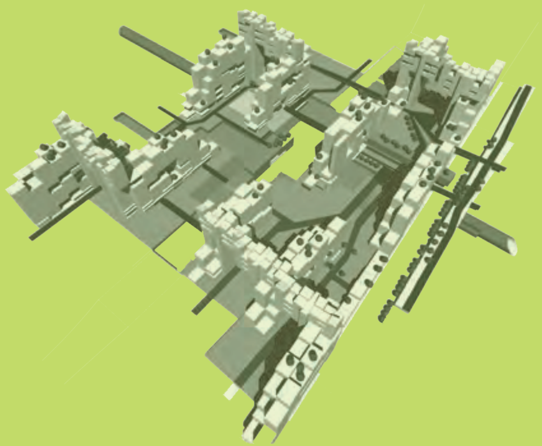
DESIGNING CLEAN ENERGY CITIES

New Approaches to Urban Design and Energy Performance

Massachusetts Institute of Technology
Tsinghua University



The Energy Foundation

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New Approaches to Urban Design and Energy Performace

Research and Studio Report, 2010

Produced as part of *Making the "Clean Energy City" in China*
a joint research project of

Massachusetts Institute of Technology
School of Architecture and Planning

Tsinghua University
School of Architecture

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2010 MIT-TSINGHUA JOINT URBAN DESIGN STUDIO

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Contents

This report is one of a series of publications on the research. Supplemental documents available from MIT and Tsinghua University on request include: *Making the 'Clean Energy City' in China* (Year 1 Report). MIT and Tsinghua University, June, 2010. *Clean Energy Neighborhoods* (Global Scan). MIT, 2010. *Clean Energy Development Patterns* (Comparative Data). MIT, 2010. Jinan Neighborhood Form Analysis. Tsinghua University, 2010.

Forward: About the reseach and this report

This report has two purposes: first to present a synopsis of our work to date on *Making the 'Clean Energy City' in China*, a multi—year research effort, and second to report on the work of the MIT—Tsinghua Joint Urban Design Studio held in Jinan and Beijing, China over the summer of 2010, an integral part of the research program.

The overall research effort is aimed at producing new patterns of development for China's rapid urbanization and a new tool, which we call the Energy Proforma©, by which developers and designers may measure and compare the energy performance of their projects. After having spent a year understanding the landscape of clean energy design globally, measuring energy-urban form relationships in our demonstration city of Jinan, and developing an alpha version of the tool, the studio was the first opportunity to bring all aspects of the work together. A first, limited test in practice.

And so the studio, more than an academic exercise, was a key step in the process of developing both the Energy Proforma and understanding new design prototypes of clean energy urban form. Students began with patterns and used Proforma to assess performance as they designed. Thus we were seeking to develop examples of new approaches to energy efficient form but also to test a new process of design and development programming.

Results were powerful and successful. Students developed five new prototypes of high–density mixed–use development, adding to the patterns we already have. They exceeded our expectations, pointing out areas where Proforma failed to capture approaches they intuitively knew would be energy saving and other limitations of the alpha version. Based on student input and more data from Jinan, we will reform the Proforma for future testing and further develop our language of clean energy urban form.

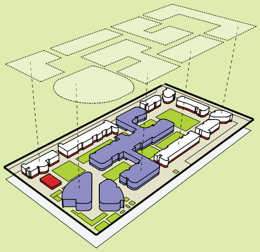
Key steps in the process are outlined in the book:

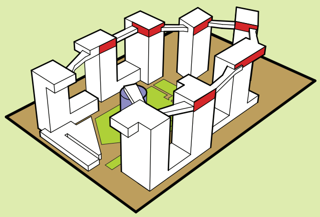
- *Chapter 1: Clean Energy and Urban Patterns,* presents an overview of the research including findings to date, and introduces the fundamental concept of urban "form–energy systems."
- *Chapter 2: Learning from Jinan,* describes the research undertaken in our demonstration city, including its prototypical patterns of urban form and what we have learned about their energy consumption.
- *Chapter 3: Five New Clean Energy Neighborhoods,* presents the products of the MIT–Tsinghua Joint Studio, including urban design proposals and assessments of their energy performance.
- *Chapter 4: The Energy Proforma©,* outlines the workings of the Proforma, discusses what was learned through the studio experience, and next steps in the research process.

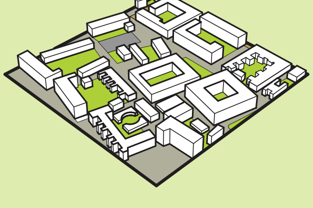
We wish to thank the many talented students who have contributed to the project thus far, and our dear colleagues at Tsinghua University for their continuing support and participation.

Dennis Frenchman
Jan Wampler
Christopher Zegras
Massachusetts Institute of Technology
January, 2011

1 Clean Energy and Urban Patterns







Clean Energy and Urban Patterns

Making the 'Clean Energy City' in China is a multi-year research effort aimed at producing new patterns of development for China's rapid urbanization and new tools by which developers and designers may measure and compare the energy performance of their projects at any stage in the design process. The aim of the project is to reform the way we think about energy goals by focusing on the physical and functional organization of the city and its influence on all human activity and resource consumption. The way in which neighborhoods are designed and operate has an enormous impact on energy requirements, economic growth, natural systems, and quality of life, yet thus far there has been little policy discussion and even less action to impel more sustainable (and ultimately more productive) forms of urban development.

"The aim of the project is to reform the way we think about energy goals by focusing on the physical and functional organization of the city and its influence on all human activity and resource consumption."

The stakes are exceedingly high. Producing its energy largely from fossil fuels, China has already become the largest carbon emitter in the world, and its massive carbon emissions are only projected to increase over the next decades. Urban development is regarded as the most important driver in the emissions scenario. Energy consumption that can be attributed to the built environment and the life of people within it has exceeded 46% of the total energy consumed in China (*China Economic Weekly* Oct. 29, 2007, 15). This proportion will continue to rise with the standard of living—as people demand more cars, living space, appliances

1.1. Neighborhood pattern in Jinan

and elevators—and with the level of urbanization. The UN estimates that China will need to build new cities accommodating over 350 million people in the next 20 years (McKinsey 2009, 32).

While numerous studies of energy utilization and avenues to reduce consumption exist at the metropolitan and building scale, there is almost no research at the urban development scale. This is the scale of neighborhoods, commercial districts, and real estate projects which are the fundamental building blocks of urban growth. We cannot hope to make a meaningful impact on reducing energy consumption in cities without addressing the issue at the scale at which the city is actually being built. But to do so raises some difficult questions: Are all urban development forms equal in their energy efficiency or is there a difference among them? How can designers and developers choose among a vast array of variables to design more energy efficient scenarios in particular circumstances? How can they practically assess the energy consumption of their project or alternatives? And finally, how can they do this in a way which is comparable to other projects to provide a basis for some kind of energy policy about the built environment?

Answering these questions requires a fundamental understanding of the relationship between energy and urban form and the tools to gauge neighborhood energy performance using commonly accepted protocols and measures. Neither of these prerequisites currently exists. *Making the 'Clean Energy City' in China* aims to fill the gaps in research and practice by giving designers and developers the tools to create more energy efficient urban scale projects. This in time will provide the basis for more enlightened public policy regarding urban design.

FORM-ENERGY SYSTEMS

Creating clean energy urban design is fundamentally different, and one might argue more difficult, than creating energy efficient buildings or regions. This is because the variables expand significantly when one moves beyond the building envelope, where interactions among buildings, spaces and streets come into play. The relationships among buildings can profoundly affect energy consumption by casting shadows on one another or blocking wind or reducing surface area. Building organization can also affect travel behavior, facilitating pedestrian movement or requiring elevators or the car. Patterns of human behavior in the public realm are more complex and variable than within the corridors of a building (and less apparent than at the resolution of the region). Certain forms can accommodate mixed uses, shopping and services, requiring less movement to meet everyday needs, and others cannot.

> "Preliminary findings confirm our hypothesis that neighborhood design does significantly affect energy consumption."

If we look across the physical fabric of the city, we see that it is composed of a collage of intersecting patterns, each with its own integrity. Designers tend to think of these as physical forms, but they also represent patterns of human interaction that consume energy at different rates. We call these "form-energy systems." The total energy consumed by each of these systems is a resultant of four key factors:

1. *Embodied energy* — in materials, construction, and eventual disposition of buildings, sites, and streets over the lifecycle of the system.
2. *Operational energy* — used in the day to day function of the system, including heating, cooling, elevators, water, and lighting consumed by private households and in the common areas of the public realm.
3. *Travel*—required to negotiate the system to participate in regular activities, work, school, shopping, socializing, etc.
4. *Energy produced*—by the system from on-site renewable sources including the sun, wind, and geothermal production. Such sources will become

increasingly important in the future, and some forms of urban development are more conducive to on-site production than others. (Solar hot water is already a significant feature of some neighborhoods in China.)

To understand the complex interactions that occur among these four factors, we are undertaking a series of studies of prototypical urban development patterns in China using the city of Jinan as a test case. We began by indentifying four prototypical patterns that make up virtually the entire fabric of the city: (1) traditional low-rise, high-density courtyard settlements; (2) gridded streets and blocks with mixed building types; (3) enclaves of walk up slabs; and (4) modernist "tower-in-a-park" developments.

In 2009, extensive surveys of household energy use, travel behavior, physical characteristics, and uses in selected neighborhoods representing each of the above types were carried out by Shandong and Beijing Normal Universities. In all, nine neighborhoods were surveyed and recorded; an additional 18 neighborhoods have been surveyed in 2010 although the results have not yet been analyzed. The studies are discussed in more detail in Chapter 2: Learning from Jinan.

Preliminary findings confirm our hypothesis that neighborhood design does significantly affect energy consumption, all things being equal (similar population, density, and location). Furthermore, the effects of the different factors can compound, making some form–energy systems of urban development far more consumptive than others. In Jinan, we found that modern high-rise "tower-in-a-park" projects consume almost twice as much energy as more conventional mixed-use neighborhoods developed on city blocks. This makes common sense, since "tower-in-a-park" projects typically consist of single use, widely spaced residential high-rise buildings with parking lots on or below grade, where occupants must use elevators and cars just to get a loaf of bread. Note that the issue is not the high-rise building but rather its setting within an energy wasteful urban context. The same building set within the intense mixed–use fabric of a traditional urban grid, like Manhattan, becomes part of a more efficient pattern of life. Nor is the issue density, since compact low–rise development can have the same density as widely spaced towers.

> "In Jinan, we found that modern high-rise "tower-in-a-park" projects consume almost twice as much energy as more conventional mixed-use neighborhoods developed on city blocks."

Ironically, the "tower-in-a-park" pattern of development has become the standard of urban growth across China and much of the developing world, which can ill afford to sustain it. Such projects are versions of the modernist city designed in the 1920's to reflect the ideals of industrialization and accommodate the new technology of the automobile. Rooted in the Fordist mindset, where efficiency was achieved through standardization and segregation of functions, modern cities were planned with separated housing estates consisting of identical buildings, shopping centers, recreation parks, office and industrial districts organized within a vast undifferentiated space where machines must link together the various aspects of daily living. It is no surprise that this energy-form system is particularly wasteful.

DESIGN ALTERNATIVES

Addressing wasteful energy-form requires more than making existing types of urban development more efficient by incremental means. Estimates show that improving the energy efficiency of individual buildings—by making them all LEED certified for example—would reduce total energy consumption of cities by just 1-2% (Block 2004, 87-99). While this is a contribution, as we have seen above it pales in comparison to the energy reductions that are possible by utilizing different, more efficient urban forms.

To understand the range of alternative forms which are out there, we analyzed neighborhood scale development projects across the globe that aim to be energy efficient. In all, close to 100 cases were considered. From among the most innovative and best performing of these projects, we deduced six different form prototypes with several variations on each. These prototypes represent very basic form-energy systems involving relationships among buildings, sites, routes of access and the surrounding city. They capture the essence not only of physical form but also activities and patterns of behavior engendered by the form, and finally strategies for saving and producing energy.

The six form-energy prototypes are summarized on the following pages. Data on all of the prototypes, their variations, and the cases on which they are based are presented in the **Appendix**. The appendix also includes the four Jinan development prototypes for comparison.

Looking across the prototypes, several conclusions can be reached. First, there are many approaches to clean energy urban form. This is important in the context of China where simple idealized policies can result in the reproduction of one type of urban development across the national landscape. Urban form-energy systems are so complex that there are many avenues to improving energy performance. Secondly, while the prototypes vary in scale and density, they are all relatively compact. This fits well with the Chinese idea of encouraging more compact growth in general, although, as we have seen, the quality of the compactness matters a great deal with regard to energy consumption. Thirdly, they mix uses with the housing to provide convenient shops, services, and employment reducing the need for a car. Finally, they stand out as high quality places to live offering diversity with the opportunity for individuality and innovation.

1.2. Design for clean energy form, MIT - Tshinghua Joint Urban Design Studio

Another key finding of the study was that while all of the prototypes consume less energy than conventional development, it is difficult to compare performance across representative projects. This is because they use different measures and strategies to save and assess energy consumption. There is simply no commonly accepted protocol or even terminology for understanding the energy performance of urban development at the neighborhood scale.

ASSESSMENT TOOLS AND CONSEQUENCES

To provide a common protocol, we are developing a new tool called the Energy Proforma. The aim of the Proforma vis to provide a platform for neighborhood energy assessment by establishing what elements are to be considered, how to measure these (sources of data), and a common unit of output that allows easy performance comparison. In doing this, the Proforma provides a tool for research, enabling us to understand and compare different projects in different contexts as well as the behavior of form-energy systems in general. More detail is presented in Chapter 4: The Energy Proforma.

Second, the Proforma provides a practical tool for designers and developers to assess the relative energy performance of complex development projects as they program and design them. The importance of this may be completely lost on anyone who has never engaged the complex labyrinth of urban design, but it should not be underestimated. Lacking such a tool is the equivalent of flying blind: one makes many small adjustments without knowing the overall consequences until one hits the ground and the project is built. The lack of such a tool also explains why projects can incorporate features that have saved energy elsewhere, even receive high ratings on the LEED scale (Frenchman and Zegras 2010, 33), yet turn out to very consumptive when people move in or the whole picture is taken into account.

> "The Proforma provides a tool for research, enabling us to understand and compare different projects in different contexts as well as the behavior of form-energy systems in general."

Based on the model of the *financial proforma*—which takes account of a huge number of variables to project the economic value of a project—the Energy Proforma is a spreadsheet based tool into which designers can enter the characteristics of their project and receive a reading on its energy performance. Behind the tool are a series of models and calculations that estimate the embodied, operational, travel, and renewable energy production aspects of the project. As with a financial proforma, these calculations must be based on data gathered from local conditions; therefore the Energy Proforma is structured so that the user may adjust background variables such as climatic and socio-economic indicators.

In the design process, the Energy Proforma becomes a tool for testing and gathering knowledge about the performance of the evolving project, helping designers to understand the effects of various moves, taking into account interactions across the whole system. As such, the Energy Proforma is a tool for feedback and decision-making rather than precise measurement (which is impossible in the design stages, anyway). As with a financial proforma, decisions accumulate—starting at the strategic level and ending with the details—to produce a more energy efficient project than would otherwise have been possible. This empowers the designer to decide how a project can best meet energy goals tailored to specific circumstances, facilitating innovation and reducing the need to rely on models from elsewhere that may or may not be appropriate.

> "The energy Proforma empowers the designer to decide how a project can best meet energy goals tailored to specific circumstances, facilitating innovation and reducing the need to rely on models from elsewhere that may or may not be appropriate."

Finally, the Energy Proforma can provide the vehicle for developing more enlightened public policy related to urban development and energy performance. It does this by being comprehensive, incorporating all of the factors affecting the energy performance of a project over its life cycle and reducing them to a single comparative measure, such as mega-joules per square meter or what may be called the *net present energy value of the project*. It is also transparent, so the data, assumptions, contributing elements, and their interactions can be traced. If adopted as a standard tool of practice by both the public and private sectors, then policy goals for the energy performance of urban form in different contexts, or for different types of projects, could be established. Over time and with experience, the goals could be raised or made more subtle or flexible, as with emissions standards for automobiles.

There are advantages to this approach. First, it does not prescribe how the goals should be met or establish an ideal model (that is likely to be repeated over and over), encouraging design innovation. Secondly, it leaves the complex decisions about how to meet energy goals in the hands of developers and designers who are in a position to try different approaches and make trade-offs in the local context. Finally, it could encourage more diverse forms of development that are more sensitive to local climate, culture and character—an antidote to standard modernist development.

China today is in a race against time. Massive urbanization once built will establish patterns of form, activity and human behavior that will last for generations, if not centuries. Unless a policy regime for urban development is adopted, we will have lost the opportunity to vastly improve the energy performance of cities at virtually no cost, since the growth will occur in any circumstances. Because of its political and economic structure, China is one place in the world that could respond quickly and forcefully to this challenge, moving from a blind embrace of the 20th century western ideal to encouraging new forms of more sustainable growth.

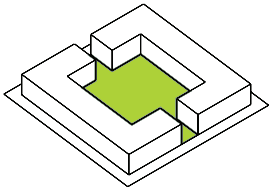
> "Unless a policy regime for urban development is adopted, we will have lost the opportunity to vastly improve the energy performance of cities at virtually no cost, since the growth will occur in any circumstances."

DEMONSTRATING THE APPROACH

To explore new forms of clean energy development, and test the Energy Proforma in practice, a demonstration was undertaken in the city of Jinan, China by the MIT-Tsinghua Joint Urban Design Studio. The studio, which includes graduate students and faculty from both universities, has a 25-year history of collaborative work on complex, large-scale urban design projects. The site for the project was a large new town for close to one million people being planned adjacent to Jinan's new high speed rail station.

Taking place over the summer of 2010, the studio pulled together all aspects of the research effort for the first time. Five teams involving 30 students analyzed the international cases as well as neighborhoods in Jinan representing prototypical urban forms. These were among the same neighborhoods that had been studied in the research so their energy performances were known. With these as benchmarks, the teams then developed proposals for new clean energy neighborhoods on the train station site using the Energy Proforma as a design and decision-making tool. The resulting projects represent innovative approaches to urban design and consumed less energy than the most efficient neighborhoods in Jinan and many of the international cases. The ability to understand energy consequences during the design process led to more creative and more technically competent solutions.

The remainder of this book charts the development of the research and studio through this demonstration experience. **Chapter 2: The Project in Jinan** introduces the city, the prototypical neighborhood forms that were studied, and their energy performance as determined by the research. **Chapter 3: Five New Clean Energy Neighborhoods** presents the design proposals prepared by the teams in detail. Finally, **Chapter 4: The Energy Proforma** reviews the development and workings of the assessment tool, results of the first application, and steps for further development.

