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Sustainable energy in cities: methodology and results of a summer course providing smart solutions for a new district in Shanghai

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Abstract

A systemic approach for integrated urban energy planning and design can increase energy efficiency, the use of renewable energy sources and bioclimatic strategies to lower the energy footprint at building, district and city scale. Such approach requires experts that are not just proficient in their distinct energy-related disciplines, but, above all, that are trained in interdisciplinary project cooperation. This approach was adopted in the summer course entitled *Sustainable energy in cities*. Held in Shanghai, China in July 2015, it provided international and interdisciplinary training as a learning environment for students and staff. It consisted of plenary presentations from researchers, local urban decision-makers and industry, discussions, and student group work with the final goal to develop smart sustainable strategies for a new residential district in Shanghai.

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Keywords: Smart city; Sustainable energy; China.

1. Introduction

China has pledged to reduce its carbon dioxide (CO_2) emissions per unit of gross domestic product by 40 - 45% compared to the 2005 level by 2020, as a part of the Copenhagen Accord of 2009 [1]. During the last Conference of Parties summit (COP 21) in 2015, China participated in the joint effort to launch Mission Innovation "to reinvigorate and accelerate public and private global clean energy innovation with the objective to make clean

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energy widely affordable" [2]. To achieve the reduction of energy wastage and greenhouse gas emissions, many policies and national standards have been put in place in the last decade by the Chinese Government with the aim to impel residential buildings to waste less energy with the target of 50% reduction compared to the 1980s [3]. In a review of the 11th five-year plan, Kong, Lu and Wu [4] showed the slowness of China in developing building energy codes on a regular basis. In fact, despite the optimistic previsions within the five-year, the period between the code revisions still remains too long to do not permit a consistent and rapid development in the field of building energy saving policies. Negative cascading effects in urban energy systems are arising with higher intensity. Energy usage by industry, urban infrastructure, buildings, and private citizens affect each other with severe consequences for human comfort and health. In Summer 2013, Shanghai was experiencing the warmest weather conditions in the previous 140 years: 25 days with air temperatures higher than 35 °C. At least 10 people dead as a direct consequence of high temperatures [5]. In order to prevent additional deaths and provide sufficient power for cooling and ventilation, industry in Shanghai was ordered to temporarily reduce its energy usage. A systemic approach to integrate urban energy planning helps to mitigate this cascading effect through better energy efficiency, more use of renewable energy sources and bioclimatic design strategies to lower energy demand. With a high construction rate of new residential areas in China, it is vital that new construction features robust, low carbon, energy-efficient solutions to prevent lock-in of high energy usage and air pollution. Chinese Premier Li Keqiang has recently "declared war" on pollution, describing it as a "blight" on people's quality of life [6]. At 277.6 Mtoe[†], residential energy consumption comprised 11% of the total energy consumption in China in 2012 [7]. In 2012, the annual per capita energy consumption of households was 205.7 toe/a. It nearly tripled since 1983 (74.6 toe/a), and nearly doubled since 2003 (107.4 toe/a) [7]. This is mainly due to the large amount of built area, and a dramatic increase in household appliances and air conditioning [8]. To promote more efficient use of energy the Chinese government embedded the concepts of Circular Economy in the 12th five-year plan. Circular Economy is also known as the 3R-principle, including reduction, reuse, and recycling of materials, energy and other resources [9]. Experiences show that public participation, awareness and information are vital to achieve the circular economy principles [9,10]. Such a systemic approach requires experts that are not just proficient in their distinct energy-related discipline, but, above all, that are trained in interdisciplinary project cooperation. The Summer Course on Sustainable Energy in Cities (SEniC) 2015 aimed to provide this type of training, by creating an international, interdisciplinary learning environment for students and staff.

