A Joint US-China Demonstration Energy Efficient Office Building

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ABSTRACT

In July 1998, USDOE and China's Ministry of Science and Technology (MOST) signed a Statement of Work to develop a demonstration energy-efficient office building and demonstration center in Beijing that will eventually house the Administrative Center for China's Agenda 21 (ACCA21). The statement calls for the Chinese side to be responsible for the basic construction of the 13,000 m^2 9-story building, the US side for technical assistance and the incremental costs of the energy efficiency improvements, and the joint establishment of a Demonstration Center to provide outreach and exhibit energy-efficient building technologies.

The US technical team made several trips to China to meet with ACCA21 and the design team, and used the DOE-2.1E simulation program to analyze the energy performance of a preliminary building design and study alternative designs and energy-efficient strategies. A feasibility study completed in September found the largest and most cost-effective savings potentials in reducing cooling and lighting energy use, and identified eight generic measures in lighting, windows, daylighting, and HVAC systems and controls. Following these and other recommendations from the US team, the design team produced a schematic cross-shaped building design that, based on the DOE-2 analysis, lowered total energy use by 40% compared to standard practice.

While the design and analysis were underway, a task force called ACCORD21 (American-Chinese Council Organized for Responsible Development in the 21st Century) was formed in April 1999 under the leadership of NRDC to solicit support and contributions from U.S. industry, A/E firms, and universities. Two design workshops were held, first in Pittsburgh and then in Beijing, that brought together the Chinese and US project participants and produced further refinements and energy-efficiency improvements to the building design. As of June 2000, the authors are completing the final energy analysis and selection of of energy-efficiency measures. Construction is expected to begin in the early part of 2001.

Introduction

The building industry is traditionally viewed as relatively local and disaggregated. Even in developed countries, commercial buildings are constructed by contractors that represent small portions of their markets, and rely on subcontractors who typically obtain their products through local suppliers. Yet, the building design and construction industry is increasingly benefiting from an international perspective that allows designers and builders to look across national boundaries and even continents to develop new building designs and techniques, and new applications for existing materials and technologies.

This project was designed to bring together buildings experts from two countries and across twelve time zones to demonstrate the application of energy saving and clean energy products and technologies to a mid-sized office building in the heating-dominated climate of Beijing, and the associated potential for reduced greenhouse gas (GHG) emissions. The project has several key elements:

- A preliminary feasibility study to provide detailed information about suitable clean energy opportunities for the building, with an opportunity for each country to assess its continued involvement based on the outcome of the study. This exploratory stage was completed in 1999 and, as of this writing, the project participants in both countries are proceeding with design development and evaluating the option of continuing with construction.
- Shared-cost construction of the office building that would demonstrate energy savings potential significantly beyond current practice or existing building codes.
- A Demonstration Center to be located within the building to provide on-going opportunities to demonstrate clean energy technologies for commercial buildings.
- On-going monitoring and reporting on the building's energy performance after completion.

This paper describes the development of the project, the preliminary feasibility study[1], and the exploration of construction opportunities, with a particular focus on the organizational arrangements needed to undertake these efforts. The paper also highlights key new findings and understandings of the potential role of energy efficient and clean energy technologies in mid-sized buildings in China's heating climate.

The Statement of Work

This project was conceived by a few Chinese and U.S. officials[2] seeking a "concrete" way to demonstrate the potential for cooperating on reducing greenhouse gas emissions. "Concrete" quickly translated into a building demonstration project when it was learned that the Administrative Centre for China's Agenda 21 (ACCA 21), a semi-government organization responsible for China's climate change mitigation program, was pursuing new office space. The Chinese side then identified a downtown Beijing site for the building next to existing MOST offices and residences, and defined the program for a 13,000 m^2 9-story office building.

The U.S. Department of Energy (DOE) and ACCA 21's parent agencies, the Ministry of Science and Technology (MOST) and the State Development Planning Commission

[1] The Chinese government procurement process for new buildings defines "feasibility study" to include the building's detailed final drawings; the term "preliminary feasibility study" is used here to distinguish the exploratory work undertaken to date from this form procurement requirement in China. This is just one of many cases in which better understanding each country's buildings, energy, and process terminology was needed to keep this project moving forward.

[2] Abraham Haspel, Deputy Assistant Secretary with the U.S. Department of Energy; Madame Deng Nan, Vice Minister with the Chinese Ministry of Science and Technology; Professor Gan Shijun, former Director General of ACCA 21; and Wang Weizhong, current Director General of ACCA 21.