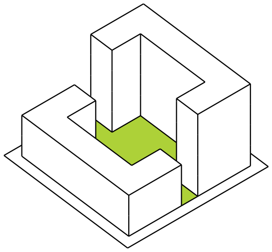


SMALL PERIMETER BLOCK

This type is defined by small scale connected buildings of 3-5 stories arranged around a central shared space, a quadrangle. The quadrangle allows sun to penetrate to all units, retains heat in the winter, and can mitigate the effects of wind in cold climates. It also allows for individual front doors on the perimeter and semiprivate spaces inside, a highly livable arrangement. Such schemes can accommodate great diversity within their simple morphology.

Simple: Forms group together many single quadrangles within a largely pedestrian environment, such as at Bo01 in Malmo, Sweden.

Complex: These forms are characterized by a series of interlocking enclosed and semi-enclosed quadrangles all oriented to the sun and connected by small access roads, as seen in Ecolonia in the Netherlands.

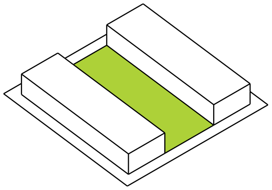


HIGH DENSITY PERIMETER BLOCK

These project forms have many of the advantages of their smaller cousins but they are larger in scale and density. Typical projects may include 8-10 story or even taller buildings grouped around the edges of an urban-scale block leaving a space in the middle. Building entrances, local shops and services face public streets and sidewalks surrounding the blocks creating a highly walkable environment while interior spaces may be developed for a variety of uses.

Simple: Low to mid-rise forms repeat variations on the basic block structure, as in Millenium Village in Greenwich, UK, where taller buildings are located to the north to allow sun penetration and to deflect wind off the Thames.

With towers: Include high-rise buildings among perimeter structures. At Symphony Park, 30 story buildings are located to shade streets and courtyards.

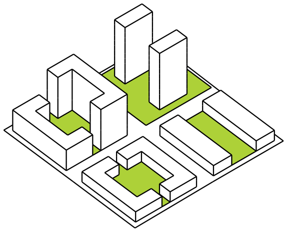


LOW-RISE SLABS

These forms consist of stacked flats arranged in linear 4-6 story buildings grouped into more or less private enclaves surrounded by streets lined with shops and services. Spaces between buildings are used for auto access and parking, alternating with “backyard” common space for the residents. These forms are typical in many clean energy projects because they are cheap to build and when aligned east-west can maximize solar gain.

Aligned: Forms follow a rigorous east-west arrangement with no variation for local conditions or community space, as found at the iconic clean energy project of Bedzed outside London.

Staggered: The linear structures are staggered and arranged to create more livable community and semi-private spaces. Geos in Denver, Colorado arranges linear buildings to make space for greenways and geothermal wells.

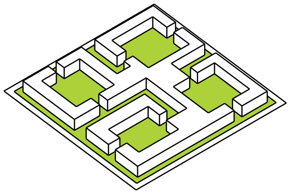


GRID

These forms represent a return to the traditional 19th century urban pattern of rectilinear public streets and private blocks. A wide variety of low and higher density housing types may be built within the blocks, with shops and services along principal routes of movement, all unified by the system of streets. This allows for high accessibility and walkability within a mixed-use, livable environment.

Regular: Forms are strictly rectilinear, such as Kronsberg in Hanover, Germany, where density increases toward the main street, which contains a tram line, shops and services.

New Urbanist: Projects use more organic grids with mid-block alleys and small lots to encourage high-density and walking. More popular in the US, Civano is a good example, where the grid focuses on a town center with shops and services.

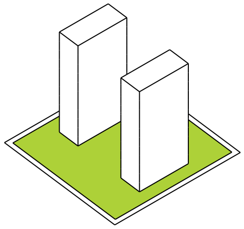


LOW-RISE SUPERBLOCKS

This pattern the opposite of the grid. Superblocks encompass large areas with no public streets. They are largely accessed by pedestrian movement or alternative forms of transportation. Freed from the car, more of the surface environment is turned over for community use and buildings may be more densely arrayed with a finer grain of mixed uses.

Pedestrian clusters: Group buildings in various ways around pedestrian movement systems. Vauban in Freiberg, Germany clusters units in different ways, an environment where private cars are forbidden, people move by tram or by foot and shops and services are closely integrated.

Pedestrian matrix: Represents a return to preindustrial were pedestrian spaces and buildings were interwoven. Masdar, Abu Dhabi, will have no cars and tightly spaced buildings will shield pedestrians from the sun.

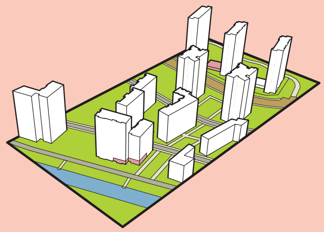


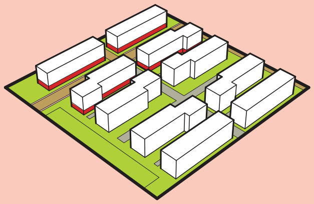
HIGH-RISE SUPERBLOCK

Significantly, none of the clean energy projects we surveyed included the traditional "tower-in-a-park" modernist urban form. Such forms are typically single use, highly oriented to the car, dependent on elevators, and not very energy efficient. Nevertheless, we did find examples of innovative very high density tower forms that were striving also to be pedestrian oriented, mixed-use, low-energy environments.

Linked towers: Connect high-rise structures at an upper level to create an interior public realm with shops and services, potentially reducing elevator traffic. This emerging form is best illustrated by Linked Hybrid in Beijing, which is also heated and cooled by geothermal energy.

Learning from Jinan 2





Learning from Jinan

Jinan, the demonstration city for our research and capital of Shandong Province, is located on the traditional route between Beijing and Shanghai. There it occupies a broad, fertile valley between the Taishan Mountain and the Yellow River. Beneath the city, underground water flowing down from the mountains is forced to the surface by an impervious layer of rock. And so Jinan is known as the “City of Springs.” In ancient times the crystal water flowing from these springs, 72 in all, provided an excuse for the founding of a city. Then, as now, Jinan centered on beautiful Daming Lake, celebrated by poet Liu Fenggao: “Surrounded by lotus, willows swaying on three sides; whole city scene deriving from the mountain, half city being water.”

Today, Jinan has a population of 2.54 million people and is the cultural, economic, and transportation heart of its region. In recent years it has emerged as one of China’s more progressive cities with 18 universities and colleges located in the metropolitan area where more than 200,000 students are studying. These support over 200 research institutes including 10 national laboratories. The focus on technology intensive industries has transformed Jinan from a city supported mainly by textiles to a more diverse economy including information and communications, transportation, appliances, and bio-engineered products. These have attracted a diverse population who live in a variety of neighborhood types.

These characteristics underlie the reasons why Jinan was selected for study:

1. The university presence includes our partner Shandong University, which has played a critical role in collecting detailed data on 27 neighborhoods and thousands of households related to energy use. The research would have been impossible without the hard work of many students and faculty in the school. Additional fieldwork on construction of the neighborhoods is about to be undertaken by Shandong Building and Technical University.

2. The long history of the city and its current diverse population has resulted in a collage of different development forms typical of many Chinese cities. These allowed us to study the form-energy systems of prototypical neighborhoods as described below.

3. Jinan is about to experience significant urbanization spurred by the construction of a new high-speed rail line between Beijing and Shanghai with a major station in Jinan. Located 20 kilometers west of Daming Lake, the station will become the focus for a new town of approximately one million people. This provided an ideal location to explore the design of new clean energy neighborhoods by the Joint MIT-Tsinghua Urban Design Studio.

URBAN PATTERNS IN JINAN

As revealed in studies by Tsinghua University, the urban form of Jinan is composed of distinct physical patterns that reflect the history of the city's development:

2.1. Baotu Spring

2.2. Jinan is located between Beijing and Shanghai


2.3. Daming Lake

1. *Pre 1910: Traditional settlement*—low-rise, high-density courtyard housing organized on hutongs with a central commercial street. This traditional form dates back hundreds of years, and remnants can still be found in the ancient center of Jinan, south of Daming Lake. Updated versions of the courtyard form were built until recently to house working class people: the so-called "urban villages." Zhang-Jia Village, east of the old center, is typical and one of several studied in the research.

2. *1920: Urban grid*—conventional streets and blocks with mixed uses and building types. This model of city form was introduced by the Japanese who occupied the city until World War Two. They developed an updated urban district outside of the traditional city walls in front of the city's train station. Now known as the "Old Commercial Center" (having been replaced by a newer high-rise center), it retains a human scale of streets and spaces and a lively, diverse character.

3. *1980: Enclaves of low-rise slabs*—rows of repetitive, 6-7 story walk-up apartments. These were developed mainly by the government or danweis (work units) to house working class families in China's first wave of urbanization beginning in the 1970's. Standardized projects were developed on available tracks of land often with their own internal street systems, hence the term, "enclave." Over time, these simple forms have been adapted and mixed uses added, so that many are now absorbed into their surroundings. One of the better examples is Dong-Cang, where shops and services, schools, and some public spaces were included.

4. *2000: Tower-in-park*—mainly single-use residential districts consisting of widely spaced 20-30 story towers with surface or underground parking. This form emerged in the 1990's when land reform facilitated private developers who generally sought to fit the maximum amount of housing on large sites in the least expensive way; however, in practice, these projects are not significantly denser than the Grid or the Enclaves. Many are gated communities highly dependent on the car, although they may include a shopping center on the periphery. One of the more attractive is Sunshine 100.

> "Although there are variations, virtually the entire fabric of Jinan is made up of these four simple prototypes."

Although there are variations, virtually the entire fabric of Jinan is made up of these four simple prototypes. Not designed with energy consumption in mind, as a set they provide a good test bed to research the relationships between energy consumption and urban patterns. They also stand in contrast to the rather more complex international prototypes developed with energy efficiency as a key determinant. Student teams in the Joint MIT-Tsinghua Urban Design Studio each began their work by studying one of the four representative neighborhood types to get an intuitive feel for how the prototype was designed and functioned as a form-energy system. Some of their observations are summarized in the following pages.

TRADITIONAL SETTLEMENT: ZHANG-JIA VILLAGE

Zhang-Jia "urban village" is representative of many traditional settlements existing in the Jinan, some dating back to ancient times, such as Furong Hutong in the old city center, which is still graced by numerous springs. Home to working class people, a number of these settlements have been subject to demolition and "renewal." Those that remain stand out as islands in the city fabric.

Zhang-Jia is located in a mixed-use, light-industrial area east of the city center served by a new bus rapid transit line. Originating as an agricultural village, it has an organic form that follows the natural topography, differing significantly from surrounding urban development that engulfed it in the mid-20th century. Land is owned by the village and cannot be sold. This has prevented major changes and led property owners to build additions to their buildings to capitalize on rental income. Today, the neighborhood serves as an entry point for new migrants from rural areas who are predominantly low income. Buildings are only 2-4 stories tall; nevertheless, the neighborhood is a dense fabric of narrow streets and very little open space or vegetation. Strongly defined edges—a canal, two major arterial streets, and a railroad line—help to maintain its traditional layout and promote interior densification. Limited access has resulted in a virtually automobile-free district.

2.4. Cluster

Key features include:

Compact living environments—The original form consisted of traditional one and two story courtyard buildings; however, owners have subdivided or filled in the courtyards and added stories in recent decades. A typical courtyard today is three stories in height and contains up to twenty single-room living units, which share common facilities. First floors may receive little light and common space is often used for storage and parking bicycles or motor scooters. Other adaptations include balconies, rooftop gardens, and solar hot water heaters.
Fabric of narrow, active streets—Due to a lack of open space and small living units, the streets serve as centers of activity. They provide for circulation, socializing, eating, shopping, and entertainment. Typical of hutongs, the streets are too narrow for car traffic; however, diverse activities are supported by a variety of morphological adaptations, including movable street furniture (tables and chairs, display racks, storage, food preparation), elevated stoops (for seating, small gardens, or product display), steps or ramps into workshops, and deployable screen coverings above the street.

Market spine—The main street of Zhang-Jia is a flourishing retail environment nurtured by its dense residential context, a limited number of entry and exit points, and the lack of automobile traffic. Only 4-5 meters wide, the corridor accommodates open market stalls and ground-floor shops providing household goods, fresh and prepared food, clothing, medicines, and other needs for residents in the area. Other activities along or near the spine include laundry, vehicle repair, printing, materials storage, waste disposal, and small-scale manufacturing.

2.5. Main street Zhang-Jia village

Edges and context—Residents rely on the edges of the neighborhood to provide a modicum of recreational space along the canal as well as access to employment via bus lines or in surrounding small-scale industries and commercial establishments.

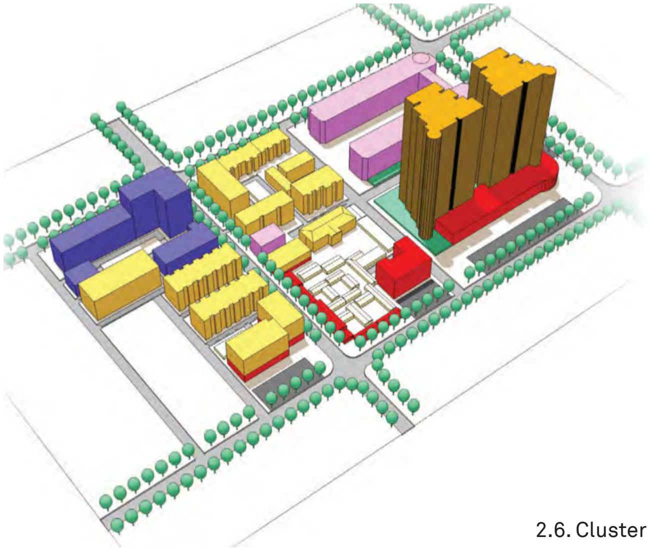
Overall, Zhang-Jia Village has a Floor Area Ratio (FAR) of .72, the lowest density of the neighborhood typologies in Jinan; however, denser versions of this typology could be designed. Energy use by households in Zhang-Jia is relatively low, which may be attributed to the small units, the lack of elevators and cars, and the mixed-use pedestrian environment which provides convenient access to goods and services.

pre-1910

1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

URBAN GRID: THE "OLD COMMERCIAL CENTER"

The urban grid is a European model of development introduced to the city in the earlier part of the 20th century intended to support a new social and physical pattern of living. The form consists of a grid of public streets defining typical square blocks of approximately 180 meters on a side. Over time, the district grew to contain over 100 blocks with several sub-districts and main streets. Within the blocks, no formal arrangement of circulation was defined leading to a rich array of secondary public and private access ways, allies, and courts. In a similar manner, land uses were left to the owners, leading to a diverse collection of building types, heights, activities and uses. While no longer the commercial center of Jinan, today the area maintains a cosmopolitan feel with good access to and within the district.



2.6. Cluster

Key features include:

Connectivity—The Urban Grid is an example of a neighborhood with a multi-modal street infrastructure as the primary organizing framework. While engineered to handle flows of vehicular traffic, the pedestrian environment is also considered, with generous sidewalks, continuous street trees, crosswalks, and protection from cars, creating unusually pleasant walking conditions. Pedestrian and bicycle movement within the neighborhood is enhanced by the scale of the blocks and the width of the streets, which can be crossed easily. The Grid also connects well to the city. The metro train station is easily accessible by foot or bicycle from any part of the neighborhood. More importantly, wider streets connect into the arterial road system, providing convenient access for bus routes which service many stops in the district. Finally, on-street parking (as well as off street) enables visitors to access shops, restaurants and employment. Given the multiple modes of transport available, many of the residents in the Old Commercial Center do not own cars.

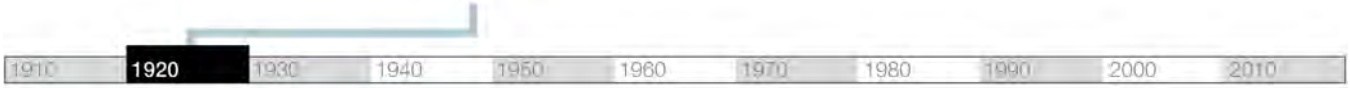
Mix of forms and uses—Within the repetitive grid framework, individual blocks have developed their own character. Some retain their historic fabric and original buildings from the 1920's. Others include dense high-rise residential and office towers next to mid and even low-rise buildings. This density is possible because the public streets allow sunlight to penetrate into adjacent blocks, meeting daylight requirements. In a few cases, the city hospital for example, blocks have been joined together to create a larger campus, which is easy to do without affecting circulation since the grid of streets is highly redundant. Because it can accommodate such diversity, the grid may be thought of as a "form of many forms." This quality gives it great agility so that it is able to accommodate change over time.

Cosmopolitan lifestyle—The daily lives of people who reside and work in the Old Commercial Center may be called more "cosmopolitan" than the other neighborhood types because it brings together a wider range of people, classes, and activities within the frame of a comfortable public realm. They can take advantage of street markets, theatres, an array of restaurants, health services, shopping streets, and meet each other on the streets and sidewalks. At the same time, the interiors of the blocks

2.7. Urban Grid Main street

provide the opportunity for very private spaces and views (even if many of them are filled with cars). Consequently, there seems to be a very a strong sense of community within the neighborhood.

Households in the Old Commercial Center consume slightly more energy than those in the traditional neighborhoods like Zhang-Jia Village, mainly because more people own cars; however, the grid consumes much less energy than the high-rise superblock projects, and it is quite a bit denser. In fact, at FAR 2.72, the Old Commercial District is the densest of all neighborhoods we studied in Jinan.



ENCLAVE OF LOW-RISE SLABS: DONG-CANG

The Enclave urban form is deceiving. These projects appear drab and monotonous, containing row after row of the same housing type and height: the 7 story walk up; however, the simple buildings and relatively generous spaces between them have proved highly adaptable over the years resulting in a more livable environment than originally designed.

The form is a result of optimizing a walk-up building height vs. meeting the minimum sunlight requirements for each unit. This relationship establishes the distance between the buildings, which all face south. The space between buildings was initially left undeveloped, simply paved over to provide access. On the inside, the buildings are composed of repetitive vertical units organized around stairwells with just 2-3 units per landing; therefore, most units have windows on at least two different exposures, providing cross ventilation.

Easily and cheaply constructed, these projects were ideal for housing a lot of people quickly, typically people migrating from rural areas, who considered them to be a 'step-up' because they contained private bathrooms with showers, kitchens and washing machines. In the case of Dong-Cang, the 4300 residents (2000 families) were displaced by a flood and moved into their new homes in 1986. Almost all the original families (or their children) remain on the site, working in nearby industries, institutions and shops.