2. Methodology

The summer course SEniC 2015 was jointly developed and organized by the Norwegian University of Science and Technology (NTNU) and Shanghai Jiao Tong University (SJTU) staff, and implemented in Shanghai in July 2015. Sixty-seven students from Europe and China (20 from Europe, 27 from SJTU, and 20 from other Chinese universities) with different academic backgrounds participated in the summer course SEniC 2015 [11]. During two weeks (July 6-17, 2015), students exchanged ideas and shared methods and experiences across cultures and disciplines in order to develop smart and energy-efficient strategies for the new residential neighborhood *Zhoukanghang (周康航)* in Shanghai. In collaboration with local Chinese industries and municipal partners, students and staff exchanged Asian and Nordic knowledge and expertise on topic such as the potential role of buildings, solar energy, refrigeration, and energy systems and services in obtaining energy-efficient cities with high quality of life and smart solutions for sustainable cities. The pedagogical methodology used in the summer course SEniC 2015 was structured in three distinct elements:

- *Experts in teams*: interdisciplinary training of students and staff;
- *Triple helix*: local industry and municipality officials suggested specific challenges for the students to address and solve in cooperation with researchers from NTNU and SJTU;

[†] Mtoe = Million tonnes of oil equivalent. Chinese data are recorded in tonnes of Coal Equivalent. According to the International Energy Agency, 1 tonne of Standard Coal Equivalent corresponds to 0.7 tonnes of Oil Equivalent.

- *Out of the lab, into the city*: summer course SEniC 2015 used the city of Shanghai as an Urban Lab for gathering empirical evidence and developing solutions for complex urban environment.

2.1. Experts in team: the groups and the topics

The experts in teams set-up forges close international collaborative relationships between students and staff of NTNU and SJTU: summer course SEniC 2015 had six interdisciplinary groups composed by international students working on the topics summarized in Table 1.

Table 1: Summary of the groups and topics treated in the summer course SEniC 2015.

Group	Students	Supervisor and tutors	Topics
A	10	Prof. Annemie Wyckmans and Dr. Wang Yu	• Key performance indicators for smart sustainable cities and communities
B	8	Prof. Dai Yanjun	• Building integrated solar energy technologies
C	15	Prof. Luca Finocchiaro and Dr. Gabriele Lobaccaro	• Bioclimatic design and increase of the solar potential of urban districts • Building integrated solar energy technologies
D	17	Prof. Salvatore Carlucci	• Mathematical optimization of the building design • Estimation of the energy impact of occupants' behaviour
E	8	Prof. Trygve Magne Eikevik	• Energy implications due to the use of phase change material (PCM)
F	9	Prof. Yong Li	• Solar-ground coupled heat pump system: a hybrid solution to heating and cooling

The students worked on a joint project of *Zhoukanghang* residential area in Shanghai. They were from 12 universities (8 from China and 4 from Europe) with multiple disciplinary majors: architecture, building engineering, environmental engineering, energy engineering, mechanical engineering, refrigeration and cryogenics engineering, thermal dynamics and solar energy. During the first day, the students discussed and defined the main challenges faced by the residential area. Then, they combined their expertise to address, develop and execute a corresponding project that they presented to the researchers, local industries and municipality officials. This type of setting forced the students as well as their guiding supervisors and tutors to get to know and build on each other strengths and weaknesses, and agree on a common definition of challenges, implementation and outcomes.