(SDPC) were the principal government agencies involved in developing a Statement of Work to allow the project to proceed. An existing "Protocol on Cooperation in the Fields of Energy Efficiency and Renewable Energy Technology Development and Utilization" signed by DOE and MOST in 1995 provided a basis for these agencies to develop this new Statement of Work.

A bit of research and project development was required even before such a statement could be drafted. Detailed demonstration objectives, explored in the following section, had to be developed, and the roles that potential partners, e.g., private firms, academic and professional institutions, Non-Government Organizations (NGOs), and other government agencies, could play in this project defined. A plan of action was developed, including the broad roles for each country, and reflecting as much as possible the typical design and construction phases for a building project of this scale. Both governments had to agree on which project activities needed to be delineated in the Statement, and which could be deferred for future decision.

Two ongoing U.S.-Chinese activities helped pave the way for the development of this project: 1) The Country Studies program had provided opportunity for many of the participants from both countries to get to know each other, and to learn about each other's energy markets and uses; 2) An existing Annex to the Protocol[3] in 1996 had created a U.S.-Chinese Energy Efficiency Team on Buildings tasked with exploring energy-savings opportunities in the Chinese building sector. The U.S. team, chaired by one of the authors (Huang), allowed this project to tap into existing contacts with representatives from government, industry, research institutes, and NGOs, with known interest in building energy efficiency in China.

In China, ACCA 21 worked with MOST, SDPC, and the Ministry of Foreign Affairs in developing the Statement of Work. After multiple drafts, the summit between President Clinton and President Jiang Zemin in June/July 1998 provided an ideal opportunity for approving the Statement. The Statement of Work was signed on July 9 by Madame Deng Nan, representing MOST for China, and Ambassador James Sassor for DOE Assistant Secretary Gee, becoming the first outcome of the Clinton-Jiang summit.

The objective of this Statement of Work was to provide enough specificity for both sides to feel confident about the project's ultimate success, but retain enough flexibility for the project to incorporate new information learned during the preliminary feasibility stage. In addition, because this was designed as a two-stage project with an opportunity for review in between stages, it was important to ensure that the results of the exploratory stage would be valuable in its own right, should it be decided that the project would not go forward to construction. Senior Chinese and U.S. officials have followed the project's progress at meetings of the U.S.-China Environment and Development Forum, establish in March 1997 during Vice President Gore's visit with then Premier Li Peng.

Demonstration Components

Demonstration projects can mean many things to different people. One of the more difficult aspects of this project was defining what would be demonstrated, and how this would be achieved.

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[3] Annex III on Energy Efficiency, signed in 1996 by the State Planning Commission (predecessor to the State Development Planning Commission).

Demonstrate Significant, Replicable Clean Energy Opportunities

Beijing lies in a heating-dominant "culture" in which buildings are regularly provided with space heat, but cooling is regarded as a luxury. To date, the only building energy standard in effect is a space heating standard for residential buildings developed in 1992. Due to the absence of other points of reference, this residential heating standard has often been applied, at times inappropriately or with marginal effect, to new commercial buildings as well. One of the goals of this project is to demonstrate that significant additional energy savings beyond this code are achievable in ways that are replicable and cost-effective in China's emerging buildings market.

Given the emphasis on replicability and significant cost savings, the project quickly focused on "state-of-the-shelf" technologies and techniques that are either currently cost-effective, or likely to be so under mature market conditions. Robustness in the technical and economic analyses was ensured by varying the assumptions. Two sets of savings estimates were made, one for a level of building services currently found in many Chinese buildings, and another for a level found in "Class A" offices or typical of U.S. buildings. Similarly, two sets of cost estimates were made, one using the existing price differentials between standard Chinese and energy-efficient US products, and another using the estimated true price differentials for the energy-efficient technology under mature market conditions.

Despite the traditional focus on heating only, new commercial buildings in Beijing are now routinely built with air conditioning to meet summer cooling loads. A key observation from the feasibility study is that the savings opportunities in reducing cooling loads far outweigh those in reducing heating loads. To account for the interactions between heating and cooling loads, a whole-building design approach is used to identify the most cost-effective energy strategies for this building, including passive solar and other clean energy options such as photovoltaics (PVs) and geothermal power systems. The use of the whole-building simulation approach is in itself a demonstration of a cost-effective technique for saving energy.