2.8. Cluster

Key features of this urban form include:

Adaptability—Over time, residents have implemented a surprising number of modifications: converting balconies into sun rooms, making larger windows, extending ground floor units to add shops, and creating outdoor patios, parking, playgrounds, seating areas, and storage (which has become a valuable commodity in China as people accumulate more belongings). In the case of Dong-Cang, this ability for families to meet changing needs through customization has enabled multiple generations to remain on the site.

Space between—The unplanned space between the buildings has been claimed for a variety of purposes. In Dong-Cang paths and places provide areas for social interaction, including potted gardens, small parks with mature trees, exercise areas, shared alleys, shopping streets, and more. In these spaces, shading and airflow create cooler pockets in the summer and provide insulation in the winter resulting in comfortable multi-use outdoor living rooms. In some areas, buildings have been replaced with hospitals, kindergartens, and offices, adding services and spatial variety. Finally, some of the space has been converted to parking for cars, bikes, and scooters. In Dong-Cang about one-third of the residents own cars, which they park in two shared lots or wherever they can find space.

Active edges—The edges of most enclaves, facing major public streets, have been filled in with stores, restaurants, entertainment, professional offices, garages, and workshops to serve the residents and the larger city. The edges also provide access to public transport. Overall, the edges complete the neighborhoods providing services that are unavailable inside, resulting in a more or less mixed-use, walkable system.

2.9. Character images

The overall density of the enclaves at approximately 1.81 is considerably less than the Urban Grid, but the households consume about the same amount of energy in general. Among the enclaves, Dong-Cang is the most efficient, operating at about the same level as a Traditional Urban Village despite having many more cars. This may be explained by the attractiveness of its public realm, which draws people out of their apartments, and the availability of shops and services.

"TOWER-IN-PARK": SUNSHINE 100

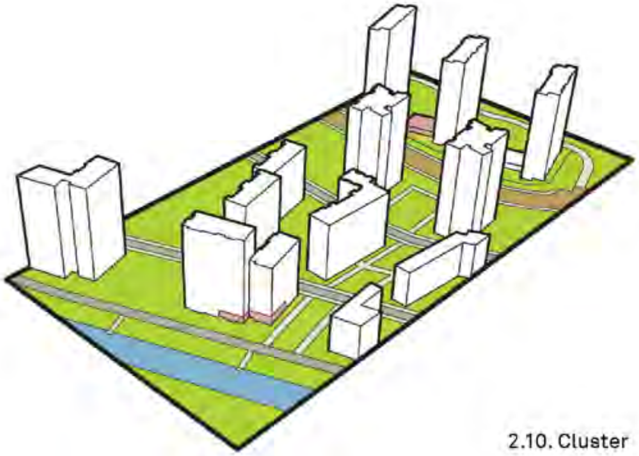
The high-rise superblock pattern represented by Sunshine 100 is the newest to be examined. These have been built over the past 15 years by private developers to provide housing for the newly emerging middle and upper-income households who have benefited from China's economic development. Most are gated communities located on very large sites outside the older city center, remote from employment and dependent on the automobile. They may provide amenities such as underground parking, a club, larger units and central air-conditioning but few if any on-site shops and services.

Key elements of this urban form include:

Residential high-rise buildings—The single-use structures range in height from 20-40 stories and may be slabs with single loaded corridors facing south or point powers, which offer good views and ventilation (if the windows are operable, which they often are not). Typically all apartments open onto interior corridors and there is a single entrance on the ground level. This means the ground space surrounding each building is neither useable by residents of adjacent apartments, nor does it create a public realm, which would be the case if other uses such as shops and services were developed.

Large open spaces—Because of their height and the shadows they cast, the towers must be placed relatively far apart to meet China's strict day-lighting requirements. Added to the building conditions noted above, this means that most of the site is devoted to planted green space which lies unused by the residents. Alternatively, these spaces could be used for parking, although at Sunshine 100, parking is located underground beneath the buildings; nevertheless, these spaces and the parking must be maintained and secured at some expense of money and energy.

Separation from surroundings—As gated communities, the large superblocks can be accessed from only one or two locations, and interior streets are entirely private. This has several consequences. First, access to public transportation by foot is inhibited, since the distance from one's building to a gate and then a stop can be considerable. Second, car travel is increased since they must move around the site to enter or exit. Finally, the private nature of the site, plus the scale of surrounding arterial roads, typically precludes any development along the edges that would connect to the city. There are exceptions to this. Sunshine 100 has developed a shopping and office complex at the edge designed to serve the wider area; however, residents of the complex must use a car to get there.



2.10. Cluster

Because of the characteristics mentioned above, the Tower-in-Park urban form consumes much more energy than other typologies in Jinan. At the same time, while these projects may appear dense because of the tower spacing, their FAR is not dramatically higher than other forms of development. Sunshine 100, for example, has an FAR or 2.37, about 20% less than the Grid.

2.12. Underground parking entrance

2.11. Sunshine 100

ENERGY RESEARCH IN JINAN

Extensive studies of Jinan's four neighborhood types, undertaken in 2009-10, have provided a more scientific understanding of the relationship between urban design and energy consumption. The data collected also provided the basis for developing a first version of the Energy Proforma, discussed in more detail in **Chapter 4**.

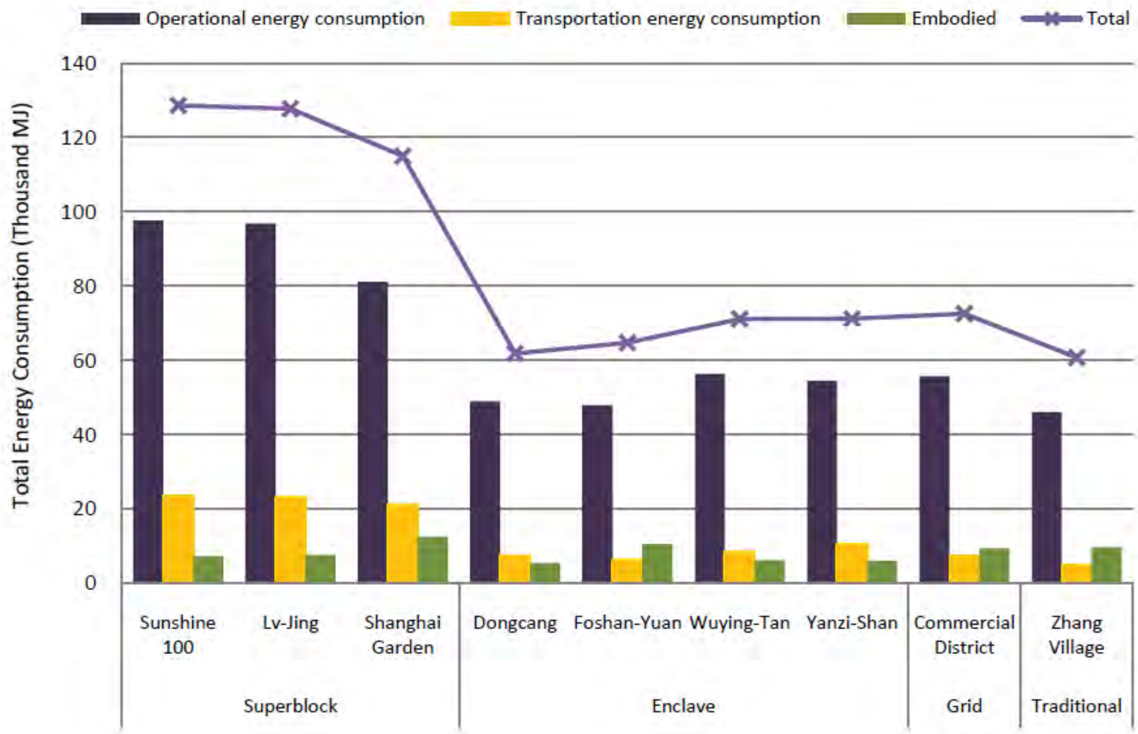
The research to date has involved collecting data on each of 27 neighborhoods across the central urbanized area of the city, shown in the accompanying map. Shandong University conducted surveys of up to 300 households residing in each of the neighborhoods, collecting information on household weekly travel activities, in-home energy expenses, fuel choices, vehicle and appliance ownership, individual attitudes, income, and other socio-demographic factors. Beijing Normal University gathered data on the physical and land-use characteristics of each neighborhood through GIS interpretation and field survey. Shandong Building and Technical University will survey site and building construction. The neighborhoods studied represent all of the fours types discussed above, although there are more enclave and high-rise superblocks reflecting their predominance in the city fabric.

Subsequent analysis of the data occurred across each of the three energy consumption areas. Calculations for embodied energy use were based on the quantities of materials in each neighborhood, estimated using the Chinese building code (MOC, 2005). The study accounted for five major construction materials in estimating embodied energy consumption—concrete, steel, timber, glass and asphalt—deriving energy intensity factors for construction materials from the literature

2.13. Nine initial neighborhoods surveyed in Jinan

and multiplying these factors by the quantities of materials used in each neighborhood. Estimates of the operational energy use accounted for: in-home energy consumption based upon the self-reported energy bills (electricity, gas, coal, and centralized heating); and, common area energy use in a deterministic linear estimation using neighborhood physical attributes as inputs. Transportation energy use was based on estimates of weekly travel patterns (distances by mode) reported by each surveyed household and estimated energy intensity factors for each mode.

Based on the embedded, operational and transportation energy estimates, the energy consumption and GHG emission patterns across neighborhoods were compared to form typologies and income groups. In addition, to statistically test the relationship between neighborhood form and household energy use (travel and in-home), multivariate regression techniques were used to control for other influencing factors such as household socio-demographics and

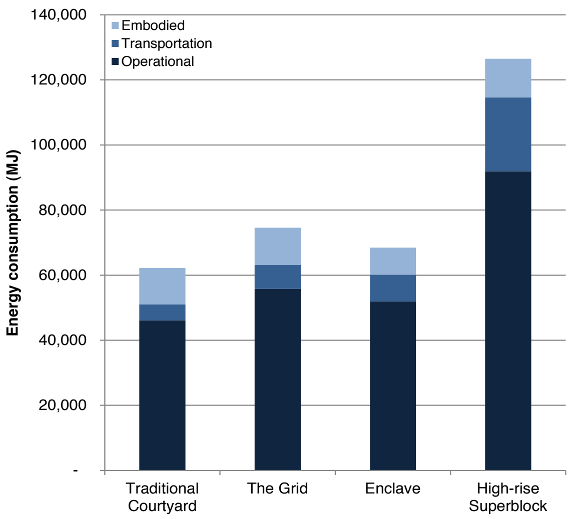


2.14. Energy consumption by neighborhood

attitudes, thereby revealing the "pure" impact of neighborhood form.

ENERGY CONSUMPTION OF THE TYPICAL PATTERNS

The accompanying tables show both the total and the per dimension (i.e., transportation, operational, embodied) energy consumption per household of each neighborhood organized by typology. Also highlighted are the aggregated results for each typology. Note that only the first nine neighborhoods in the study are included in this analysis.



2.15. Energy consumption by prototype

Comparing across neighborhood typologies, we see that households in the high-rise superblock typology consume much more energy than the others—up to twice as much. Households in the low-rise enclaves, like Dong-Cang, and the traditional neighborhoods, like Zhang-Jia Village, have the lowest per household energy consumption, although the variation among all the non-tower-in-park forms is relatively modest. Looking more closely at the individual dimensions:

- *Operational energy*—The graph confirms that operational consumption (in-home and common area) accounts for the largest estimated share, approximately 71-79% of estimated household total energy consumption in each case. The high level of operational energy in the superblocks is due mainly to the need for vertical transport of people, water and goods, but also to the operation of parking facilities (lighting, ventilation) and vast open space.

  Another factor may be usability of common space. The relatively low operational energy of the enclave typology may be partly explained by the abundance of "outdoor living spaces" that are heavily used by the residents, resulting in less use of air conditioners and other energy in the apartments. By contrast, residents of the urban grid are less likely to find these spaces, and residents of high-rise superblocks are either culturally disinterested in using their outdoor spaces, feel that they're inaccessible, or perhaps most likely, simply lack the mixed-use ingredients that make them desirable.

- *Travel energy*—The results revealed a significant relationship between neighborhood form types and transportation energy use. Households in the high-rise superblock projects consume on average 2-3 times more transportation related energy than those in other neighborhood types, while only modest differences exist among the grid, enclave, and traditional forms. Household use of the automobile accounts largely for the difference in energy use. The single use nature of the "tower-in-park" projects requires that households use automobiles to accomplish all the daily activities of living; this is reduced in the other types by the presence of shops, schools, services, and employment made accessible by walk-able environments.

  National and international comparison puts the travel energy consumption estimates for Jinan into perspective. Although Chinese urban households still consume a relatively low level of transport energy compared to those in the developed countries of the West, energy consumption levels in the high-rise superblock households already approach those in affluent Asian cities.

- *Embodied energy*—The enclave neighborhoods have relatively low embodied energy consumption per household (with the exception of Foshan-Yuan). Shanghai Garden, a "tower-in-park" superblock, has the highest embodied energy per household. The great bulk of embodied energy per household, 84%, comes from the residential space constructed in each neighborhood. Comparing across neighborhoods, this reaches a high of over 12,000

MJ/household/year in Shanghai Garden and a low of less than 6,000 MJ/household/year in the enclave of Dong-Cang. Interestingly, the traditional typology, Zhang Village, with low rise buildings prevailing, has relatively high embodied energy per household (10,400 MJ/household/year). This might be due to characteristics such as the high building coverage (54%, the highest among all 9 neighborhoods) and the relatively low household density.

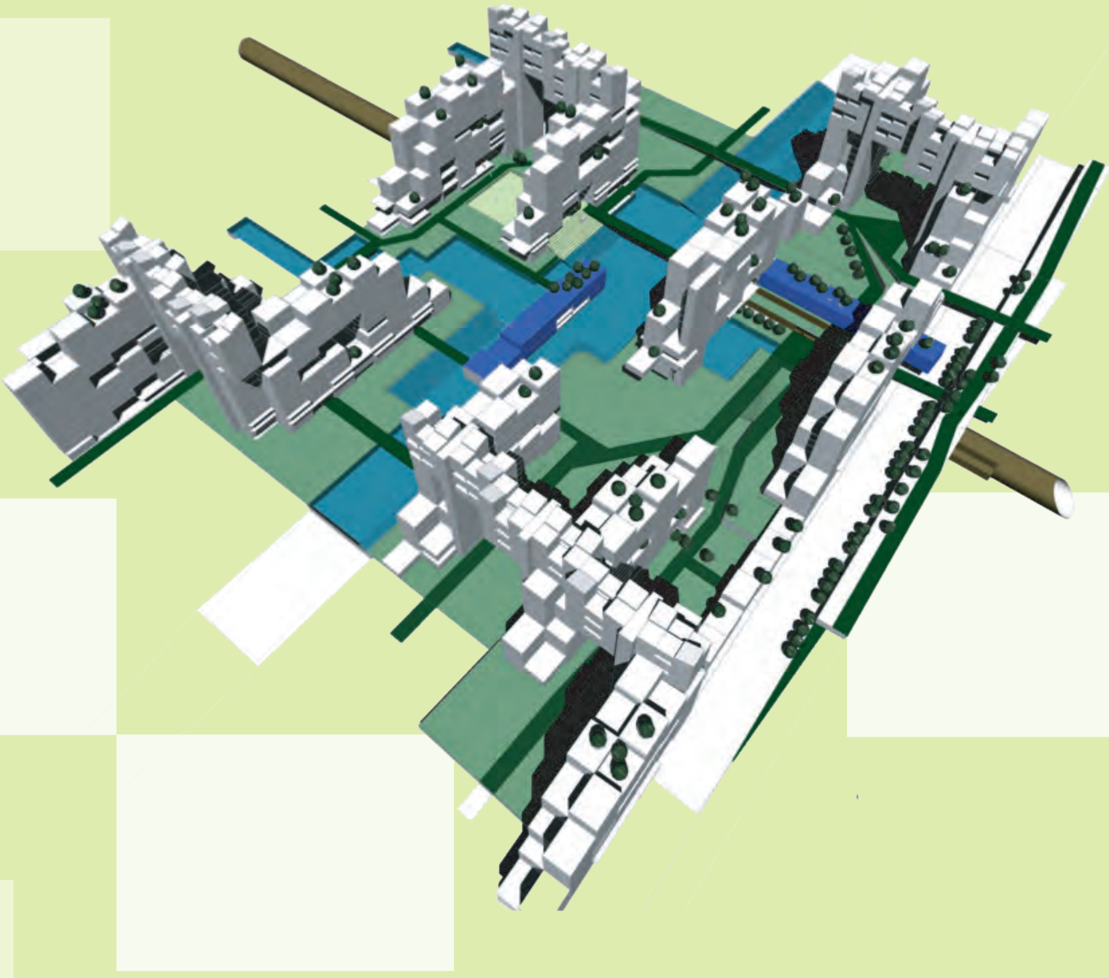
The empirical studies in Jinan begin to dimension the attributes of neighborhood form that affect energy consumption. The findings also help explain some of the strategies used in the international cases and prototypes discussed in Chapter 1 and hence become more generally applicable. Among the findings:

- *Operations*—Heating, cooling, elevators, water and lighting account for the greatest amount of energy consumption. High-rise "tower-in-park" schemes consume significantly more energy per household than other types in this regard. Gridded blocks, and enclaves with slabs, favored by many of the clean energy cases, consume much less energy; high-density, low-rise schemes consume the least energy of all.
- *Travel*—Travel to work, school, shopping, and friends is the second most important factor in neighborhood energy consumption. The "tower-in-park" typology generates the most travel and related energy use, since such projects include few services within walking distance and typically require a car for the daily activities of living. Compounded with the operational energy findings, this helps to explain why none of the international clean energy cases were of this type.
- *Embedded energy*—Materials and construction practices are a rather small factor in the overall energy picture and seem to vary less across neighborhood types in Jinan, perhaps because most construction in China is of reinforced concrete. More important to embedded energy may be the fact that some project types are more prone to peripheral locations requiring extensive new infrastructure and land development, such as the "tower-in-park." Traditional and grid forms are more adaptable to existing urban situations requiring little new infrastructure.
- *Energy production*—While not included in our original studies, work is now underway at MIT to investigate the inherent potential of various forms of neighborhood for renewable energy production. This is equally important to achieving the goal of clean energy design and an important component of the Energy Proforma. For example, in Jinan, the low-rise enclave projects were most likely to include roof-top solar hot water collectors. This is consistent with our scan of international clean energy development, in which low-rise, high-density, solar-sensitive clusters were the most prevalent forms we encountered.