2.2. Triple helix: involvement of stakeholders of local industry and municipality officials

During the preparation phase of the summer course SEniC 2015, a working group of NTNU and SJTU staff cooperated with stakeholders such as local industry and municipal officials (*triple helix*) to select a real use case in Shanghai, and decided upon the *Zhoukanghang* residential area. They gathered the necessary data for the students to be able to develop their projects, such as climate data, local building and energy codes, architectural plans and sections, and a set of tutorials to teach the basics of the simulation and modelling tools (i.e. *DesignBuilder*, *DIVA for Rhino*, *Climate Consultant* etc.). The students were educated in order to use the tools for developing their analyses. Supervisors and tutors from both NTNU and SJTU, also were corresponding activities, site and study visits to local industries such as *Yanhua Smartech* [12] and the *Trina Solar Shanghai R&D* [13] headquarters, and pilot projects such as the *Rishang Jiangcun* ("River Village over the Sun") [14], the SJTU competition house for Solar Decathlon China 2013 [15], the *SJTU Green Energy Lab* [16] and the *Shanghai Research Institute of Building Science* [17]. Representatives of local Chinese industries and Norwegian companies based in China actively interacted with students by exchanging ideas, strategies and methodologies for the project. Hence, the summer course SEniC 2015 was getting involvement of local problem owners in the students' project work. Finally, experts from Norwegian industry in Shanghai (*JOTUN*, *Kongsberg*, and *DNV-GL)* were invited for the final presentation of the projects. In this way, students got direct feedback from the local industry and stakeholders.

2.3. Out of the lab, into the city: the case study of Zhoukanghang

Moving the project work "*out of the lab, into the city*", gave the students and staff a more intensive experience of mobility and engagement with local challenges by interacting with local stakeholders. The students worked on a real case in Shanghai: the development residential area of *Zhoukanghang*. It is a residential area under construction that will be used to relocate a number of residents who used to live in the downtown of Shanghai. The project, initiated in 2013, is still under construction in the *Pudong* New District in a southeastern part of Shanghai. The *Zhoukanghang* resettlement residential project represents a typical Chinese housing development project constructed after the introduction of the Reform and Opening-up policy [18]. It includes nine high-rise multi-residential building blocks of 18 floors and a community center on 2.45 hectares of land. The total construction area consists of around 60 000 m^2 and will host 918 households.

3. Results

3.1. Role of Smart Low Carbon Districts in the Transformation towards a Green Society

Group A studied examples of smart cities characterized by similar location, population and climate as Shanghai.

Table 2: Summary of the selected fields, strategies, systems and smart solutions to be included in the *Zhoukanghang* residential area.

Field	Strategies	Systems	Solutions
Community	Smart community platform	Share, collect and monitor data	• Design a digital app and interactive visual point and monitoring stations • Social participation in collection of the data and monitoring of the life activities • Energy monitoring system (i.e. prediction of energy use and production, etc.) • Public affair service (i.e. education, financial service facilities, communication etc.) • Real property management service (i.e. daily management work; construct community culture, convenient service for residents, etc.) • Access to municipal information platform (i.e. local traffic safety information network, online registration and payments, weather forecast and prediction, etc.) • Community commercial information service (i.e. public and private information such as incident, forecasting alert, etc.)
	Smart medical service and pension system	Daily health service system and remote medical system	Monitoring tools and sensors for health electronic archives: • Patient: (i.e. heath conditions, notification of the exams and of the pills' to take; develop a medical scheme • Elderly: (i.e. Online monitoring of elderly activities and living conditions, track position information, remote exchange with friends, relatives and health counseling) • Emergency medical supplies
		Pension system	• Pension service system
Energy	Renewable energy	Solar Energy	• Solar Photovoltaic (PV) and Solar Thermal (ST) panels integrated in buildings • Smart grids; EV (Electric Vehicles) charge stations; Solar street lamp
		Reclaimed water system	• Clean water for domestic use • Collect life wastewater water, rain, etc.
	Improve energy efficiency	Small-temperature difference air conditioning	• Reduce the energy consumption of air source heat pumps • Increase the uniformity indoor temperature distribution
		LEDs lights	• Reduce power consumptions
		Garbage Disposal	• Garbage classification
	Energy management	Community energy management	• Monitor the community energy consumption through sensors and mobile devices
		Home energy management	• Smart meters, home automation systems, smart appliances
Mobility	Traffic redirecting and information	New transport systems	• Shuttle buses • New metro lines and more frequent train • Rent of public electric cars; Incentives for electric and hybrid cars' use • Bike and car sharing - Electric bicycles and scooters
		Smart mobility service network	• Real time traffic and parking information • Information and calculation of the shortest, cheapest and less carbon emitted ways

The literature review of the smart solutions provided by group A allowed selecting energy strategies, community and mobility services as well as security and wellness models to be replicated in the *Zhoukanghang* residential area. The proposed strategies are summarized in Table 2. Some of the pointed out strategies and solutions related to energy field were in parallel developed by the other teams of students: the results are described in the next sections.