Finally, the project is flexible about showcasing more innovative technologies while remaining faithful to the concept of being a "state-of-the-shelf" building. If suitable opportunities arise, the project will incorporate emerging technologies, such as PVs or fuel cells, into small portions of the building on a limited basis. In addition, the Demonstration Center in the building will provide a venue for introducing energy efficient products and technologies that may not have been applicable to this building, but can be well suited to other buildings or climates in China.

Ongoing Demonstration

Good communications and cooperation are essential to the success of any building project, and even more so for a project that attempts to introduce new products or techniques from abroad. Each stage of this project will require ongoing professional collaboration between Chinese and U.S. building professionals, companies, and research institutions.

Once the building is complete, there will be ongoing energy performance monitoring consistent with the requirements for an Activities Implemented Jointly (AIJ) pilot project. In addition to allowing the calculation of greenhouse gas emissions reductions, this monitoring will provide a valuable data on the energy performance of specific HVAC and other energy-efficient technologies, as well as an opportunity to fine-tune the building's energy performance. One of the activities of the December 1999 design *charrette*[4] described later was to define the monitoring and control specifications needed for this activity.

The proposed Demonstration Center will likely be modeled after facilities in the U.S., such as the Lighting Design Lab in Seattle, that provide a hands-on opportunity for architects, builders, and others in the buildings community to learn about energy saving and clean energy opportunities. Because of ACCA 21's role in sustainable development in China, the building will attract visitors with varied interests in clean energy buildings. The Demonstration Center could also provide training and serve as an educational resource for local schools. Furthermore, the Center will explain the building's energy features and record its energy performance.

Appropriateness of Proposed Project to Demonstration Goals

Every building has the potential to be a demonstration project in one way or another; and, of course, every building can benefit from the type of attention placed on a demonstration project. However, the demonstration component of energy efficient building project adds to project costs. As a result, we sought a project that provides maximum opportunity for new insights and diffusion of these results to the building industry at large. Key characteristics of this project that make it particularly attractive as a demonstration building include:

- **Location.** The building site is in a downtown business district next to MOST and just south of Yuyuantan Park, the second largest green space in Beijing. The prominence of this location enhances the building's visibility, and increases the exposure for the participating U.S. firms. The downtown site does present a number of energy and environmental challenges, such as limitations on the building's shape, height, and shading from nearby structures. Although adding to the project's complexity, these challenges paradoxically help to demonstrate the broad applicability of the selected techniques and products under "real-world"conditions.
- **Use.** Most of the building's space will be standard office configurations, likely the largest share of commercial building growth, as well as one of the most homogenous.
- **Climate.** Although traditionally viewed as a heating climate in China, Beijing actually has slightly warmer summers than Washington, DC, as well as significantly colder winters. These climate conditions allow for demonstrating the performance of energy-efficient strategies under both cooling and heating conditions.
- **Building size.** The 13,000 m^2 (150,000 ft^2) building is large enough to be visible, have relatively complex energy systems and energy-building interactions, but is small enough to be affordable to both sides.
- **Energy availability.** The building site has access to a variety of energy sources. District heating and, of course, electricity are already available on site. Natural gas is available in

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[4] *Charrette* is a French word frequently used in the architectural profession to describe an intensive design session involving a group of architects over one or more days.

the proximity of the site. Together, three energy sources provide the bulk of energy used in buildings in Beijing, and increasingly in new buildings throughout China.

Partnerships and Project Structure

The Statement of Work indicates high-level government support for and interest in this project. However, for it to be successful, the project still needs the involvement of building and energy experts from both countries.

ACCA 21 has assembled a team of architects and engineers from the Beijing Urban Planning and Design Institute, as well as experts in building materials and energy use from Tsinghua University and other design institutes. Prof. Gao Lin is the lead architect for the project, and heads an A&E team that includes engineers in electrical, lighting, and HVAC design. The entire Design Team has participated in meetings with the U.S. team throughout the project. This level of involvement provides design continuity and a chance to address the interactions of building and energy systems from very early in the design phase.

The U.S. team has two principal components: An analysis team based at LBNL and NREL headed by two of the authors (Huang and Judkoff), and a private sector team headed by another author (Watson). The Analysis Team has provided preliminary design recommendations and ongoing building simulation support to the Design Team, and worked with the Design Team to gather required data for simulations and identify strategies consistent with the building's overall uses and site conditions.

NRDC was selected from among eight entities that responded to a "Notice of Opportunity" placed in the Federal Register by DOE for a volunteer to coordinate the private sector participation in the project. Working with the other respondents, private firms and other organizations that have expressed interest, NRDC established ACCORD 21 (American-Chinese Coalition Organized for Responsible Development in the 21st Century) in support of this project. Because the project provides for U.S. funding of the incremental costs for the energy-efficiency measures through its private sector, the ACCORD 21 activities are particularly important to the project's eventual success.