A complete discussion of all findings from the nine neighborhoods and their implications appears in *Making the Clean Energy City in China: Report on Year 1*. (MIT and Tsinghua University 2010)

Five New Clean Energy Neighborhoods

3



Five New Clean Energy Neighborhoods

A DEMONSTRATION PROJECT

The urbanization of Jinan is about to accelerate dramatically with the introduction of national high-speed rail service. The new Jing Hu high speed railway will connect the city directly with Beijing and Shanghai and to handle the traffic an enormous new station is under construction in the western area of Jinan. Along with the travelers will come pressures for development, and so the city has planned for a new town in front of the station that may house up to a million residents.

Interested in promoting green development, the City of Jinan suggested the town site as a location to explore new forms of clean energy design. The site provided an ideal, real world setting for applying the knowledge and tools gained from our research on Making the 'Clean Energy City' in China. And so, in the summer of 2010, 30 students and faculty in the MIT-Tsinghua Joint Urban Design Studio convened in Jinan for five weeks of intense activity. This chapter presents the results of the work.

The conceptual master plan for Jinan West is illustrated in the accompanying diagram. Prepared by an American consultant, it is a typical 20th century Euclidean layout with separated land uses organized around a central axis, running east-west perpendicular to the station entrance. The axis contains enormous public spaces, high rise office buildings, and a cultural center. To the north and south are residential areas composed of high-rise superblocks that decrease in density moving away from the axis. Similar plans for new towns can be found all over China.

OBJECTIVES AND PROCESS

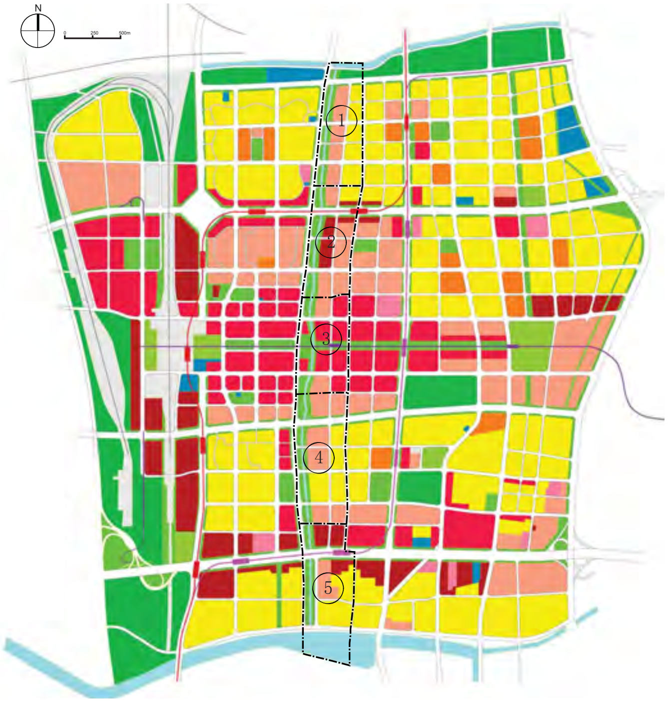
Rather than take on the whole plan, teams were focused on one of five contiguous areas, which together formed a cross section extending north-south across the center of the site. This ensured that all conditions were considered, from the dense commercial spine to less dense residential areas on the edges of the town. The cross section follows the route of an existing drainage canal intended to be a recreational spine.

Teams were given the option to either accept the master plan as provided or to suggest alterations to the land use distribution or overall framework; however, they were asked to retain the general alignment of the proposed transportation network and the configuration of major roads.

To begin, the teams investigated the design of existing prototypical Jinan neighborhoods being studied in the energy research, described in **Chapter 2**, whose energy performance was known. These plus the international cases provided a benchmark and inspiration to create not only more energy efficient, but also more livable neighborhoods. Energy efficient urban form that does not possess qualities of high livability is not only inadequate but also problematic in introducing a more sustainable way of living. (Luckily in our experience the two goals are mutually reinforcing.)

The urban design work proceeded across several scales, from a context plan for the whole area to a "cluster" plan, representing the most basic generative form underlying their proposed urban pattern, to details of buildings and public spaces. Emphasis was placed on the invention of new form-energy systems that might be applied elsewhere, rather than idiosyncratic designs.

At each step in the process, an alpha version of the Energy Proforma was used to inform the work, providing feedback on the energy performance of the projects as they evolved. This differs dramatically form the typical urban design process where energy consumption cannot be assessed and therefore is not a prime consideration. Our hypothesis was that—as with a financial proforma — continuous testing, adjustments and feedback during the complex process of moving from concept to



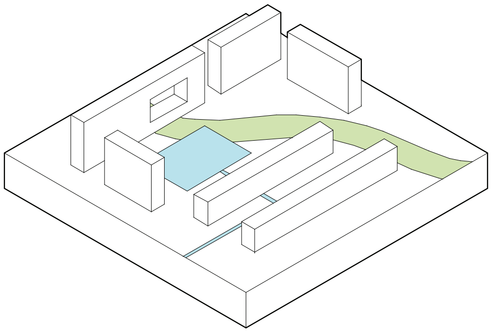
3.1. Plan of of new town in west Jinan and five project sites

developed proposal would lead to more refined product in which all elements of the design reinforce each other — an optimal form—energy system.

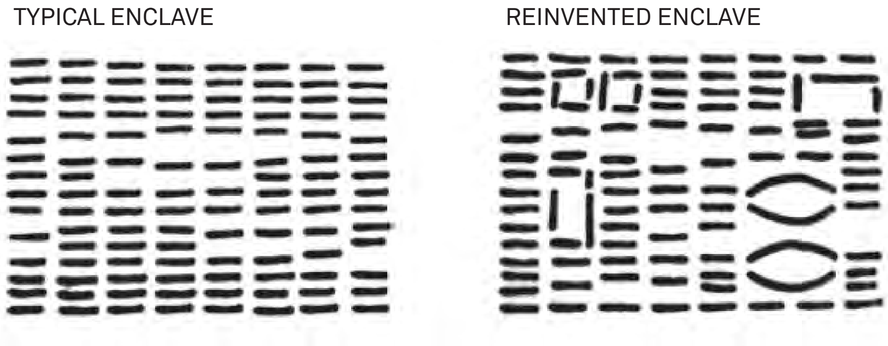
The work of the teams, illustrated on the following pages, confirms the value of the approach. All represent new systemic prototypes of clean energy urban form. They exceed the energy performance of even the most efficient neighborhoods now in the city, while creating high quality, livable neighborhoods. As the five teams worked independently, the five final schemes do not necessarily create a coherent plan for the whole cross section. Instead, they propose different form interventions that could be abstracted and replicated to create an overall town.

RE-INVENTED ENCLAVE 1

This project takes as its inspiration the many enclaves of walk-up slab buildings that blanket Jinan and much of China. As we learned from our study of Dong-Cang and other enclaves in Jinan, the simple, repetitive urban form is actually quite energy efficient. This is due partly to the buildings which have no elevators and orient south to receive good sunlight and ventilation. An equally significant factor is that the neighborhoods have been adapted over time to improve the private and public living space of the residents, and to mix in uses—shops, schools, health centers, restaurants—reducing travel and making the enclaves both more livable and energy efficient. The Reinvented Enclave leverages the good aspects of the typology to create a more advanced urban form. The scheme embraces simplicity and repetition, but introduces site features that break the uniformity of the system. These involve changes in topography, wind courses, water courses, and nodal spaces that serve multiple needs. Vehicular traffic is deemphasized while providing for bikes and pedestrians. Finally, the building type has been reinvented to make more diverse, livable, and efficient dwellings.



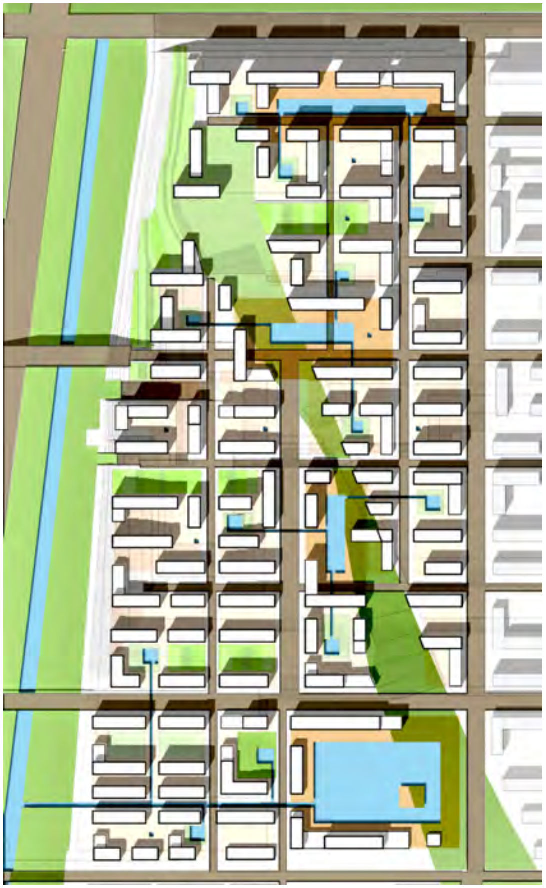
3.2. Overview rendering showing landscape and architecture adaptations allowing water and wind flows respectively



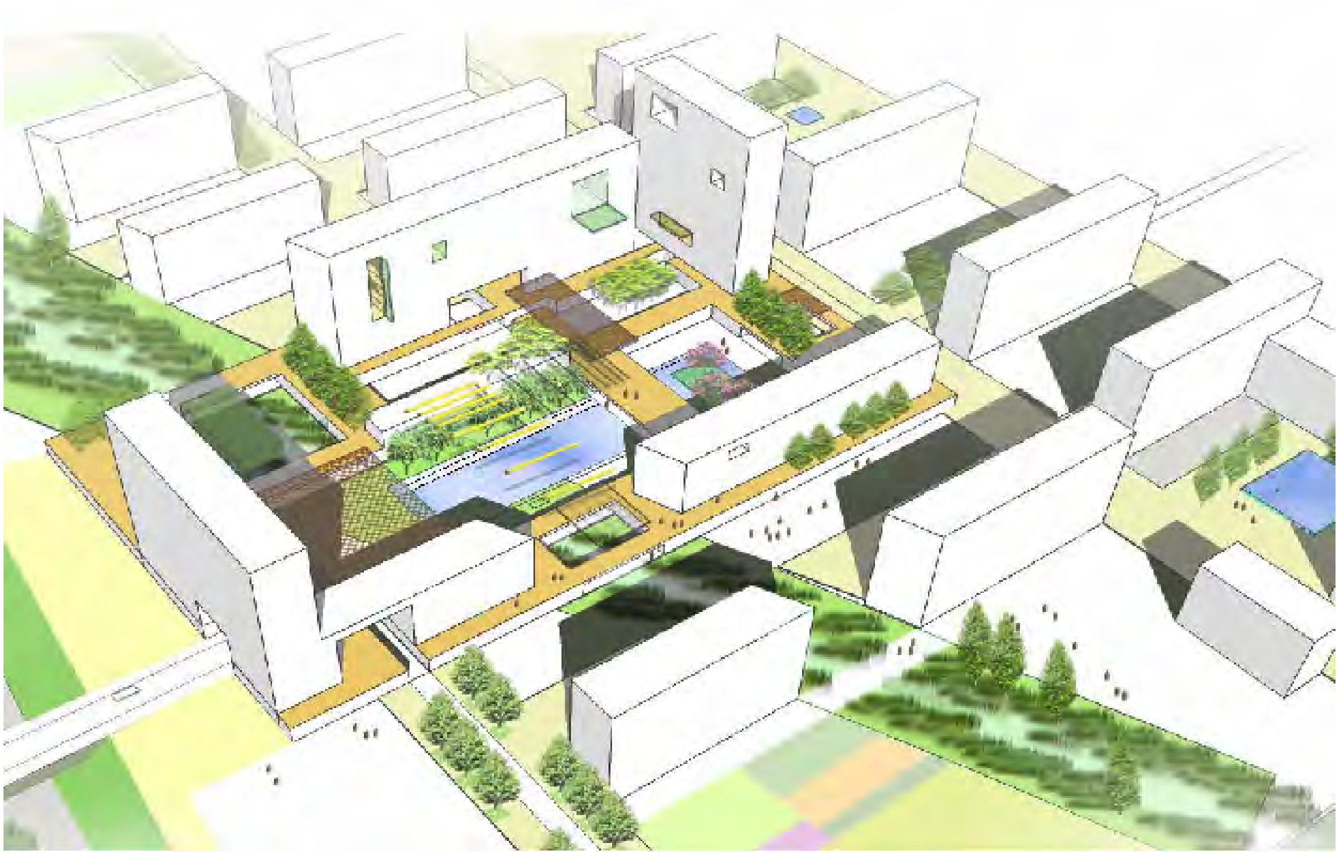
SITE ORGANIZATION

Generative ideas for the form are apparent in the neighborhood scale plan. A semi-grid of blocks provides the framework for horizontal slab buildings facing south. These are interrupted by wind and water features which introduce diversity and a higher level of organization to the site. A wind course and greensward cuts through the entire neighborhood, funneling summer breezes from the southeast that are cooled by water features. These water features in turn provide focal points for organizing "village centers" in the landscape, much as the ancient settlement of Jinan clustered around natural springs.

Day-to-day activities and amenities are clustered within these mixed-use village centers, accessible within a 5-10 minute walk from surrounding residences. The centers are connected by larger roads, but only limited parking is offered on site to encourage use of an extensive network of exclusive pedestrian and bike paths. Overall, the system blends a familiar type of housing and lifestyle with a higher level of amenities, technology, and energy consciousness.



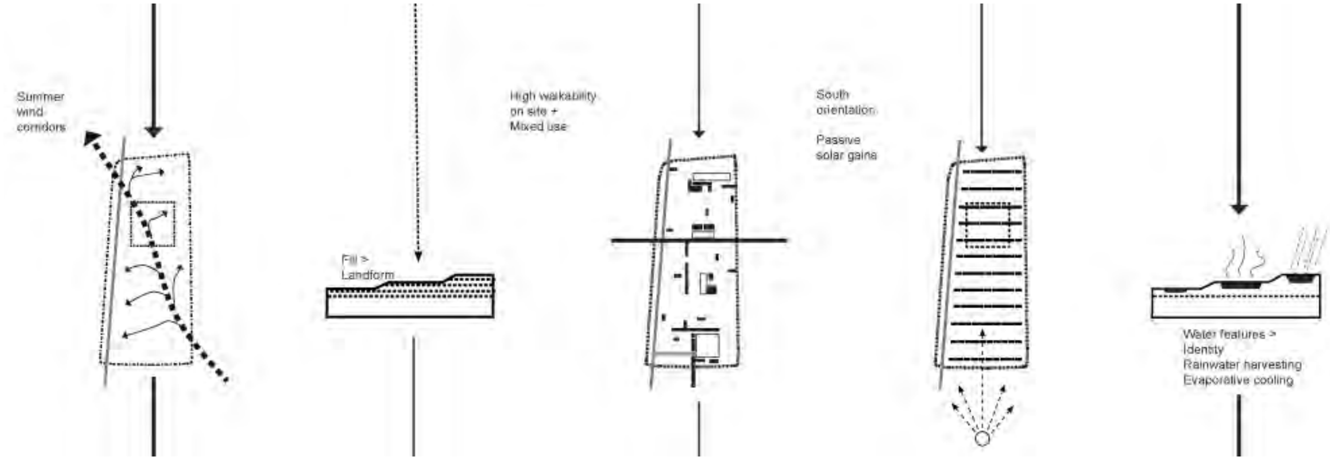
3.3. Neighborhood plan


3.4. Bird's eye vew of a building cluster surrounding an open space intented to mitigate the heat island effect

The view of a “village center” illustrates how these various features come together. The building cluster is organized around a body of water set within an outdoor community space. During the summer, evaporation fed by southeast winds contributes to a pleasant microclimate. During the winter, the water acts as a thermal mass warming outdoor spaces. Trees are complemented by a system of movable canopies that provide shade (or sun) and collect solar energy. Taller buildings on the north side of the cluster prevent cold northeast winter winds from entering the space, while shorter buildings located on the south side admit sunlight. Each center has a different character. One may serve the entire neighborhood with offices, markets, shopping, a movie theatre, cultural institutions, and school. Others would be more locally oriented, including such services as a kindergarden, health center, post office, and convenience store.

A key feature of the concept is to create an artificial topography on the site and reduce its embodied energy by making innovative use of construction debris. Currently, the site is covered with a deep layer of rubble left from the demolition of prior buildings and roads. Typically, such rubble is trucked away and either deposited in landfills or reclaimed as construction material, requiring an enormous expenditure of energy. The Reconsidered Enclave project proposes an alternative approach of reclaiming the rubble on site to form gabion building blocks and to re-shape the topography.

3.5. Existing site rubble



3.6. Energy strategies at the neighborhood level

3.7. Neighborhood bird's eye view showing how the aggregate urban form can serve to funnel and harness predominant winds

3.8. Neighborhood bird's eye view showing how the aggregate urban form can serve to funnel and harness predominant winds

As illustrated in the section, the rubble would be graded to gradually slope from a high point on the north edge of the site to the natural grade at the southern edge and covered with clean earth. The resulting landscape would augment natural water flows, but also reinforce the desire for greater exposure to desirable southern winds and sunlight. In the design, water serves as a functional cooling feature as well as an aesthetic landscape element. The slope of the new ground provides a gravitational path for rainwater collection and gray-water infiltration across the site, reducing water consumption while increasing the amount of quality habitable outdoor space. As secondary benefit of using the rubble as fill, is that it greatly reduces the need to excavate for below-grade infrastructure, basements, with further saving in embodied energy.

These site moves, aggregated with the building and cluster design discussed above, result in an integrated form-energy system in which all the elements work together. As seen in the view, the greensward crosscutting the site serves multiple purposes: providing space for outdoor recreation and living (outdoor living rooms); a path for pedestrians and bicycles; a channel for natural water flow, integrated wetlands, and recharge; and a funnel for desirable southeast summer winds to help cool outdoor and indoor rooms. Five large wind turbines are strategically placed to harness predominant winds and mark the most important community spaces. These serve as symbols of the project.

ARCHITECTURE AND SPACE BETWEEN

This same integrated approach has been taken in the design of buildings and associated outdoor areas. Natural ventilation, and passive solar principles guide the building form. All are single loaded, and most are oriented south and spaced according to required sun-angle design regulations. Echoing the site theme, buildings are designed to naturally harvest rainwater and channel it by gravity to cool interior spaces. As illustrated in the view, small-scale water elements located on balconies and outside south-facing windows create a building-scale microclimate through evaporative cooling. The same water may used to irrigate small gardens and green roofs, further moderating indoor temperatures and giving the buildings a distinctive appearance. On the interior, movable partitions allow for spatial flexibility while maximizing cross ventilation. Transom windows and adjustable elements remove warm air during the summer, or allow cool breezes to enter, part of a permeable façade system that can be adjusted to the climate and weather.

