justifies implementation as an energy saving measure.

  While the increased number of openings with more efficient shading lead to a slightly higher energy demand, the revision of openings towards the east orientation improve daylight utilization of the wards, and allow for remaining visual contact to the exterior.

- **OPTION 5**: The use of Inverter type split units suggests significant energy savings with a payback time of less than 6 years. Despite their investment costs of about 1,000,000 THB, their utilization may be considered as their payback period 5,7 years may still be acceptable.

- **OPTION 6**: The use a PV system leads to additional investment costs of about 1,000,000 THB and a payback time of 14.5 (PV) years. Considering the high investment and the long payback due to short operation time limitations and low electricity costs the use of a PV system seems needless.

COMBINATION OF ENERGY MEASURES

- **COMBINATION 1**: (LED + roof insulation) is the most economically effective combination option and reduces the energy demand around 30% compared to the baseline

- **COMBINATION 2**: (LED + roof insulation + inverter) reduces the energy demand by up to 40%

- **COMBINATION 3** (LED + roof insulation + inverter + solar PV) leads to the highest additional investment costs, however reduces the energy demand by up to 58% compared to the baseline

COOLING LOAD CALCULATION

With the provided specifications for the air-conditioning system’s split units having unnecessary high load requirements of 200 W/m2, a revised cooling load calculation will reduce investment costs for air-conditioning system. A proper cooling load calculation and the reduction of the air conditioning unit size will not only improve their energy efficiency, but reduce investment and energy costs of the project further.
RECOMMENDATION

It can be said that combination options 1 and 2 of the suggested energy measures qualify for implementation. While combination option 1 (LED + roof insulation) is economically the most efficient option, combination option 2 (LED + roof insulation + inverter) leads to the highest energy savings without sacrificing economic aspects of the project. Considering the possible energy saving between 30 – 40%, implementation of either option 1 or 2 is highly recommended.

Further, while not the objective of this study, it was discussed in meetings between the Building Department of the Chiang Mai municipality, the GIZ Urban Nexus, and Unexpected, whether the visual comfort, especially of the nursery wards could be improved in terms of visual comfort and well-being. In the current design, especially in the ward areas the aspect of comfort and well-being for the elderly seems not sufficiently addressed. It can be improved by providing windows that allow for visual contact to the exterior and the integration of green zones, such as plants in the interior spaces as well as exterior balconies.

February 9, 2017

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