Results from the Preliminary Feasibility Study

The building simulation analysis undertaken as the preliminary feasibility study for this project confirmed a number of likely sources of cost-effective energy savings, but also provided new insights about the mix of strategies that are likely to work best for this particular building (Huang, Judkoff, and Sherman 1999). For example, a principal finding from this study is that the optimum energy-savings strategy for commercial office buildings in Beijing should be focused on cooling and lighting energy reductions.

A series of visits to both China and the U.S. beginning in Sept. 1998 allowed for iterative improvements in the building design and the computer modeling, with results that show the limitations of the current residential energy code, or identified strategies unexpected by the analysts prior to the study.

The Analysis Team started by modeling a very preliminary design from the Design Team for a square-shaped building designed to the current residential heating code, and then explored the energy savings achievable by modifying the building's geometry and orientation, and those achievable through inclusion of energy saving measures or components. The preliminary results were discussed at various stages with the Design Team either in China or in the U.S.

Through the first half of 1999, the Design Team reviewed the preliminary simulation results from the Analysis Team, supplied additional data on building materials and operating conditions, and developed modified building designs that responded to the recommendations from the Analysis Team. This new information were in turn incorporated into the final preliminary feasibility study completed by the Analysis Team in September 1999.

The exploration of building geometry led to the selection of a cross-shaped base building with windows predominantly located on the north and south facades. This design maximized the potentials for daylighting and natural ventilation, while reducing excessive solar heat gain through the east and west facades. Figures 1 and 2 show the current design as of June 2000, which is a refinement of this basic design.

The base building is defined as having the same cross-shaped building geometry, but with energy-efficiency levels in accordance with the existing residential energy code. The energy saving estimates are calculated as the reductions in energy use for additional energy-efficiency measures. The energy savings due to the change in building geometry (which are estimated at 5-10%) are not included in these energy savings estimates to avoid the ambiguities in estimating construction costs for different building shapes and surface-to-volume ratios. For the base building, lighting, air-conditioning, and ventilation make up from 69-74% of the total energy cost for the building (see Figure 3). Expected heating costs have already been substantially reduced through the incorporation of the existing residential building code specifications in the base building.

Energy analysis of this base building produced a list of eight (see box) additional cost-effective energy savings measures with predicted energy cost savings of 40% to 42% (see Figure 3). Assumptions about building operating conditions--whether at more traditional ("reduced") levels or more modern ("full") levels--changed the resulting savings somewhat, but did not affect the measures selected. When the building's orientation and geometry are factored in, the energy cost savings compared to a typical office building are expected to be from 45% to 50%. Additional energy cost savings through the use of measures that have not been analyzed and the "fine tuning" of the final overall building specifications are also highly likely. One such measure that is hard to simulate but likely to provide additional energy savings is an Energy Management and Control System.

Cost-effective Measures:

- Light colored wall/roof surfaces
- Recessed windows
- High efficiency lighting
- Low-e window glazing
- Bi-level light switches (daylighting)
- Reduced window height
- Staged chillers
- Improved chiller efficiency

The large contribution of lighting and cooling to the base energy costs resulted in recommended measures that focused on these energy uses. Although achieving an overall cost savings of over 40%, the recommended package of measures would actually increase heating energy requirements for this building due to the reduction of lighting and solar heat gain. These increases are not surprising since the base building design already incorporated heating-related conservation measures.

Because the energy savings from these measures derive entirely from electricity savings, the expected greenhouse gas emission reductions attributable to these measures depend on the energy source used to produce electricity. The typical coal-to-electricity conversion rate for China is 3.67, meaning that any savings in electricity translate to 3.67 as much savings in greenhouse gas emissions. The smaller increases in heating energy needs would mitigate these savings somewhat, with final savings depending on whether heating is natural gas or district steam, and the types of energy used to produce the district steam.

Finally, it should be noted that the savings reported here are based on a package of measures developed through a "whole-building" or integrated analysis that takes into account the various ways in which the measures interact within this base building. Changes to either the base building or the set of measures utilized could change the final results.

Results from the First Design *Charrette*

A four-day intensive energy design *charrette* was held at the Robert L. Preger Intelligent Workplace at Carnegie Mellon University (CMU) in Pittsburgh in December 1999, three months after the completion of the feasibility study. Approximately 40 people attended the *charrette*, including ten representatives of the Design Team and building owner. Other attendees included CMU professors, product manufacturers and professional members of ACCORD 21.