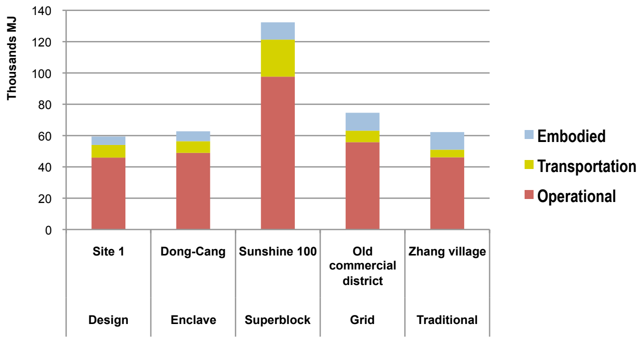
As seen in the section, buildings and adjacent spaces are designed to work together. Rain and grey water from the buildings and run-off from site are collected in pools, cleaned by natural means and recycled for use in the project. These same water features provide an amenity for the public environment. Moveable sun-screens shade the lower levels of buildings and adjacent outdoor spaces and double as solar collectors. The whole works as a lining machine to reduce resource consumption and enhance livability.

3.9. Detail of a typical building and its energy harvesting formal features

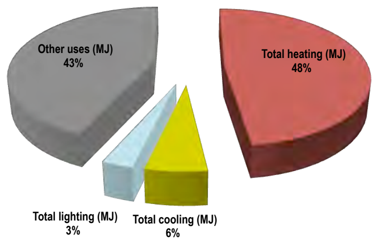
3.10. Cluster section illustrating water catchment area achieved through ground plane manipulations

KEY FORM-ENERGY CONCEPTS: RE-INVENTED ENCLAVE

- The new urban form improves upon conventional enclave developments which are simple and monotonous but basically energy efficient.
- Site-wide features and "village center' nodes are introduced to add diversity and service community needs. Mixed uses in the village centers are convenient to residences and reduce the need for travel.
- Rubble that currently exists on the site is reused to configure topography and as a building material to save embodied and operational energy.
- An artificial slopped topography transforms the landscape to augment natural hydrological flows. The use of the rubble not only eliminates the need to excavate for below-grade parking structures but also acts to accentual the benefits of wind and water ecological functions.
- The form of the new ground facilitates rainwater collection and grey water infiltration and remediation, therefore reducing water consumption.
- The urban form channels desirable south-east summer winds through the site to facilitate natural ventilation, while blocking undesirable cold north-east winter winds.
- The wind corridor also forms a greensward crosscutting the neighborhood, providing space for integrated wetlands, water features, and public open space amenities.
- Five large wind turbines generating electricity are strategically placed along the wind corridor to harness energy and mark important community places.
- Buildings are single loaded and most are oriented east-west and spaced according to required sun angle design regulations. Unique water and wind features incorporated into the design create a beneficial micro-climate.
- Reduced vehicular circulation is achieved through limited vehicular accessibility, an extensive bike and pedestrian system, and easy accessibility to all day-to-day needs.

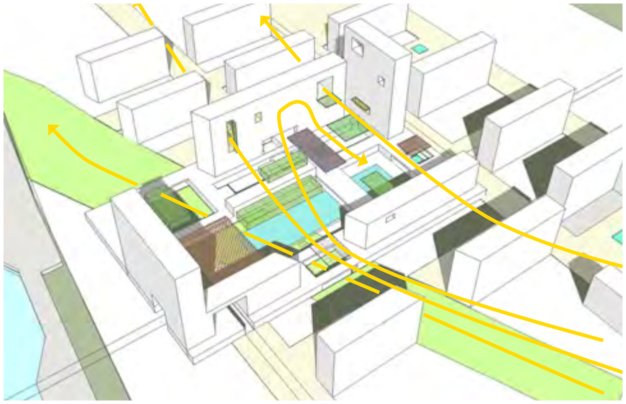


3.11. Annual energy consumption per Household (MJ)

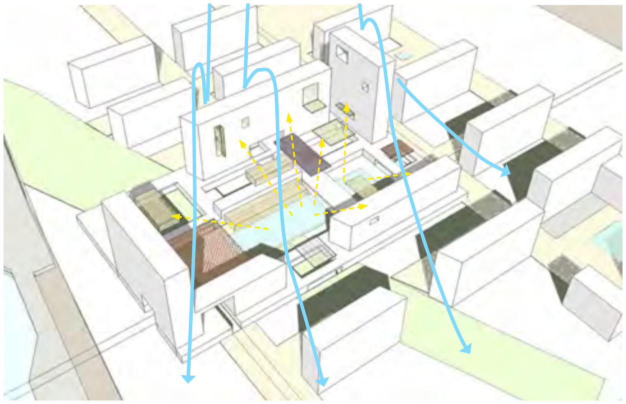


3.12. Annual operational household energy consumption by use

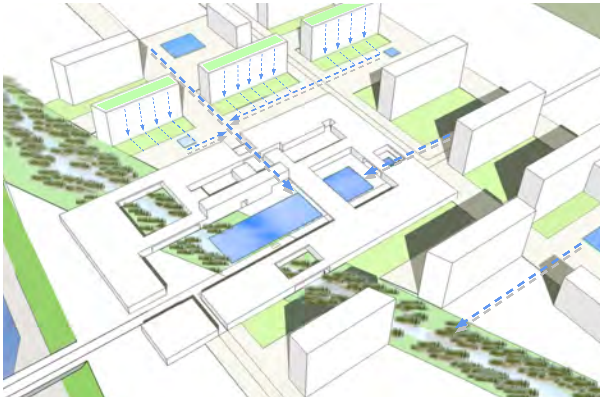
WIND - SUMMER



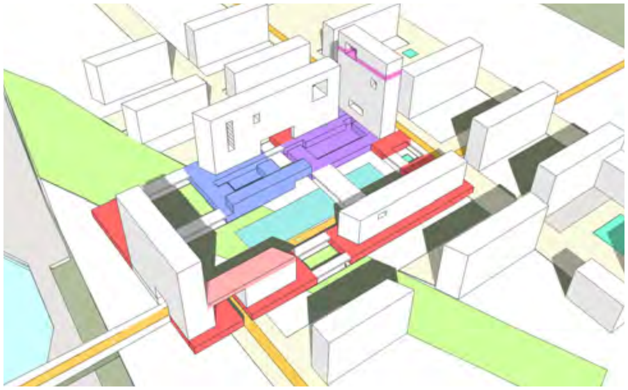
WINTER



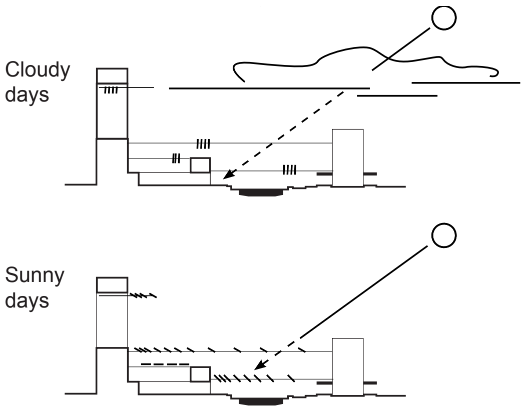
WATER

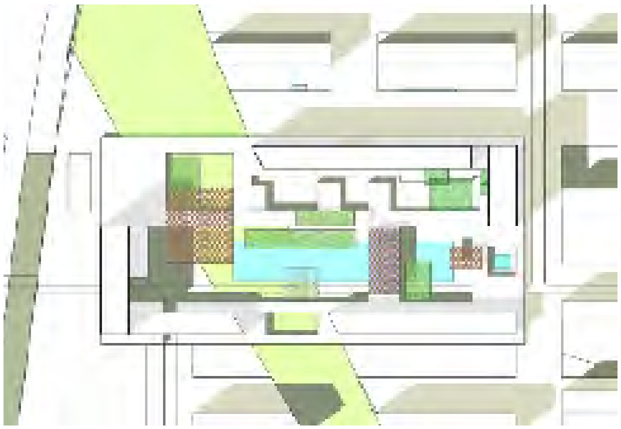


MIXED USE



SUN-MOVEABLE SHADING



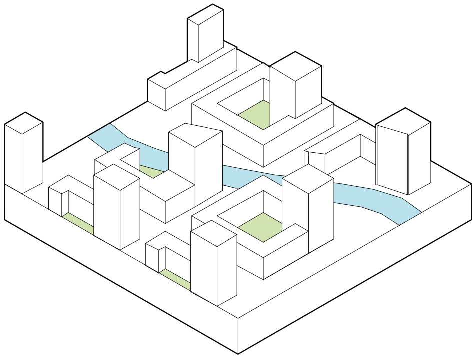


HIGH LOW RISE 2

Traditional low-rise development can create high quality, low energy, places to live and work but cannot satisfy the density currently demanded in China. High-rise typologies have the potential for greater density but, as currently observed in the Chinese urban landscape, are not particularly dense, or energy efficient, because the buildings must be widely spaced. Dependent on the car, such developments do not typically incorporate convenient access to employment or any of the other necessities of daily life found in traditional, more integrated urban environments. In response to these contradictions, the new High-low Rise prototype exemplifies how urban form can simultaneously address energy consumption and livability considerations.

The High-low Rise prototype is inspired by the traditional urban village form as seen in the Zhang-Jia Village and Furong Hutong in Jinan. As noted in the previous chapter, these traditional urban forms are characterized by low energy consumption patterns directly attributable to a highly mixed-use development of the ground plane with housing on the floors above. This arrangement offers the residents of the neighborhood

3.13. Shopping on a street well defined by perimeter blocks

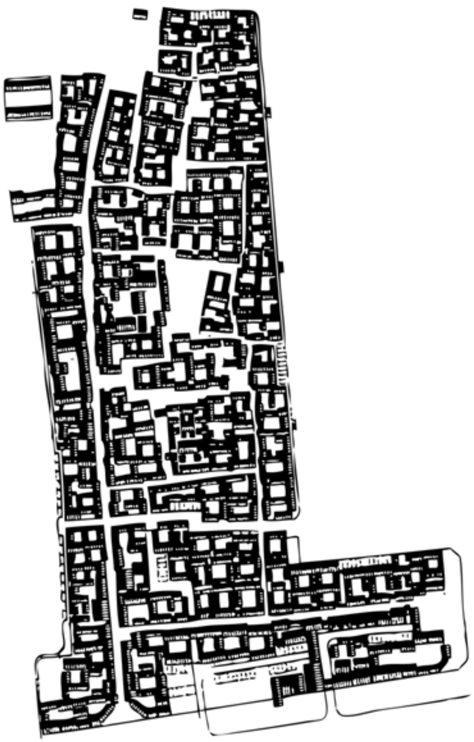


3.14. Bird's eye view showing a mixed typology of towers and perimeter blocks, green roofs and courtyards easy access to employment opportunities, shopping, neighborhood services, schools, and even recreational offerings (in the natural springs and pools) reducing travel and operational energy consumption.

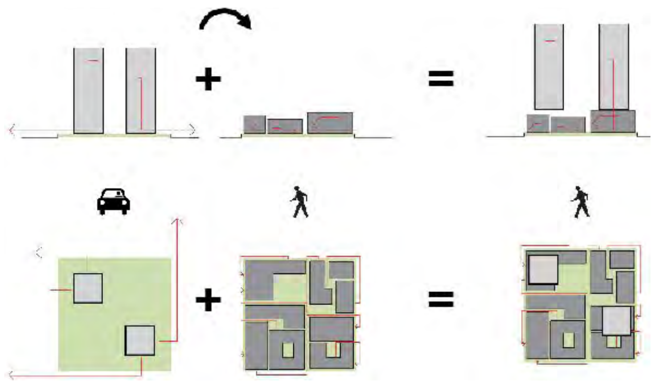
These neighborhoods can accommodate such diverse kinds of activity yet still deliver good living conditions because of the courtyard arrangement of the buildings. A fabric of courtyards can accommodate intense activity along public streets, while at the same time providing relaxed semi-private living space within the courts. These courts also moderate the microclimate increasing comfort in the summer and winter and reducing energy consumption. To capitalize on these advantages the new prototype integrates a contemporary adaptation of traditional fabric with high-rise structures.

GENERATIVE IDEAS

As shown in the accompanying diagrams, the High-low Rise urban form is composed of distinct building clusters. The prototypical cluster consists of a perimeter of low-rise structures defining an interior courtyard, and includes at least one high-rise tower. The central courtyard provides semi-private open space for



3.15. Traditional porous plan texture



3.16. Generative diagrams

3.17. Mix of uses in a well proportioned streetscape

3.18. Cluster plan showing how perimeter blocks adapt to landscape features and a variety of open spaces the residents and moderates the microclimate. It also provides space for geothermal wells that assist heating and cooling. To minimize casting shadows on adjacent structures, the high-rise buildings are strategically placed to take advantage of the courtyard spaces.

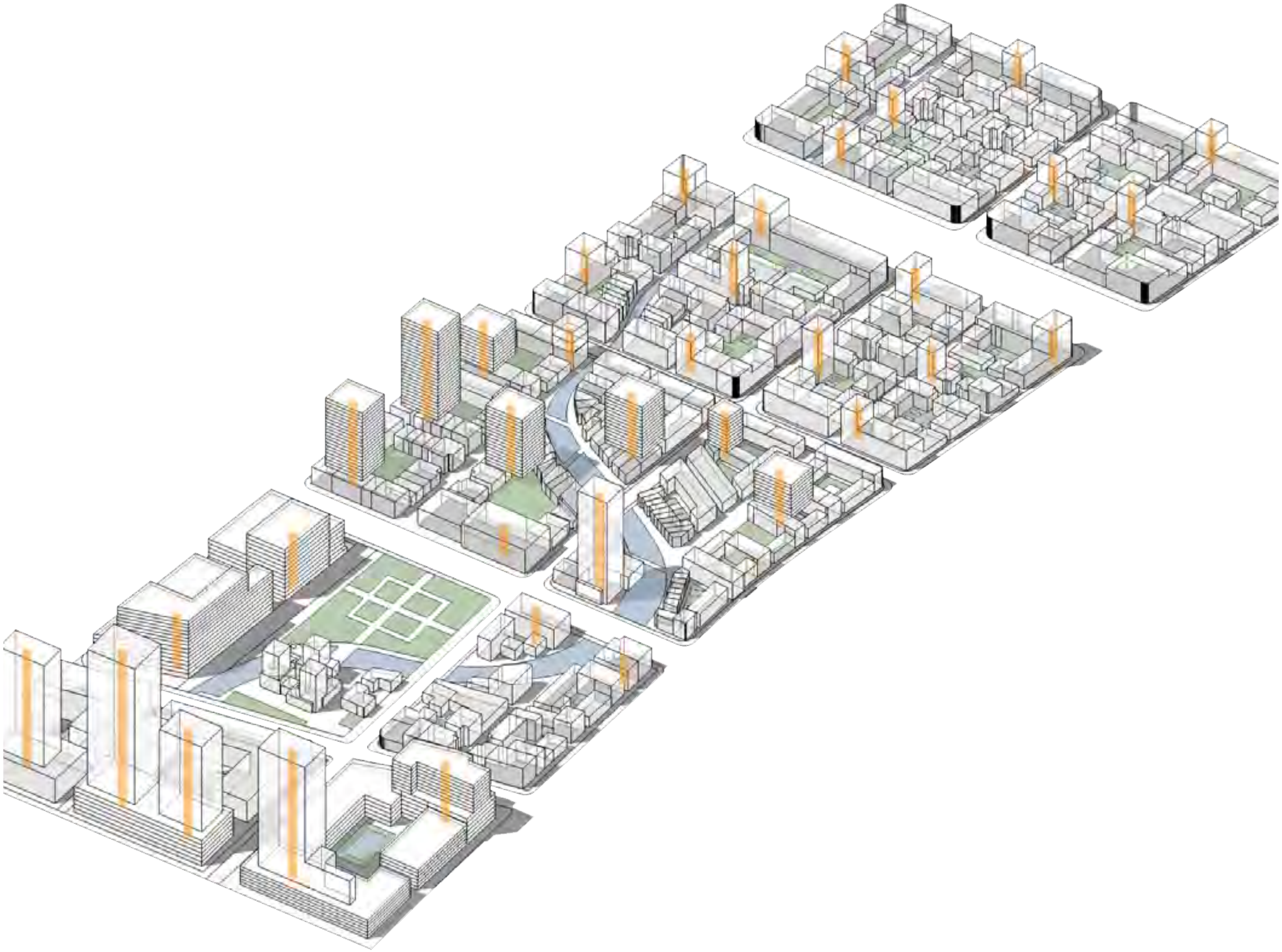
Added together, the clusters yield a fine-grained, mixed-use environment that includes high-rise development within a conventional grid of human scaled streets and blocks. The density of this new prototype is considerably higher than the "tower-in-park" developments of Jinan, such as Sunrise 100. Yet the new design offers a pleasant urban experience, characterized by increased livability, walkability, and activity options. The cluster plan illustrates a section of the proposed neighborhood along the canal, near the center of town. There is a clear hierarchy of access and public spaces, ranging from intense retail, restaurant and entertainment activities along the canal, to services developed on the streets, to semi-private interior courtyards for residents and school children.

3.19. Site plan showing a gradient of textures and uses

SITE ORGANIZATION

Moving up in scale, the neighborhood site plan demonstrates how the system can be adapted to serve various uses and densities. Overall, the neighborhood is unified by the canal, which meanders north-south across a loose grid of streets and blocks, providing a distinctive, continuous public realm. Along the way, it passes through three distinct zones of activity. The north is primarily a residential district with supporting community services and shopping. The center of the neighborhood is characterized by highly mixed land uses, pedestrian, and tourist activity oriented mainly around the canal. The southern portion—close to the center of town—is predominantly commercial, containing offices and several key cultural institutions. In all areas, the courtyard cluster and the integrated High-low Rise building pattern is prominent.

Note that the courtyard form is loosely applied, adapted in scale and shape to fit local conditions and the demands of different types of uses. In the north, the pattern is fine grained, with a smaller scale grid of streets and building footprints. To the south, the



3.20. Site axonometric view showing elevator shafts grain becomes coarser to accommodate larger scale structures. Looking more closely, in one case two courts have been combined to create a larger interior space, elsewhere there is no space at all or the perimeter form has been broken to admit sunlight. As a result, while the pattern is consistent overall, each courtyard, street and public space is unique: the pattern is fractal.