3.2. Bioclimatic design strategies and integrated energy efficient systems for sustainable district of Zhoukanghang

Student groups B and C worked together on developing bioclimatic strategies for optimizing human comfort, while ensuring energy efficiency to be applied at both, district and building level. Shanghai climate aspects were studied at mesoscale and microscale to explore available natural resources and challenges related to climate adaptation of the site. In addition, the groups mapped existing climate and environmental hazards of Shanghai for their effects on human comfort. The city of Shanghai (latitude 31.20° N, longitude 121.50° E) is classified with the code *Cfa* in the climate classification of Köppen and Geiger [19] being in the hot-summer-and-cold-winter (HSCW) region. It is characterized by humid, subtropical climate zone with hot, moist, and rainy summers and overcast, cold winters. Analyses related to wind characterization, quality of the air, level of precipitation, solar radiation, the yearly profile of temperature and humidity have been carried out not only through literature review, but also through dedicated software for climate data analysis (*Weather tool* and *Climate Consultant*) using the .epw file of Shanghai made available by the US Department of Energy [20]. Simulations were run to study solar accessibility and solar availability in two scenarios: (i) *current design scenario* and (ii) *optimized design scenario* in which the orientation of all the designed buildings was changed to the optimal angle of exposure (148° clockwise from the North direction). The analyses were conducted to evaluate the impact of the overshadowing effect (i) on the designed buildings of the site and (ii) on the buildings in the nearby areas. The results demonstrated that, in the *current design scenario*, for the worst case (Building 1 in Fig. 1) the reduction of solar accessibility is up to 25% due to the presence of the other designed buildings in the site. The new layout developed in the *optimized design scenario* confirmed quantitatively (800 kWh/m^2 a) the level of solar accessibility of the designed buildings in the site area. While the solar accessibility of the neighborhood buildings has been improved in the best case by 18% for direct radiation and 13% for the global one. Finally, a study on the use of integrated solar energy technology in the building has been performed. The students individualized the most efficient existing products on the market for both photovoltaic (PV) and solar thermal (ST) panels, including façade-integrated solutions such as sun shading louvers system, thin solar film cell integrated in windows and in the railings by maximizing the solar radiation and avoiding the overshadowing effect among the modules. The solar systems were coupled with a direct expansion solar-assisted heat pump. The outcomes revealed that this strategy can reduce the energy use by up to 50% for gas water heater and auxiliary electric heating while up to 80% for electric water heating.

Fig. 1 (From the left) Rendering of the area, the view of the actual design and optimized design with PV and green façade of the building, solar mapping analysis with the indication of the height from the ground that resulted the most useful for PV installation.

3.3. Mathematical optimization of the building design and estimation of the energy impact of occupants' behavior

The students of group D investigated the influence of the occupant behavior on the energy performance of the multi-residential high-rise buildings of the site area in *Zhoukanghang*. The goals of this group were:

- To model and simulate a building's numerical model under typical conditions,
- To adopt a mathematical optimization technique to minimize its energy need for heating and cooling,
- To generate randomly from a probabilistic occupancy model sets of occupant's presence and occupant-dependent schedules, and implement them in energy simulation models,
- To statistically quantify the effects of the occupant behavior on the energy performance of building's model.