The Design Team presented their existing building design, which had incorporated many of the recommendations from the Analysis Team, and the results from the feasibility study. Working groups were established for each major building system area: (1) Massing & Site, (2) Enclosure & Lighting, (3) HVAC and (4) Interior Systems & Plug Load, as well as a group looking at measurement and verification issues surrounding the energy and climate performance of the building. Each day, these groups would meet for several hours to discuss the issues particular to their area, then at the end of the day an hour-long integration plenary was held where each group presented the results of their discussion and noted where their issues overlapped with those of other groups. A great deal of informal "cross-pollination" occurred during the day as well.

The following sections describe the recommendations made by the U.S. participants at the *charrette* to the Design Team.

Massing & Site

The building site is next to a large public park, and adjacent to high rise apartment buildings. The large public park contains a number of nationally significant buildings such as a government guesthouse.

The present building layout, to a large degree, is the result of the zoning requirements that stipulate a minimum distance between neighboring buildings, the roadway and access. The original proposed building layout was square-shaped. DOE-2 analysis of five different building footprints performed by the Analysis Team found that a cruciform shape would be the most energy efficient. The Design Team subsequently adopted this layout.

The proposed core layout was felt to require an inordinate amount of space for vertical circulation, hallways, vertical shafts, toilets and ancillary facilities. Alternative positions of the vertical shafts were proposed, with the objectives of maintaining the valuable orientation to the large public park, freeing the center from the large core spatial requirements and providing the potential to create a large uninterrupted continuous floor plate and a flexible space design.

The design experts in attendance recommended de-emphasizing the reliance on automobile access on the ground level. They proposed raising the entrance platform of the facility ½ floor above ground and providing auto access ½ floor below ground to permit natural ventilation of below ground facilities and a clear separation of upper floors. This would improve IAQ of the floors above by eliminating potential for car exhausts to be drawn upwards as in a chimney.

There was a controversial discussion on the need for parking. Many participants of the workshop felt that the Chinese government should set an appropriate example with their own facilities. Such an example seemed especially necessary considering the primary use of the building was for a group charged with promoting sustainable development. Participants recommended to reduce parking and car access to the absolute minimum and to provide prominently located protected bike stalls.

Systems Integration – Main Concepts

Workshop participants also suggested a number of structural and interior systems and HVAC cabling schemes. First, it is proposed to eliminate the beam at the perimeter, which spans between columns below the spandrel unit. This will allow significantly more daylight into the facility and favor the upper portions of the façade in each floor, which typically provides higher levels of luminance than the lower portions, given the luminance of the sky dome. Several participants noted the following advantages of floor-based over ceiling-based infrastructure for HVAC, wiring, and cabling :

- When well integrated, a raised floor with structured wiring and HVAC ducting solutions can be cost-competitive with ceiling distribution schemes
- A floor distribution scheme provides easy and flexible access of all necessary services.
- Occupant control of thermal and IAQ comfort increases significantly with properly designed and maintained floor distribution, leading to greater energy effectiveness and enhanced productivity.

Under this proposed layout, the role of ceilings is limited to acoustic absorption and light reflection from daylight and electric lighting.

Enclosure and Lighting

The most important issue for the enclosure is overall energy effectiveness and user satisfaction in visual, thermal and air quality.

Lighting was found to be the largest energy load in the building. Through the use of proper shading and light redirection devices, the need for ambient lighting in the facility could be minimized, mostly concentrated in the evening hours. In order to maximize the benefit of the daylight availability, a direct/indirect task-ambient lighting system with T-5 lamps and electronic ballasts for dimming is recommended. In addition, each occupant should have control of their own efficient task lighting.

Although Beijing's climate is conducive to the use of natural ventilation and thermal conditioning for much of the year, the city's air quality is very low. Therefore, operable windows might not be a viable option. Ironically, coal-fired power plants are responsible for a large part of Beijing's ambient air quality problems and air conditioning and filtering requires substantial energy and material resources. Although energy savings from insulation were not found to be very significant, radiant imbalances at the perimeter would lead to occupant thermal discomfort. The workshop participants recommended thermal bridging in facade be minimized.

Double-glazed, low-e windows with a high visible transmittance and a shading coefficient below 0.5 was recommended to meet the daylighting and thermal comfort goals of the project. In addition, the owners were urged to consider building integrated photovoltaics on the facade.