At all scales, the theme of water is carried across the site. In addition to the canal, water dots the landscape of courtyards, moderating the microclimate and sustaining vegetation. This also hearkens back to the traditional fabric of Jinan where the courtyards were developed around natural springs.

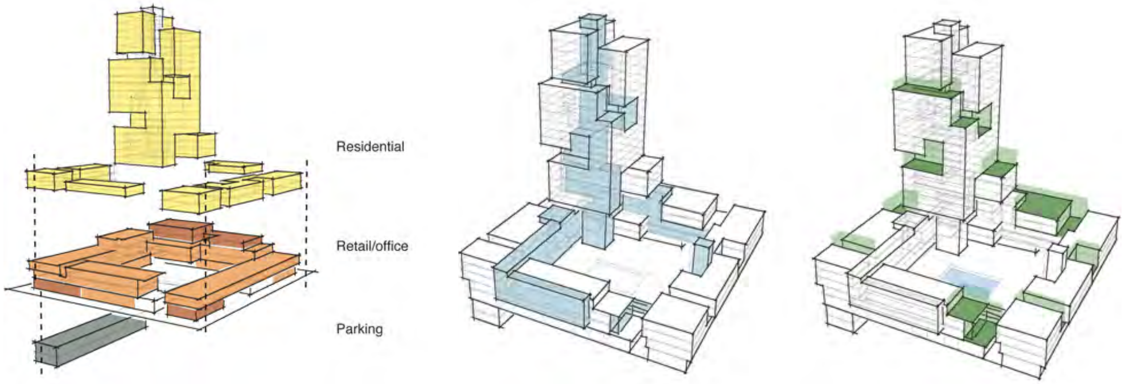
BUILDINGS AND SYSTEMS

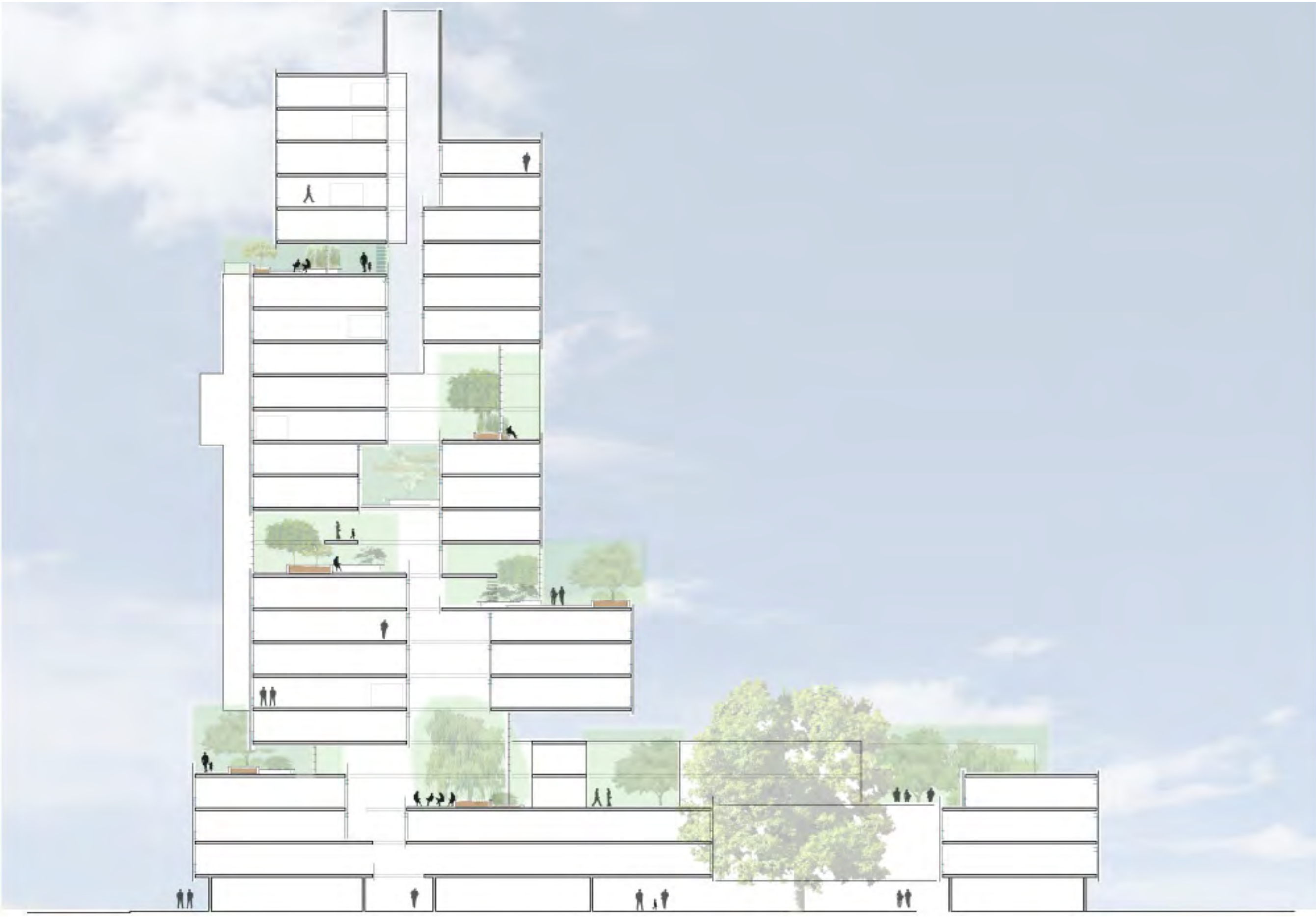
An unusual feature of the scheme is that high and low rise elements of each courtyard cluster are designed to act as an integrated unit from an energy perspective. Thus each tower is designed with an interior ventilation atrium that can naturally draw air from the entire complex. Through an integrated building-heat exchange system, spaces connected to the atrium expel either hot or cold air depending on the season and the time of the day. Additionally, floor plates constructed of concrete core slabs provide for unit-to-unit exchange of conditioned or heated air. The open floor plan allows for adaptability as the needs of residents or other users change and offers a way to divide space to create discrete temperature zones. The combination of the open floor plan with the central atrium offers natural ventilation, limiting the need of HVAC usage and decreasing operational energy consumption.

3.21. Rendering of typical tower - perimeter block

The functionality of the system is enhanced by the creation of multi-level interior gardens, which like 3-D courtyards help to clean and moderate the atmosphere inside the building. Centralized heating, plumbing, mechanical, and electrical systems that serve the entire cluster contributes to material efficiency, the maximization of the usable space volume and the adaptability of the units. Finally, integrating a high-rise tower with walk-up buildings on the periphery minimizes the use of elevators.

The High-low Rise typology yields a dense mixed-use neighborhood of high accessibility that provides residents with daily amenities, sufficient FAR, and meets sunlight requirements, all within a realistic design that can be replicated throughout the city at different scales. This new prototypical urban form outperforms the energy consumption of “typical” high-rise developments in Jinan at a rate comparable to the older, lower-density developments of the city, partly by encouraging pedestrian and non-automobile travel.

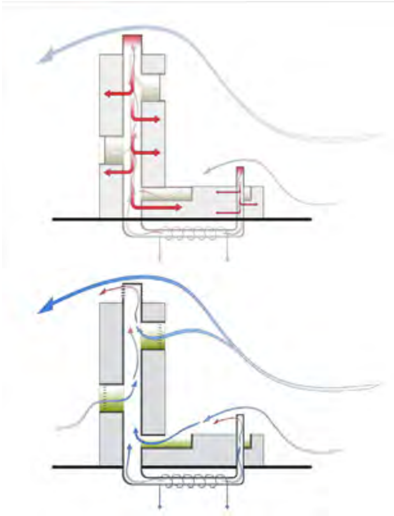




3.22. Cross section showing green roofs, planted terraces and courtyard

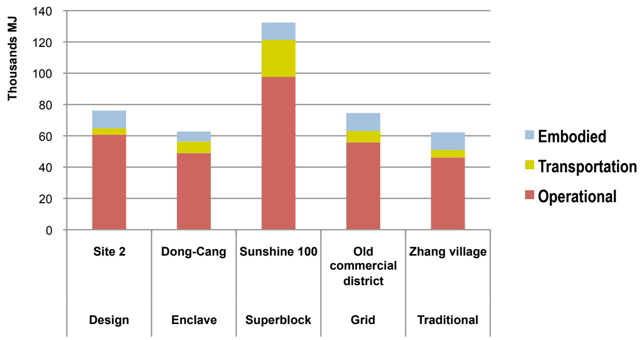
KEY FORM-ENERGY CONCEPTS: HIGH-LOW RISE

- The integration of high-rise with low-rise forms creates a high density neighborhood that is human scaled and energy efficient, combining valuable qualities of the two prototypes.
- The new urban form provides services and amenities that residents need daily within close walking proximity creating a highly functional and livable environment.
- The basic unit of development consists of a mixed-use perimeter block of 4-6 stories enclosing an interior courtyard, and includes one or more high-rise towers. The courtyard provides semi-private space for residents (or workers) in the cluster, and moderates the microclimate. It also provides space for geothermal wells which can supplement heating and cooling.
- Towers are carefully placed in each cluster to insure adequate sunlight in all residential units and beneficial shade in the summer months.
- Clusters are organized into a semi-grid of streets and pathways defining an active public realm. This basic pattern is loosely applied across different uses and scales, adapted to conform to local conditions.

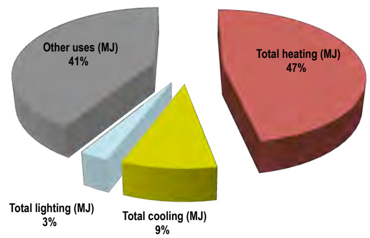


3.23. Natural cooling scheme

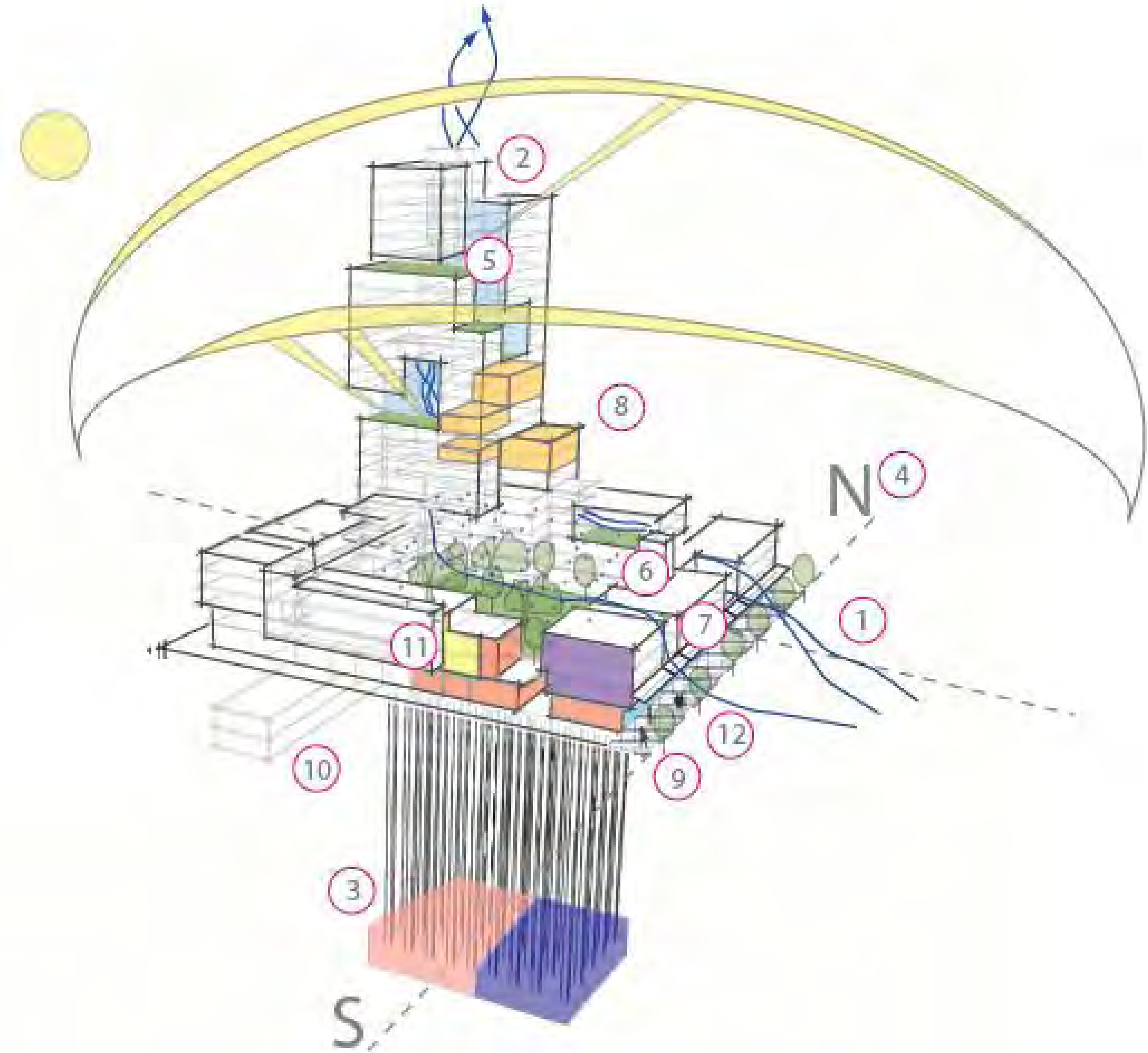
- A canal meandering across the grid creates a zone of special spaces and activities, while connecting all zones of the neighborhood. Water is a theme throughout.
- High-rise buildings in the cluster are designed with interior vertical spaces that serve as wind towers, drawing air naturally from all parts of the cluster. The high-low rise concept includes an integrated heating and cooling system among commercial areas in the bottom and the residential areas in the top, balancing energy demands and reducing overall consumption.



3.24. Annual energy consumption per Household (MJ)



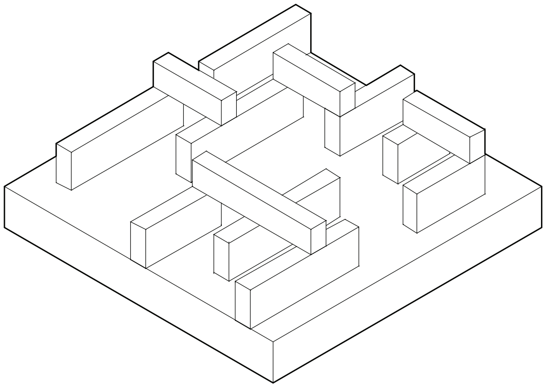
3.25. Annual operational household energy consumption by use



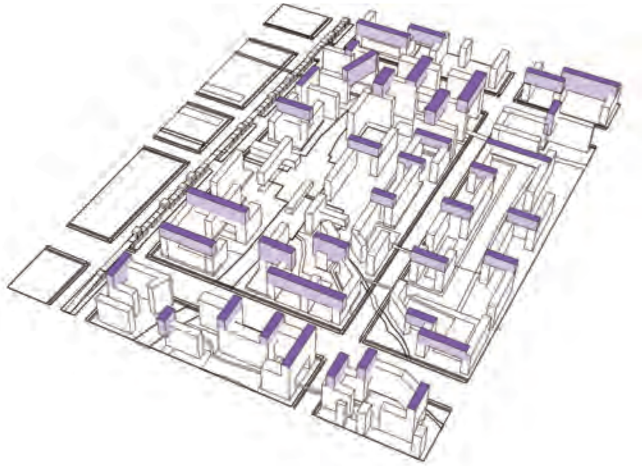
3.26. Form - energy components

CRISS CROSS 3

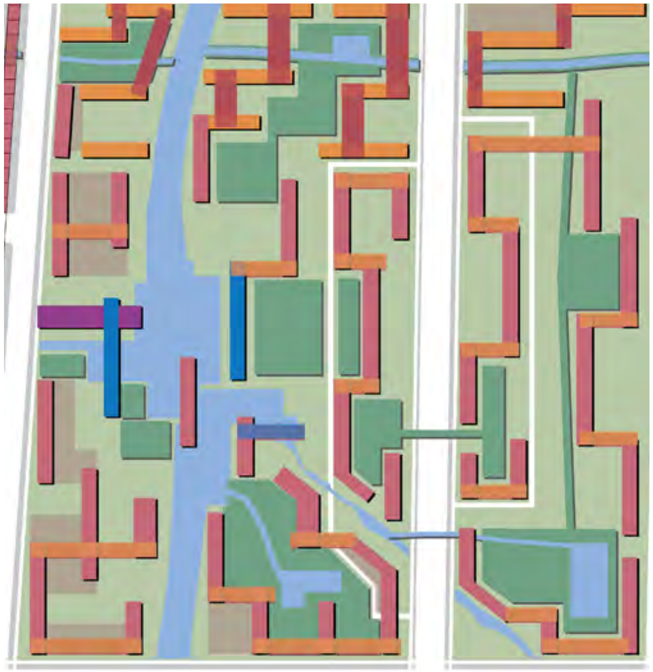
The proposal for a new central business district illustrated in this prototype offers an alternative model to contemporary high density city design in China. Inspired by the "Old Commercial Center" of Jinan, which is organized on a rectilinear grid, CrissCross integrates land uses within a new building envelope formed from a hybrid of east-west and north-south structures. Lower level north-south structures contain offices, commercial functions, and all of the employment opportunities found in business center. These are connected at the upper levels by east-west residential structures. This enables residential development—which must orient south—to coexist with commercial development yielding a highly integrated and efficient urban matrix.