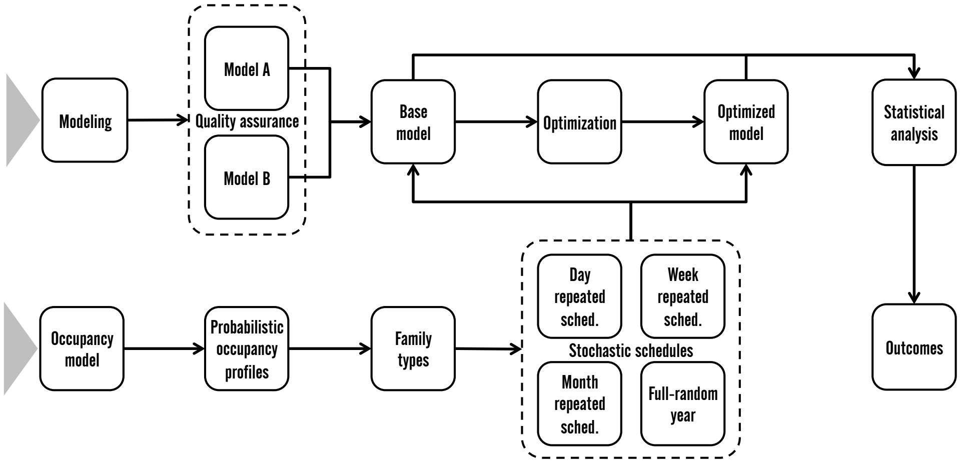

Fig. 2. Flowchart of the activities done by the students of group D.

The students were guided to analyze the building's energy performance under two design proposals: a *Base case* developed by the designers and an *Optimized case* carried out from an automatized optimization process [21,22]. A statistical analysis quantified the energy implications of adopting different degrees of temporal and spatial randomness when creating occupancy and occupancy-dependent schedules. The students were first divided into two groups that worked in parallel (i) to create the numerical model of the *Base case* that represents the current design scenario and to carry out the mathematical optimization of the *Base case*, obtaining the *Optimized case*, and (ii) to use the Yamaguchi and Shimoda's probabilistic occupancy model [23] to stochastically generate 200 sets of occupants' presence schedules and occupant-dependent schedules, i.e. schedules that model the use of electric lighting and household appliances. Specifically, the probabilistic model was used to create an activity scenarios, that provide the probability to run a given activity for each hour of a typical day, for four family-components (working person, non-working person, child, retired person). Then, 25 typical days were randomly extracted for each of the four family-components and were combined to created nine types of family compositions. So, the nine types of family compositions were translated in room occupancy schedules and, finally, applied to the numerical models of the building. The building's model was created in *DesignBuilder*, version 4.2.0.054; all simulations were executed in *EnergyPlus*, version 8.1.0.009; and finally the optimization was carried out in *GenOpt*, version 3.1.0. All students contributed to simulate both the *Base case* and the *Optimized case* using the stochastically generated sets of occupancy and occupant-dependent schedules. Afterwards, since the variables failed to pass the Shapiro-Wilk's test, several non-parametric techniques were adopted to statistically analyze to identify patterns and find general outcomes in the dataset that was created by collecting all the data exported from the simulations. Spearman's Rank Order Correlation was used to explore the strength of correlation among variables. The Wilcoxon Signed Rank test was used to statistically characterize the energy performance of the building in the two proposed design cases. The Mann-Whitney U test was used to assess the dependency of energy quantities on spatial randomness. Finally, the Kruskal-Wallis H test was used to investigate the dependency of energy quantities on temporal randomness. The flowchart represented in Fig. 2 shows the methodology that the students of group D followed. All the detailed information related to the adopted methodology, the modeling and optimization techniques implemented, the statistical methods used for elaborating the outcomes and their discussion have been widely reported in a previous work [24]. In brief, the most relevant findings were:

- The statistical analysis has shown that temporal and spatial randomness of occupancy and occupant-dependent schedules have a statistically significant influence on the building's energy performance: spatial randomness is estimated to be in the order of 5%, whereas uncertainty due to temporal randomness is in the order of 10%.
- At least in Shanghai, occupant behavior affects cooling more than heating, and its influence on the energy performance is stronger in high-performance buildings than in poorly insulated ones.
- The accurate modeling of high-performance buildings would require a detailed and precise description of occupancy and occupant-dependent input variables even if this increases the modeling effort and costs.
- For the studied case, the energy need for cooling can be reduced by about 26% while heating need can be reduced by about 78%, implementing an optimal combination of building elements and control strategies.
- Multi-objected optimization method is a usable method to identify reliable ways of reaching highly energy effective buildings such as nearly zero-energy building.

3.4. Smart energy use: Energy saving on PCM used in smart buildings

Groups E and F mainly worked on smart energy use at building scale. Group E studied and tested the use of phase change materials (PCM) in order to save energy in smart buildings during summer. Group F studied a Solar-ground coupled heat pump system that is described in Section 3.5. Group E used *Fluent* software to conduct numerical simulations in order to calculate the temperature distribution of the building envelope blending with PCM. The thickness of the wall was set about 18 mm and an interlayer of 10 mm of PCM was added. The height of the model was fixed up to 120 mm and the width of the model equal to 180 mm. The material used in the simulation model was the capric alcohol-decanoic acid (CA-DA) and concrete. The following assumptions subtend the mathematical model:

- Capric alcohol-decanoic acid (CA-DA) is used as the PCM and is assumed to have an isotropic behavior.
- CA-DA will become incompressible Newton fluid after melting; the density of the CA-DA is consistent with the Bounssinesq hypothesis.
- The flow of the CA-DA is consistent with Darcy's law.
- The flow caused by the difference between the density of the solid and the liquid is ignored.
- The change of the velocity and the surface tension caused by the phase change is ignored.
- The physical parameters of materials do not depend on the temperature.
- Heat convection is ignored after the PCM's melting.

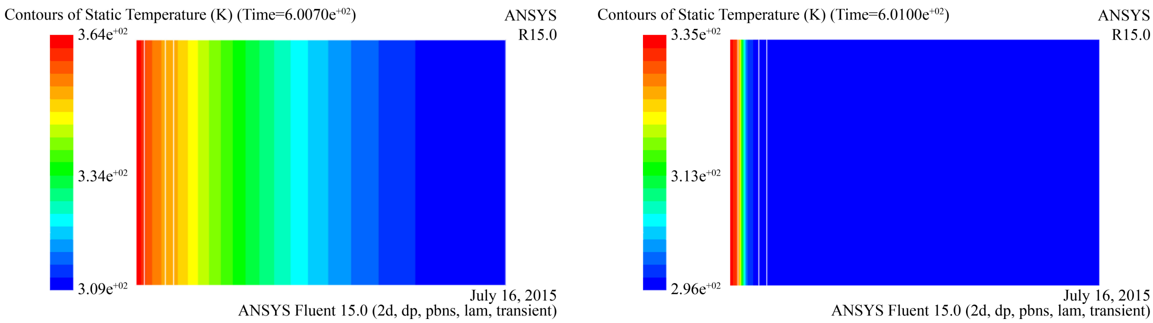

Fig. 3 Temperature distribution of the models at 600 s without PCM (on the left) and with PCM (one the right)

The comparison of the simulations' outcomes between the walls that incorporates or not the PCM shows that the heat is transferred faster inside the room when the PCM is not incorporated into the wall construction. On the contrary, with the presence of PCM, the indoor air temperature of the room is kept almost constant throughout the calculation period (Fig. 3). These results indicate that building wall with integrated PCM not only contribute to reduce the indoor air temperature fluctuation (Fig. 4) by improving the indoor thermal comfort, but can also reduce the energy need for air conditioning. The outcomes of the simulations have been briefly listed below.