Interior Systems & Plug Load

The recommendations from the interiors planning and design working group were:

- The cut-outs in the raised floor tiles for diffusers and telecommunications connections should be in a consistent location and possibly of uniform size. The air diffusers should allow locational, volume and directional control of airflow at a minimum.
- Underfloor networks for data, power and voice should be configured for easy modification.
- The carpet tiles should be the best available in resource conservation, durability and indoor air quality.
- All interior components should: (1) meet the State of Washington standards for limiting volatile organic compound outgassing; (2) minimize the use of scarce materials or combinations with toxic materials (3) regional materials and/or regional manufacturing plants where possible.
- Remote outgassing should be required before installation.
- Interior subdivisions should be modular and relocatable. Appropriate stability, fire and acoustic properties must be considered.
- Explore articulated (not flat) acoustic ceiling forms with 100% recycled or recyclable materials, for maximum sound absorption and light reflection. Integrate the design of the ceiling with an 80% indirect- 20% direct lighting or a ceiling ambient only system.
- Modify structure and partitioning to enable variable floor plans. Eliminate extra columns within the East/ West occupied areas, move free columns in North/ South spaces to the façade, but do not penetrate the façade with structure due to thermal bridging and moisture migration.

HVAC and Total Energy Systems

The HVAC system proposed by the Design Team is a central VAV system with a conventional air handling system in the ceiling plenum. The principal recommendations from the *charrette* are 1) minimize interior and exterior loads before HVAC system is considered, 2) distinguish between air flow for ventilation and space conditioning, and 3) utilize an underfloor air distribution system.

Focusing on the floor-by-floor distribution, the advantages of floor-based HVAC infrastructures were emphasized. The plug and play nature of such systems provides for highest level of user satisfaction in thermal comfort and air quality, organizational flexibility, and technological adaptability, including easy change out of systems and components needing repair, improvement or replacement.

In addition to the standard cooling plant, i.e., chiller and cooling tower, several different system configurations were explored:

a. Use of natural gas turbine for power generation with an absorption chiller operating off the waste heat.
b. Ground-source heat pump system: Use a radiant floor for heating with a forced air system for cooling. There would be four ground source units on each floor. A vertical water loop passing through the building and connected to the ground source would be used for distributing hot/cold water.
c. Use of heat recovery wheel for desiccant dehumidification
d. Use of ice storage system.
e. Use of water-cooled rotary chillers.
f. Use the existing hot water supply to run absorption chiller.
g. Use of fuel cell for power generation. The waste heat can be used for heating as well as by absorption chiller for cooling.

No specific recommendations were made, pending further study by the Analysis Team of the cost-effectiveness of the above configurations.

Performance Measurement and Verification

In this area, there was considerable discussion about the definition of a baseline performance for the demonstration building. It was noted that the baseline could be defined in different ways. One way was to define it as current "standard" practice. However, this approach has difficulties in that "standard" practice varies widely across China and also across different building types, and is hence difficult to define. An alternative is to define the baseline simply as the base building, without the added high-performance features. While this approach provides for a well-defined baseline, its drawback is that the energy impact of high performance alternatives would be seen as lower than in the previous approach, since originally proposed base building was substantially better than conventional Chinese construction. The consensus was that both approaches should be followed. The comparison to a "standard" practice will allow for an assessment of the impact of adopting energy efficiency measures across the broader Chinese building stock, and the comparison to the base building will allow for the assessment of the performance measures for this particular demonstration building. The two approaches are represented in Figure 4.

It is recommended that the demonstration building be substantially sub-metered to allow for detailed analysis of energy use by type and space. Separate zonal metering for the underground and ground floors, the technology demonstration center, and the upper office floors is recommended. End-use monitoring would cover: lighting, HVAC (heating, cooling and fans) and plug loads. Beyond energy use, it is recommended that a number of other performance attributes should also be measured:

- Visual environment – illuminance and glare
- Thermal environment – air temperature, mean radiant temperatures, humidity, air speed
- Indoor air quality – carbon dioxide, volatile organic compounds
- User Satisfaction – This can be done using protocols developed by CMU’s Center for Building Performance and Diagnostics (CBPD) and the International Energy Agency (IEA).