3.27. The Linked Slab building, the basic unit of the Criss-Cross cluster typology



3.28. A heterogeneus grid of perpendicular buildings

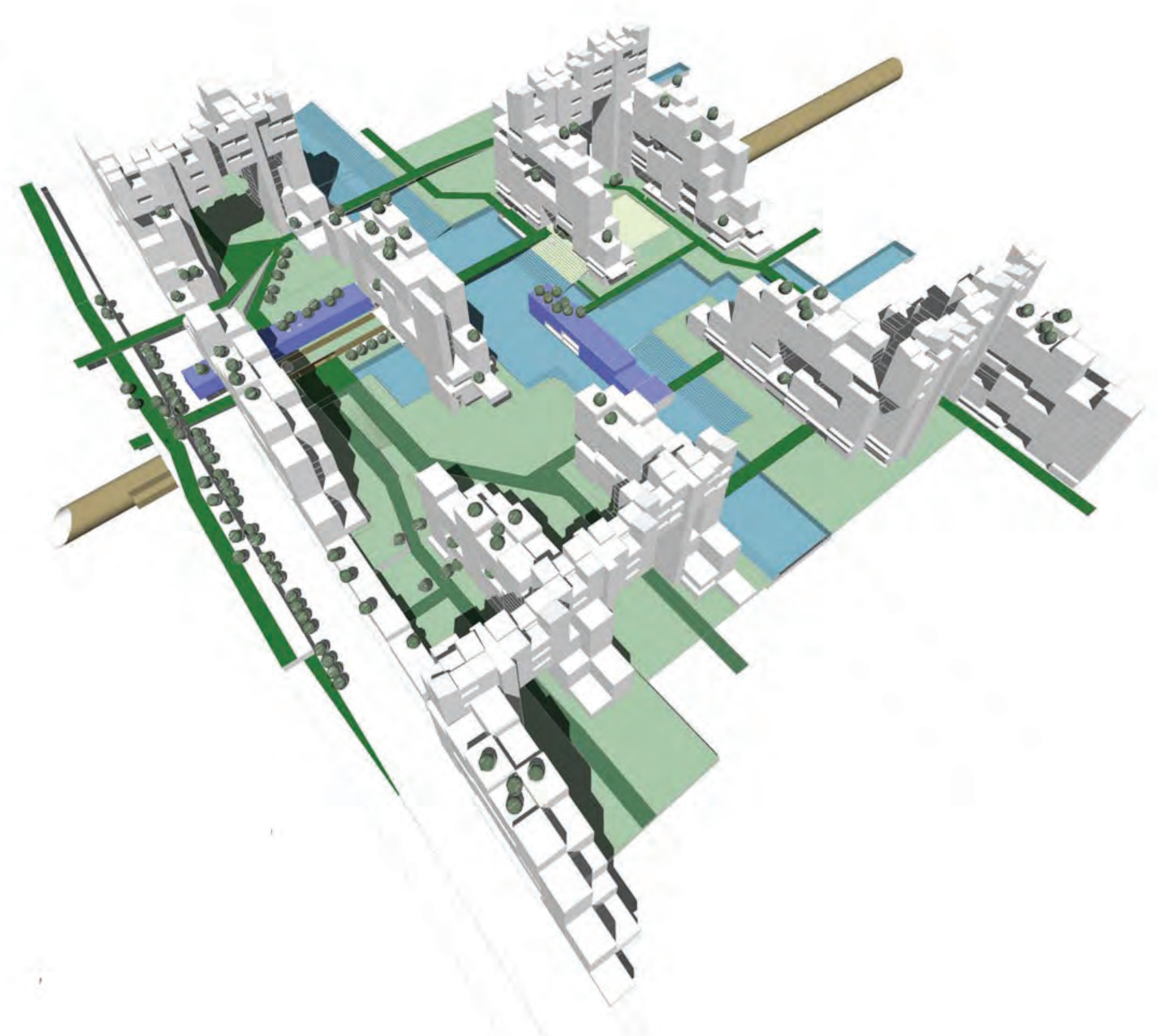


3.29 Site plan showing N-S slabs and suspended E-W links

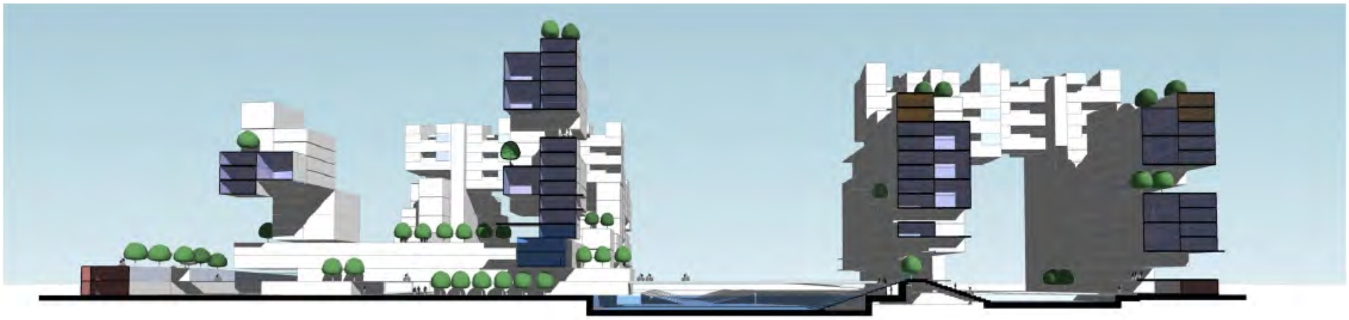
GENERATIVE IDEAS

The mixing of a central business district with a substantial residential community—including supporting institutional and civic programming—creates the potential for a vibrant environment that is inhabited throughout the day and night by various user groups. Nodes are created within the Crisscross form to support different civic functions. For example, the plan illustrates a regional cultural center for Jinan, organized around a transit stop and major water feature at the center of the site. The center is linked to other community nodes by the main canal and intersecting east-west branches. These waterways break down block sizes without the addition of vehicular roads and organize a network of pedestrian and bicycle paths that connect the clusters. The emphasis on pedestrian and bike circulation creates the potential for a scenario in which biking or walking is actually more time-efficient than driving. Additionally, the canals organize a rainwater collection and grey-water reclamation system across the site to provide useable water for urban agriculture.

Other major site features are illustrated in the diagrams. Commercial buildings are oriented north-south in the southern portion of the site, allowing southeastern summer winds to penetrate the development. Atop the commercial buildings, east-west oriented residential wings become gradually taller from south to north across the site to capture maximum sunlight. In the northern area, the orientation of commercial structures also becomes east-west to block winter winds.

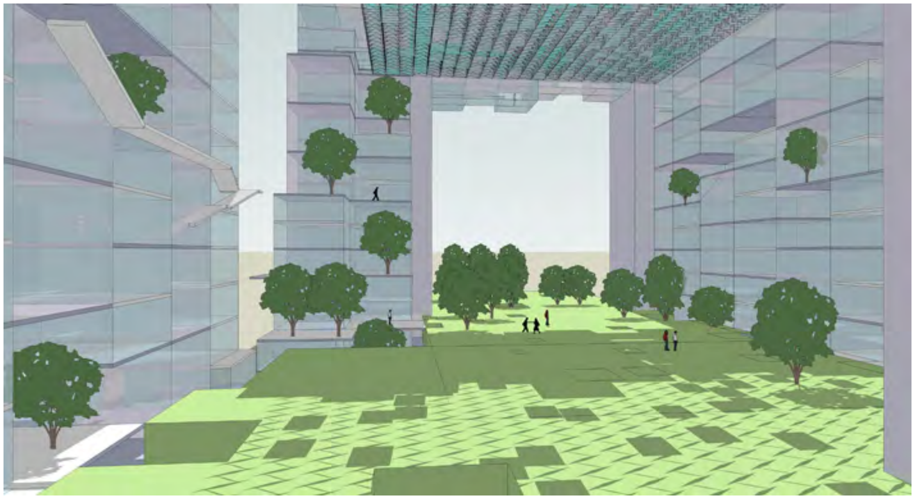


3.30. Bird's eye view showing green spaces, non-motorized circulation and a finely textured building envelope



3.31. Section showing the distinct levels at which outdoor life takes place at the variation of the ground plane

3.32. Section detail



3.33. Public space. Shading devices also serve as solar collectors

Both man-made and natural ecological systems support new ways of living and working that reduce incentives to use the automobile yet increase time-efficiency between neighborhood centers and transit stops. Parking, accessible only from roadways along the perimeter of the site, is located in ground-level garages that underlie each of the clusters. The ground level garage structures reduce the need for excavation and ventilate naturally, lowering embodied and operational energy costs. Their roofs are planted to create raised courtyards designed to offer recreational opportunities and landscape elements that moderate the microclimate.

BUILDINGS AND SPACES

The building articulation suggests perforated and terraced building structures that increase ventilation across not only individual buildings but the overall site. On the building scale, vertical louvers are incorporated along the east and west facades of commercial and

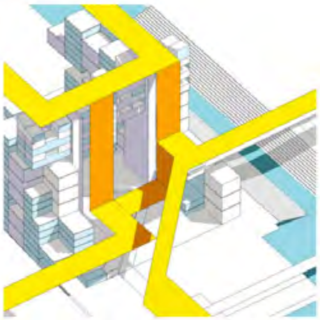
3.34. Detail of the meeting point between a slab building and the elevated link office building structures to shade interior spaces from sunlight. Correspondingly, horizontal louvers are incorporated along the north and south facades of residential building structures. The elevations designed for all units optimize cross-ventilation.

3.35. Individual units assemble into a whole.

On the site scale, a system of moveable shades cool and protect open spaces in the clusters. The CrissCross form creates a variety of outdoor spaces for public, semi-public, and private activity. Outdoor green spaces of various sizes, introduced at multiple elevations and integrated with design elements that capture rainwater, support opportunities for agriculture, horticulture, and community recreation. The interaction of the outdoor with indoors spaces, the interplay of canals and greenways and considerations for sunlight exposure and natural ventilation are the driving forces behind the design.

The buildings create a three-dimensional urban environment including all of the functions of living. As shown in the diagram, retail, service uses and parking occupy the lover levels of the complex. Office and institutional spaces come next, concentrated in the north-south wings. Residential apartments are located at the top, linking the complex together. In between the residential and office wings are "live-work" units designed to service the growing trend toward at-home employment. Living and working units are designed to be flexible over time and to optimize sunlight and

3.36. Different sectional layouts of individual units



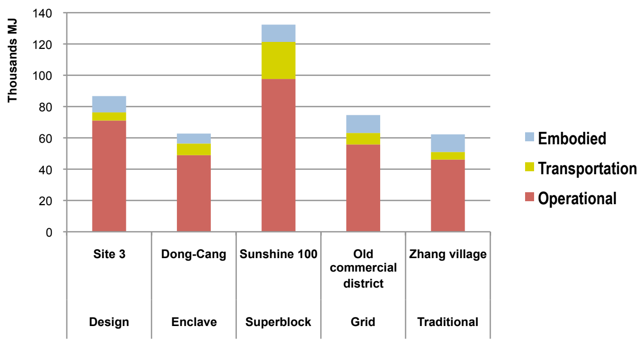
3.37. Circulation

3.38. Axonometric showing assemblage of distinct unit types natural ventilation. To respond to the unique needs of the Chinese household, where multiple generations often live in one apartment, the units are designed to allow transformation over time. Vertical transportation and movement is shared by all the uses, creating a complex but efficient 3-D public realm

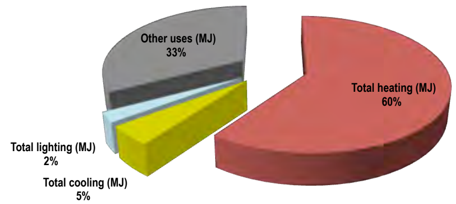
The CrissCross prototype achieves an FAR of over 4.0 and much better energy performance than observed in typical high-rise developments in Jinan, yet it provides all of the mixed use metropolitan lifestyle found in the Old Commercial Center; in sum: a new urban center for the 21st century.

KEY FORM-ENERGY CONCEPTS: CRISS-CROSS

- Vertically integrated urban uses are incorporated with a new hybrid building envelope formed by the intersection of east-west and north-south structures. The resulting high-density form is highly integrated and efficient, promoting a livable, vibrant 24 hour urban environment.
- East-west oriented residential wings are situated atop commercial buildings to allow maximum daylight exposure.
- Commercial buildings are oriented north-south in the southern portion of the site to allow southeastern summer winds to penetrate the development, while on the northern portion of the site, programs and placements are reversed to block northern winter winds.
- Buildings become gradually taller from south to north across the site in order to capture maximum sunlight.
- Flexible and temporal spaces adapt to changing needs across seasons and over time.
- Nodes of activity in the community are connected by the canal system, which also defines a bicyclist and pedestrian transport system that emphasizes the non-vehicular transportation
- The canal system also accommodates rainwater collection and grey-water reclamation to support new endeavors in urban agriculture.

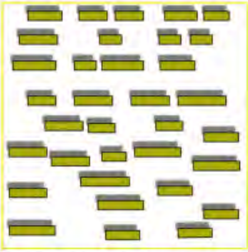


3.39. Annual energy consumption per Household (MJ)



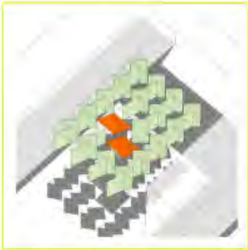
3.40. Annual operational household energy consumption by use

SITE SCALE | **CLUSTER SCALE** | **UNIT SCALE**



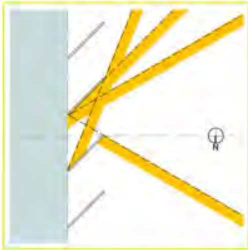
Residential facades face north and south to ensure natural daylight for residents.

住宅向北朝南为了确认日光的渗入



Courtyards can receive a canopy structure of photovoltaic and shade panels. Panels are oriented to let light through during the winter, block light in the summer, and capture solar rays throughout the year.

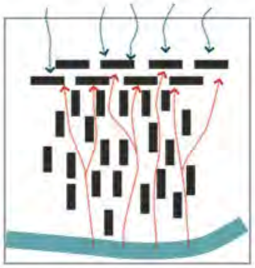
广场上方将有一个华盖状的遮阳板。 遮阳板的设计会使冬天的阳光可以射入，而阻挡夏日的阳光。



Commercial facades are encased with vertical louvers, while residential facades receive a horizontal louver treatment

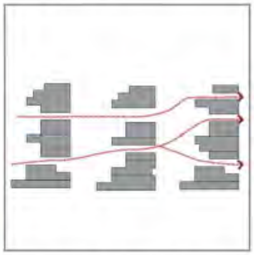
商务区正面为垂直遮阳板，住宅区则设计为水平遮阳板。

SUNLIGHT
日照设计



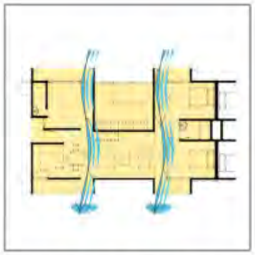
Building masses are oriented north-south at the southern portion of the site to allow south-eastern breezes to penetrate the site in the summer. Buildings oriented east-west along the northern edge block northern winter winds.

地段南部，建筑设计为南北向，如此可使东南风在夏季渗入建筑群。位于地段北边的建筑为东西向，用来阻挡冬季的北风。



Buildings are perforated at multiple levels to increase natural ventilation through the site.

建筑的缺孔设计以及多阶设计增强真个地段的自然通风系统。 设计的独立的住宅和办公单元可由开窗处进行通风。



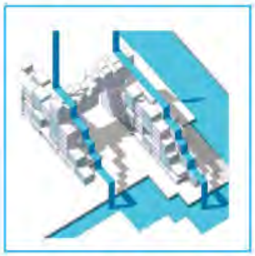
Individual living and working units are designed with floor plans and fenestration to allow for natual ventilation.

建筑的缺孔设计以及多阶设计增强真个地段的自然通风系统。 设计的独立的住宅和办公单元可由开窗处进行通风。

WIND
通风设计

Large pools of water to the south-east of each neighborhood passively cools wind as it passes over.

东南处的大型水池无形中为通过的风降温。



Building terraces capture and filter rainwater, and canals store water to be used at a later time.

梯田状建筑可存储和过滤雨水，储存于水渠之中，以备后用。

WATER
水体设计

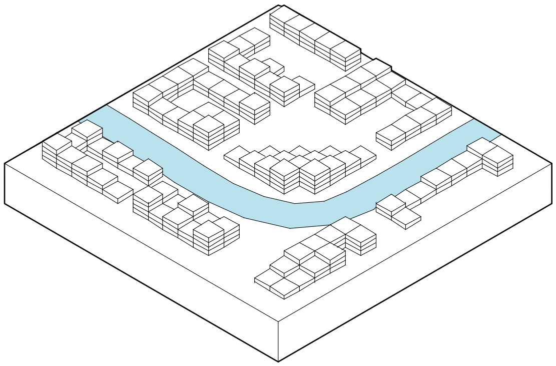
3.41. Overview of energy strategies and their physical embodiment

THE 3-D GRID 4

The primary objective of this prototype is to develop a 21st century, higher density, and more livable version of the traditional urban village form of development as represented by Zhang-Jia in Jinan. Such neighborhoods may seem disheveled, but possess qualities that could attract people of all income groups, including a fine-grained fabric, intertwined living, working, and commercial activities, all within 2-4 story buildings. Incorporating such characteristics results in a walkable environment where residents can fulfill their daily needs within the neighborhood. Low-rise buildings, particularly prominent in this scheme, contribute to a human-scale character, minimize the excavation and embodied energy required for construction, and reduce the operational energy used for climate control, elevators, and utilities.

The 3-D Grid illustrates how all of these qualities could be achieved in a high quality, contemporary urban setting. The concept is based on controlled vehicular access to maximize livability and promote pedestrian circulation on several levels. Specifically, emergency and delivery vehicles are allowed to circulate on the

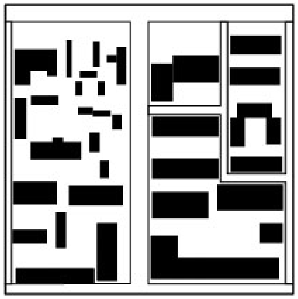
3.42. Streetscape in a traditional Hutong



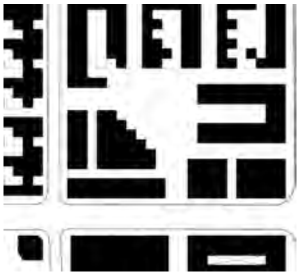
3.43. Rendering overlooking interlocking green spaces and circulation on different levels

3.44. Cluster plan

TRADITIONAL GRID



3-D GRID



	TRADITIONAL GRID	3-D GRID
size (ha)	53	65
residential units	6,879	8,683
pop density (1000 ppl/sq km)	38	47
parking spots/100 hh	16	21
avg building height	5.5	6
FAR	1.7	2.2
energy use/hh (MJ)	**74,600**	**67,600**

interior streets, which are not otherwise open to through traffic. At the same time, a complete multi-modal transit system complements the rich pedestrian realm.

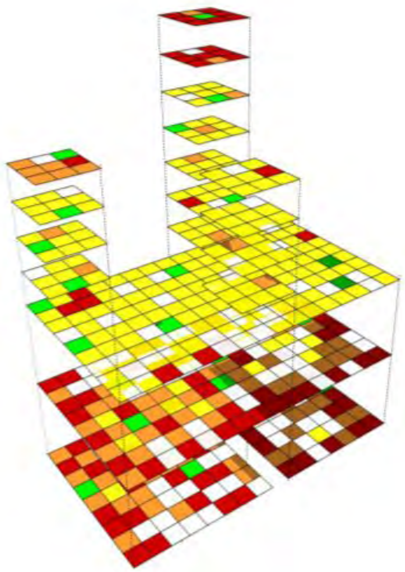
Both building structures and open spaces are designed to optimize passive sources of energy. Additionally, generation of energy on site from renewable sources is integrated into the design in several forms. The design is also highly flexible, incorporating both interior private and exterior public spaces that can adapt to the seasons, changes in resident demographics, and transformations of space usage over time. This framework reduces the need for altering structures, enhances functionality by allowing for personal choice and customization, and provides for a livable environment by fostering place identity.