- The internal surface of the wall that incorporates the PCM:
- It takes about 1900 s for the indoor temperature to be increased up to 3 ℃.
- The indoor air temperature would keep constant for a long time ($T_0 = 22$ ℃).
- The internal surface of the wall that does not incorporate the PCM:
- It only takes 200 s for the indoor temperature to increase 3 ℃.
- The indoor air temperature keeps constant for a while and then increases dramatically with the time pass by.

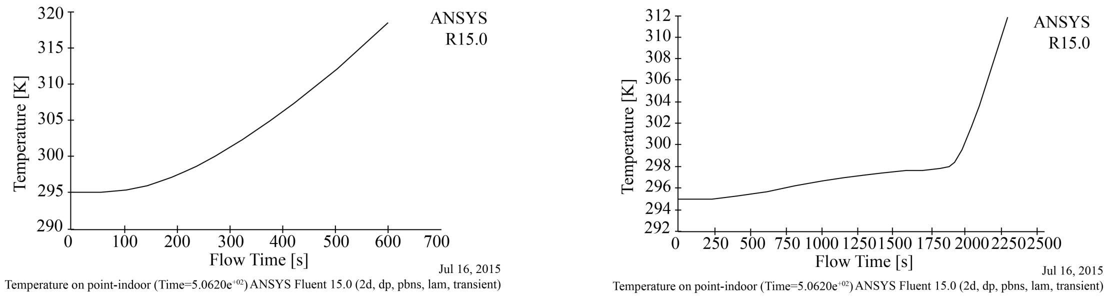

Fig. 4 Indoor temperature without PCM inside the wall (on the left) and with PCM (one the right)

Furthermore, the students built a physical model to test the performance of the PCM paraffin wax. A foam board of 4 mm thick made the physical model. The gap of 10 mm between the two foam boards was covered by glass insulation and PCM. The dimensions of physical model were 360 x 360 x 120 mm. Fig. 5 shows the layers of the foam board structure, the physical model and the monitored results. The physical model was left in an air-conditioned room before the experiment in order to guarantee the temperature consistency of the physical model and the room temperature. Then the physical model was heated in two conditions, with PCM and without PCM. The temperature was recorded every 10 s on the PCM plate and inside of the physical model. After the heating process, it was noted that the temperature change of cooling process every 10 seconds. The results of the conducted experiments demonstrated that the temperature increases very slowly inside the physical model compared to the condition without PCM. Furthermore, the temperature difference can be up to 17 ℃ between the plate and inside of the model. On the contrary, for the PCM inside the model, the temperature difference is below 2 ℃.

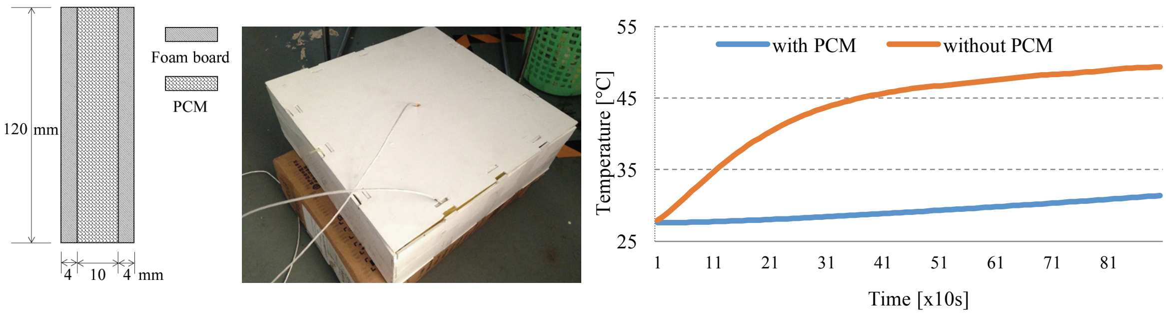

Fig. 5 Description of the layers of the physical model (on the left); Profile of the indoor temperature of the physical model (on the right)