Design *Charrette* Follow-up

After the Pittsburgh workshop, the Design Team incorporated many, but not all, of the suggestions from the Pittsburgh workshop. The planning approval resulted in a minor design revision, which required that the southern wing of the building be shortened by 8 meters (26 ft.). The lost floor space will be made up with a newly-added partial floor penthouse on the 9th floor. The lobby space has been redesigned to better accommodate workers and visitors to the second-floor Technology Demonstration Center. These changes are reflected in in Figures 1 and 2, which date from May 2000**.**

The new design incorporates a "beam-free" open span that increases perimeter ceiling height from 2.60 m (8.5 ft.) to over 2.75 m (9 ft.) and columns have been moved to the perimeter to open up the space for daylighting. A flexible wall partition system is favored to complement the column-less design and beamless ceiling.

The Design Team is considering ice storage cooling and has adopted a two-zone under-floor air distribution strategy. Variable frequency drives will be specified for all appropriate pumps and fans. Low-e windows with an appropriate shading coefficient will be specified for the envelope. Light shelves are being considered to enhance the daylighting characteristics of the space. Figure 5 is a typical floor section showing the under-floor air distribution system and light shelves.

Public "green spaces" are being considered for the roofs of the east, west and north wings of the building that face Yuyuantan Park, with the south wing being proposed for a photovoltaic array. Interior system design changes include a task-ambient lighting design strategy with direct/indirect pendant fixtures, indirect lighting with T-5 lamps and task lighting as necessary. The underground parking garage has been redesigned to be open with no direct connection to the occupied space to avoid stack effect-induced contamination of the indoor air.

Conclusions

In May 2000, ACCORD 21 held another design *charrette* in Beijing that was attended by ACCA 21, the Design Team, and representatives from ten U.S. companies, NRDC, and Carnegie-Mellon University. The workshop was successful in refining the building design, and clarifying the level of support from the attending U.S. industry representatives. At the same time, the Chinese partners have expressed their commitment to proceed with construction.

As of June 2000, the Analysis Team is updating its DOE-2 simulations to reflect the changes in the building design, and to study the cost-effectiveness of the alternate HVAC system configurations such as the under-floor air-distribution system, multiple staged chillers, thermal storage, and passive solar absorption cooling. This analysis will be done by early Summer 2000, and sent to ACCORD 21, ACCA 21, and the Design Team for use in the final selection of energy-efficiency measures.

Since this is still an ongoing project, it would be premature to make any conclusions about its outcome or success as a demonstration building. However, the feasibility study has has already helped to clarify the energy use characteristics, and identified the potentials for energy saving technologies in the commercial building sector in China. At the same time, DOE and NRDC, through the formation of ACCORD 21, have developed a novel mechanism for collaboration between government, industry, and environmental interest groups to promote building energy efficiency in a major foreign country.

References

Huang, Y. J., R. Judkoff, and M. Sherman. 1999. “Feasibility Study of a US-China Demonstration Energy-Efficient Commercial Building”. LBNL-44306. Berkeley, CA: Lawrence Berkeley National Laboratory.

www.accord21.org - ACCORD 21 web site.