3.5. Smart energy use: Solar-ground coupled heat pump system: a hybrid solution to heating and cooling demands

Student group F worked within the scope of building and district heating and cooling; waste to energy conversion and smart buildings and grid technology. Based on their competencies, they selected to design a system that could supply the site with heating and cooling energy by combining available renewable energy sources in order to achieve high-energy efficiency. The work was divided in three main objectives:

- Use thermal solar collectors to cover the hot water production;
- Use a Ground Source Heat Pump to produce heating and cooling for air HVAC (Heating Ventilation and Air Conditioning) needs;
- Design a system coupled the first two parts for one building.

The students worked on the calculation of heating and cooling demand and hot water load related to one of the building in the site area. A model of three typical floors of one building was built in *DesignBuilder* environment.

The air-conditioning was assumed to have a coefficient of performance (COP) of 2.2. Display default lighting density was set to 7 W/m^2 and target illuminance was 100 lx. The value of 2.7 was set as person/apartment for a typical family in order to better simulate the occupancy of this case. The air temperature in the common areas was set equal to 18 ℃ in winter (from the middle of October to the end of March) and 26 ℃ in summer (from the beginning of April to the middle of October). Finally, hot water usage per person was assumed equal to 50 litres per person per day. The results of the simulation are summarized in Table 3. In order to cover the total energy demand for domestic hot water (DHW) of the building has been decided to install ST collectors on the roof of the building. This surface resulted the most radiated one from the analysis conducted by group B, 1350 kWh/(m^2 a). In this part of the study, the group F conducted a parametric analysis on how much surface of the roof should be used in order to cover the entire energy demand for DHW of the building. Three scenarios have been analysed: (i) average day characterized by 700 W/m^2 as the average power exchanged by radiation, (ii) average winter day with 400 W/m^2, and (iii) worst winter day with 300 W/m^2. For the calculation, it was chosen a solar vacuum tube thermal collector with heat loss coefficient of 0.642 W/m^2 K.

Table 3: Total energy demand for cooling and heating of the building: comparison between simulated results and Chinese standard values.

Type of energy	Simulated results, kW/(m^2 a)	Chinese standard building results, kW/(m^2 a)
Total heating demand	52	65
Total cooling demand	45	43
Total energy demand	97	108

The results shown that by utilizing the total available area of the roof, equal to 90% of the total roof's area (4270 m^2), it will be an excess of 48% and 13% of heating power for DHW during the scenario (i) average day and (ii) average winter day respectively. While in scenario (iii) during the worst day, the output of heating energy will not be enough to meet the energy demand for DHW. In this latter case, it would be necessary to have 1.75 times the available area of the roof in order to meet the entire demand for DHW. The efficiency of coupling a ground source heat pump system with the solar system was also studied. The calculation demonstrated that the average seasonal performance factor of the heat pump increases from 3.8 to 6.1 if coupled with solar thermal system.

4. Conclusions

During the summer course entitled *Sustainable Energy in Cities*, jointly organized by NTNU and SJTU, each student group analyzed specific challenges related to transforming the *Zhoukanghang* area in Shanghai into a smart energy-efficient district. For two weeks, the students were intensely working in an international environment for interdisciplinary learning and training, in cooperation with researchers, local industry and municipal officials. The students studied smart and sustainable strategies at district level, energy solutions at building scale and materials at component level by using simulation software, analytical calculations, literature studies and experiments. During the summer course, the students gained:

- Basic understanding of Asian perspectives on sustainable energy in cities;
- New technical skills and competences in conducting simulation analyses and experiments;
- Practical experience on how to work in an interdisciplinary international team to obtain energy-efficient cities with high quality of life.

The SEniC 2015 summer course was a good example of educational experience in which students, professors, researchers, experts of industries and municipalities' actors collaborated to propose, test and develop new strategies and solutions for improving sustainable energy in Shanghai.

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