Figure 1. North Elevation of Demonstration Building

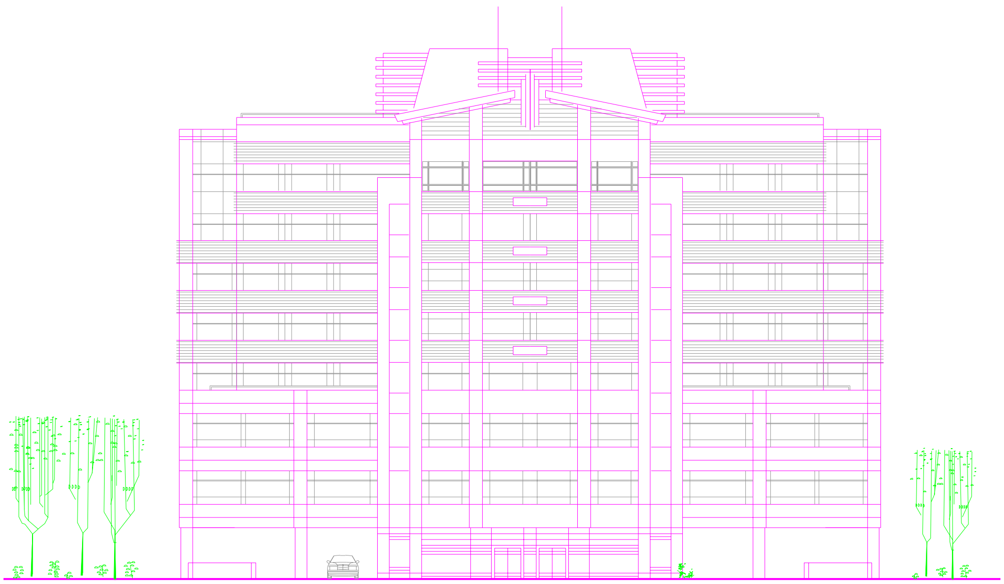


Figure 2. Floor Plan of Typical Floor

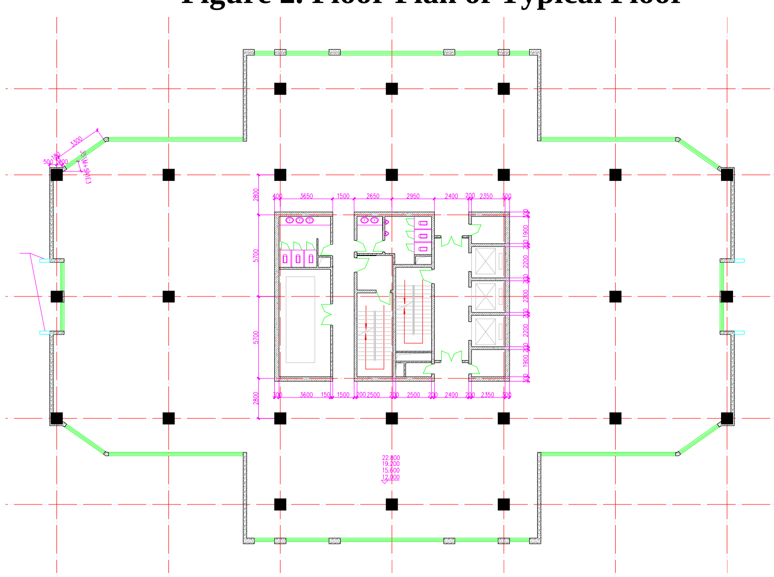
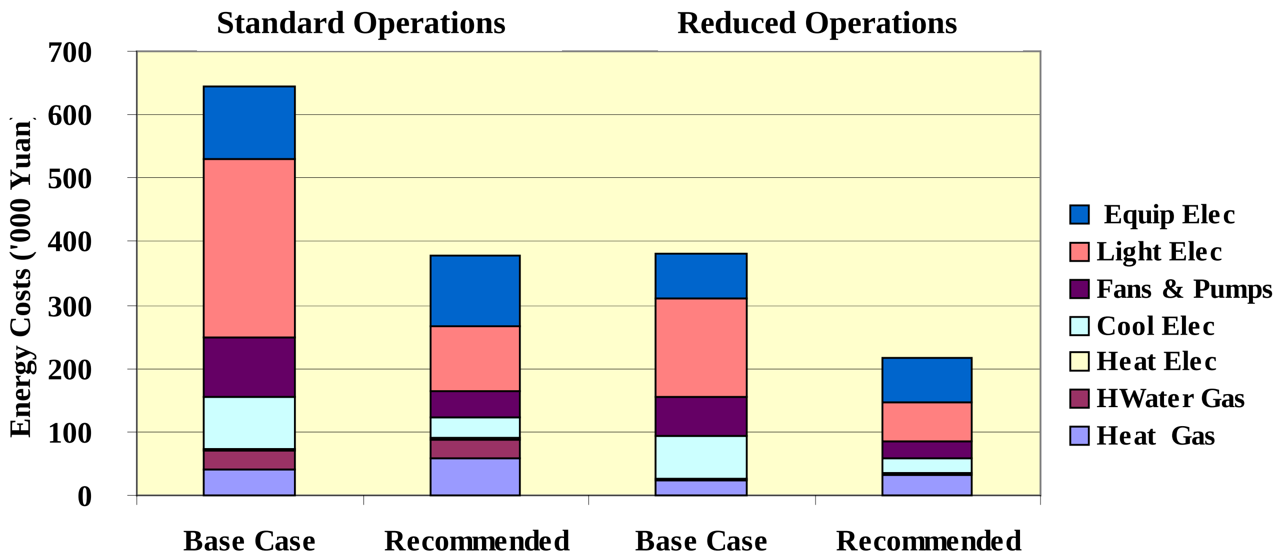


Figure 3. Comparison of Energy Costs for Base Case and Recommended Case



* 1 US $ = 8.6 Chinese yuan.

Figure 4. Evaluation of Energy and Environmental Performance

↑ High Performance Measures ↓	**ACCA 21**
↑ Agenda 21 ↓	**Project Baseline**
	"Standard Practice"

Figure 5. Cross-Section of Typical Office Space