GENERATIVE IDEAS

The 3-D Grid is developed as a collection of small, highly permeable blocks each with its own character. The blocks contain low-rise 3-5 story buildings, designed to interpenetrate exterior spaces to allow for airflow, light, shading, and wind protection. This results in a complex hierarchy of green spaces – ranging from small individual gardens, to courtyards, neighborhood parks, and large greenswards along major waterways. The permeable environment also affords multiple paths of movement in and among buildings and spaces, much like a traditional village, that encourage walking and reduce the need for transportation. The combination of all these factors leads to energy conservation in the embodied, operational, and travel dimensions.

The intricate fabric is given larger form by an urban waterway system—developed from the existing canal

3.45. Bird's eye view showing cluster composed by compact, low rise, fine grained blocks



3.46. Generative diagram explaining multiplicity of uses

—which flows through the neighborhood. A main canal feeds smaller watercourses that help to define blocks and different zones within the grid, contributing to place identity. The system also provides the backbone for a water-born transportation system that services all parts of the site. For example, the center of the neighborhood is developed around a major station on the water transit system, where it intersects a principle thoroughfare in the road system, as shown in accompanying drawings. Here we find more intense development, including shops, offices, institutions and schools integrated within the ubiquitous residential matrix. The environment operates on multiple levels, allowing recreational uses along the canal, while urban activity goes on above.

LAND USE

The land use strategy fosters a fine-grain mix of uses such that a parcel may contain multiple activities horizontally as well as vertically. The mix is further complicated by the fact that the basic unit is a live-work loft in which residential functions may be combined with offices or small scale production, and are sufficiently flexible to accommodate change in use over time. In general, commercial and civic uses are concentrated on the ground floors with residential above, although any use may occur on any level. Over time, given sufficient flexibility, the 3-D grid would develop areas with different characters and distinctive mixes of activity arranged in three dimensions.

The transitional nature of the site, located between the downtown of the new city to the north and residential areas in the south, suggests the integration of commercial uses throughout the development

3.47. Plan showing commercial corridors

3.48. View showing open spaces and building envelope rather than the creation of large shopping centers. As illustrated in the accompanying diagrams, retail spaces are developed along roads and paths of movement through the grid and may occur on, or extend to upper levels. In a similar way, recreation, services, planting, and amenities are scattered across the neighborhood in a more or less even pattern of development with equal levels of accessibility.

BUILDINGS AND SPACES

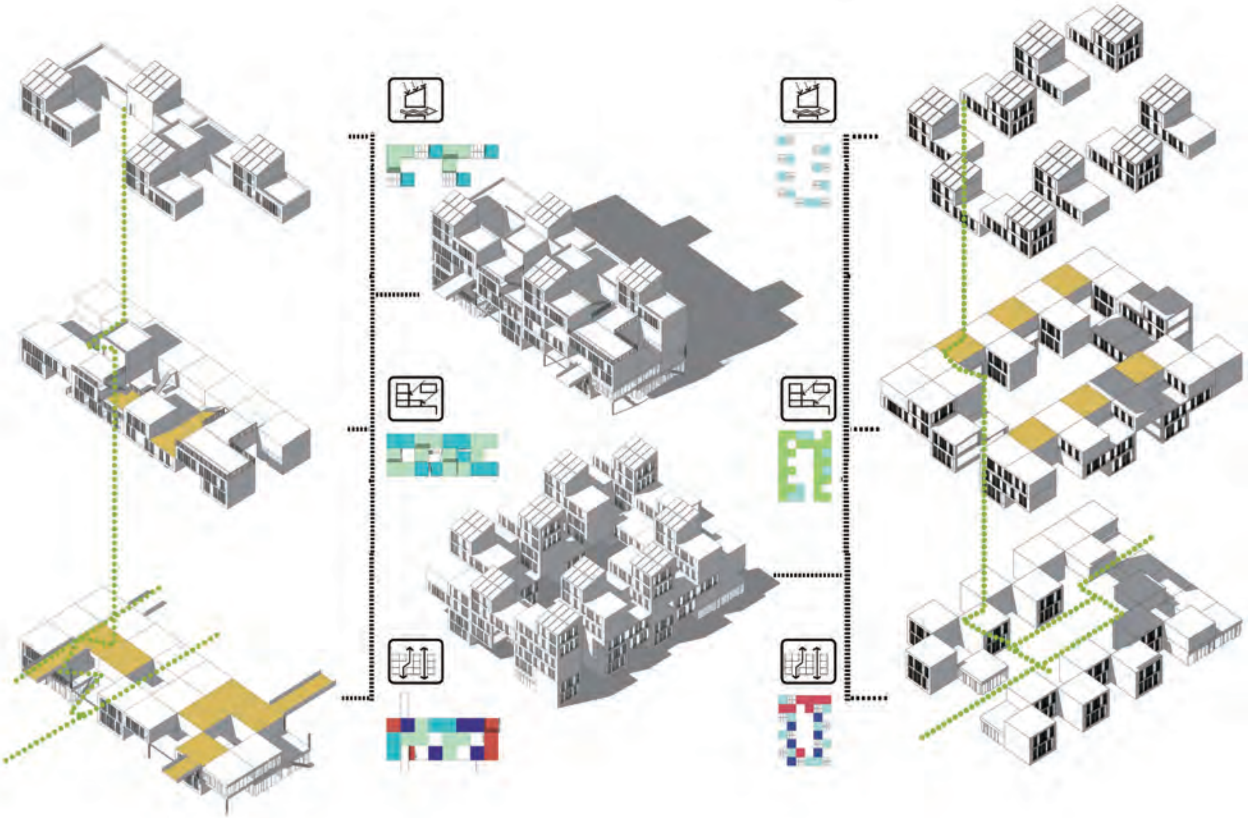
The consideration of natural systems and their form implication becomes more evident at the building scale. The building orientation allows for optimum ventilation while the courtyards on various levels are designed to provide a cooled microclimate for the interior rooms. Circulation at the ground, 2nd and 3rd levels means more options for pedestrian movement, so that moving between buildings or addresses need not require going to the ground.

Individual units are designed to be easily adaptable to meet the needs of different lifestyles and changing family sizes. The core unit is a small-office/home-office ("SOHO") live/work unit that can accommodate a range of home businesses. Modifications of the core unit result in units for larger families. All unit sizes are designed to be flexible and to expand and contract as necessary. Units are arranged into buildings that integrate uses, community space, green spaces and circulation three dimensionally. In addition to vertical green spaces, the buildings feature ground-level courtyards, which form cooling microclimates and are adaptable to the needs of the residents.

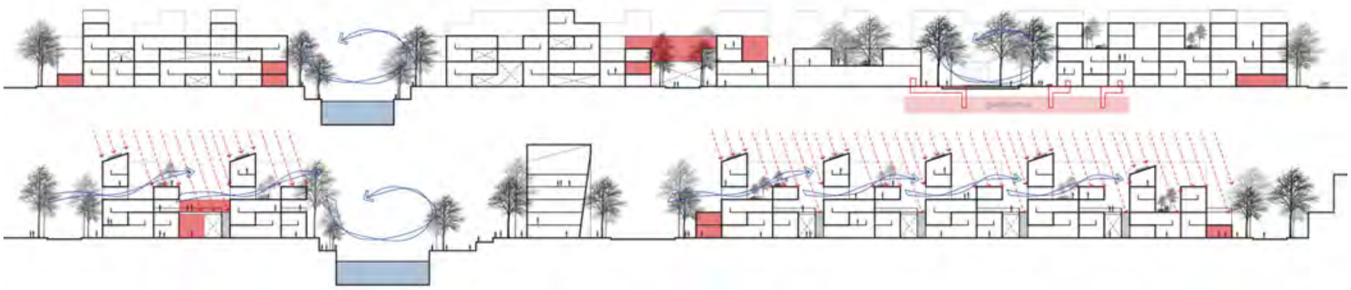
3.49. Multiple layers of movement and space

The proposed tree cover and vegetation scheme consists of evergreen trees located on the north sides of buildings to block winter winds and deciduous trees located on the south side to block the summer sunlight while allowing the winter sunlight when they lose their leaves. Groundcovers and shrubs diminish the amount of heat-absorptive surfaces for the sake of runoff. Pavement and building roofs are shaded by tree canopy coverage to reduce heat-island effects. The canal creates a channel between buildings resulting in cooled airflow to the adjacent buildings. In the residential areas, gray-water filtration zones that abut the canal serve the surrounding buildings.

The combination of low-rise buildings, mixed-use and high-density urban design form, controlled car use, alternative modes of transportation, integration of natural systems, and the creation of adaptable space result in the development of a livable modern development form that requires half the operational energy of high-rise projects at similar densities and less operational energy per household than even the traditional neighborhoods studied in Jinan.



3.50. Detail of form - energy strategies at the unit level



3.51. Section showing natural ventilation schemes, passive heating and heat island effect mitigation

KEY FORM-ENERGY CONCEPTS: THE 3-D GRID

- The integration of mixed-use and high-density qualities, inspired by traditional urban villages, yields an urban environment in which neighborhood services are in close proximity to the inhabitants.

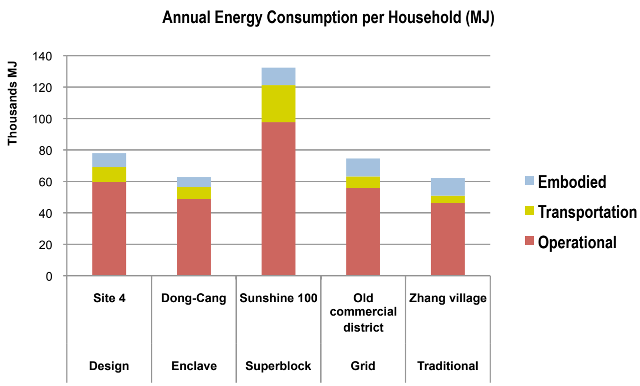
- Low-rise buildings are particularly prominent in this scheme in order to minimize excavation and embodied energy needed during construction, and to reduce the operational energy needed for climate control, elevator usage, and utilities.

- Controlled vehicular access, the availability of water transportation, and a rich, multi-level pedestrian realm throughout the site encourages pedestrian circulation.

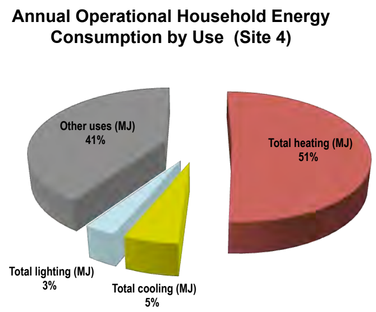
- A network of canals and watercourses reaches all parts of the site, supporting water transportation and cooling airflow to adjacent buildings and spaces. In the residential areas, grey-water filtration zones that abut the waterways serve the surrounding buildings.

- Buildings structures and open spaces are intertwined for optimal operation of passive natural systems, and energy generation on site is integrated into the design.

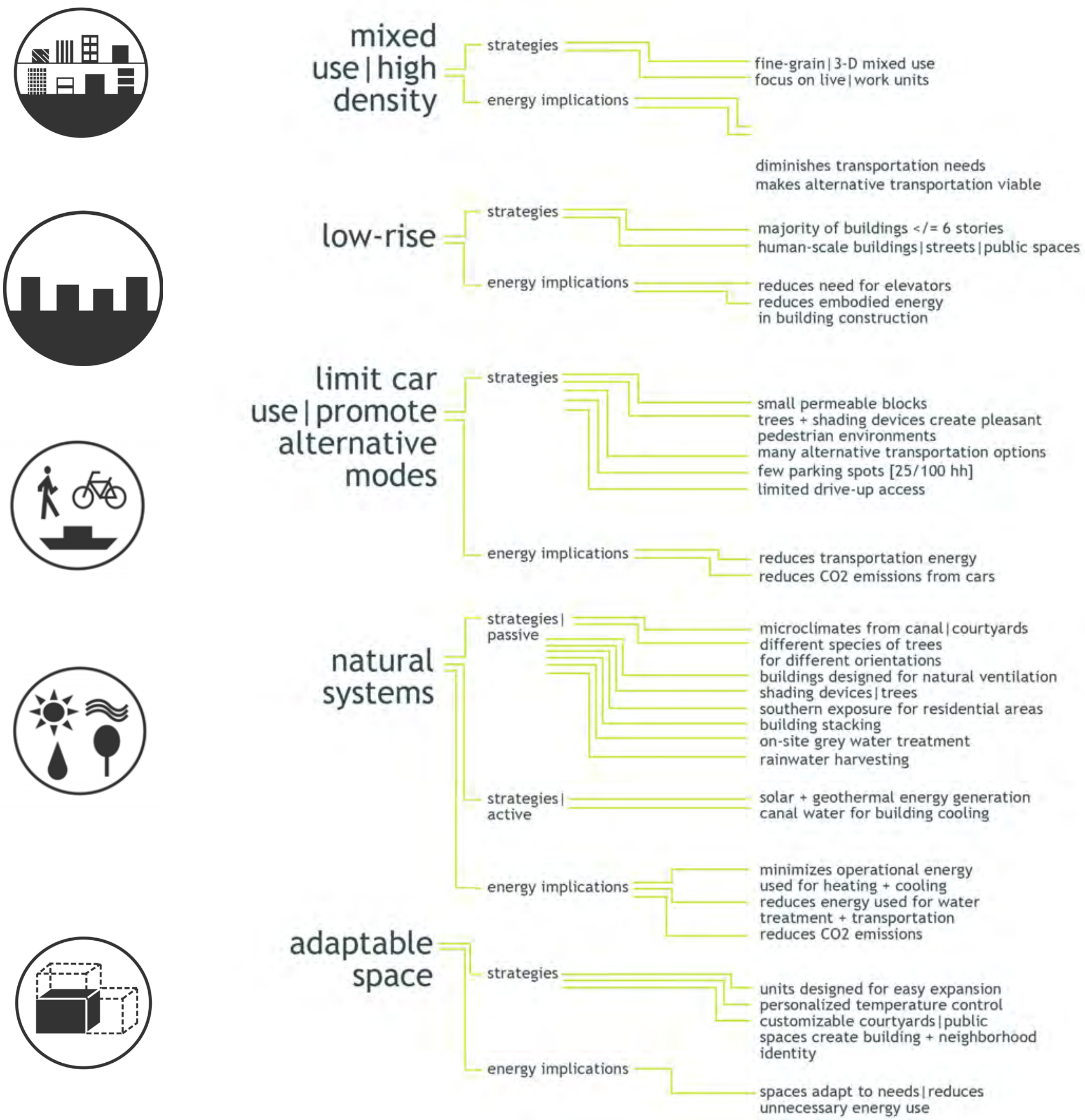
- The core unit is a live-work loft that can accommodate a range of home businesses and is easily adaptable to changes in uses and size needs. The design accommodates seasonal climate, changes in the life stage of residents, and transformations of space usage over time.



3.52. Annual energy consumption per Household (MJ)



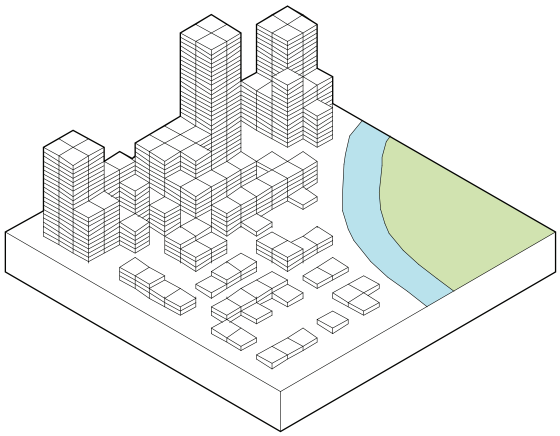
3.53. Annual operational household energy consumption by use



3.54. Overview of adopted energy strategies and their implications

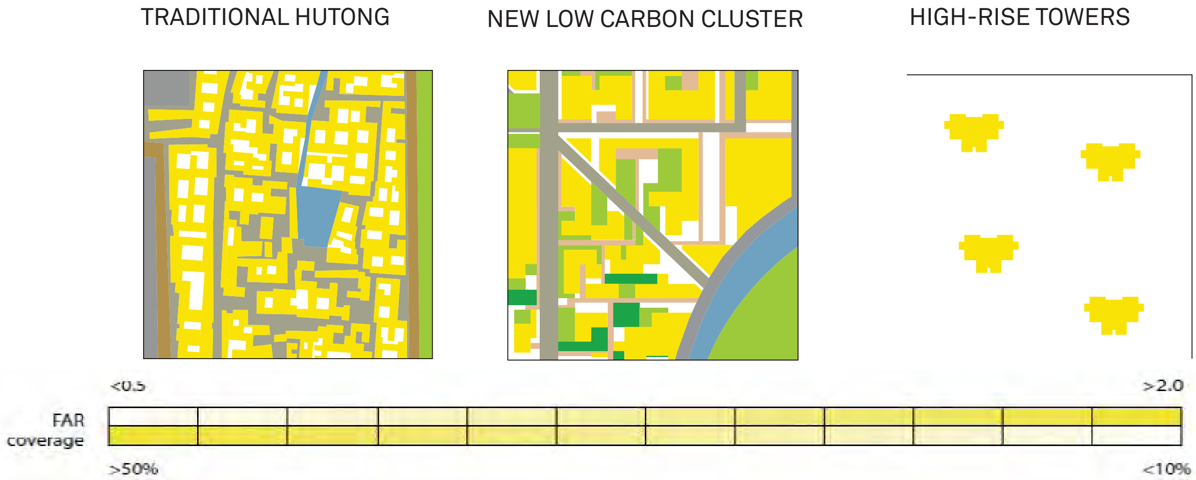
URBAN SPONGE 5

This project, designed to overcome liabilities of the "tower-in-park" typology, proposes a modern eco-city characterized by higher density, integrated residential and commercial opportunities, and reduced energy consumption. The Urban Sponge prototype represents a departure from the conventional height–coverage relationship, where height and land coverage are inversely proportional. By carefully crafting heights and sun exposure it achieves both high FAR and high coverage with a mix of high-rise and low-rise structures, in turn freeing up large areas of land for recreation and open space. The sensitive modeling of sunlight exposure and other environmental requirements results in a highly articulated form and relationship to space: the Urban Sponge.

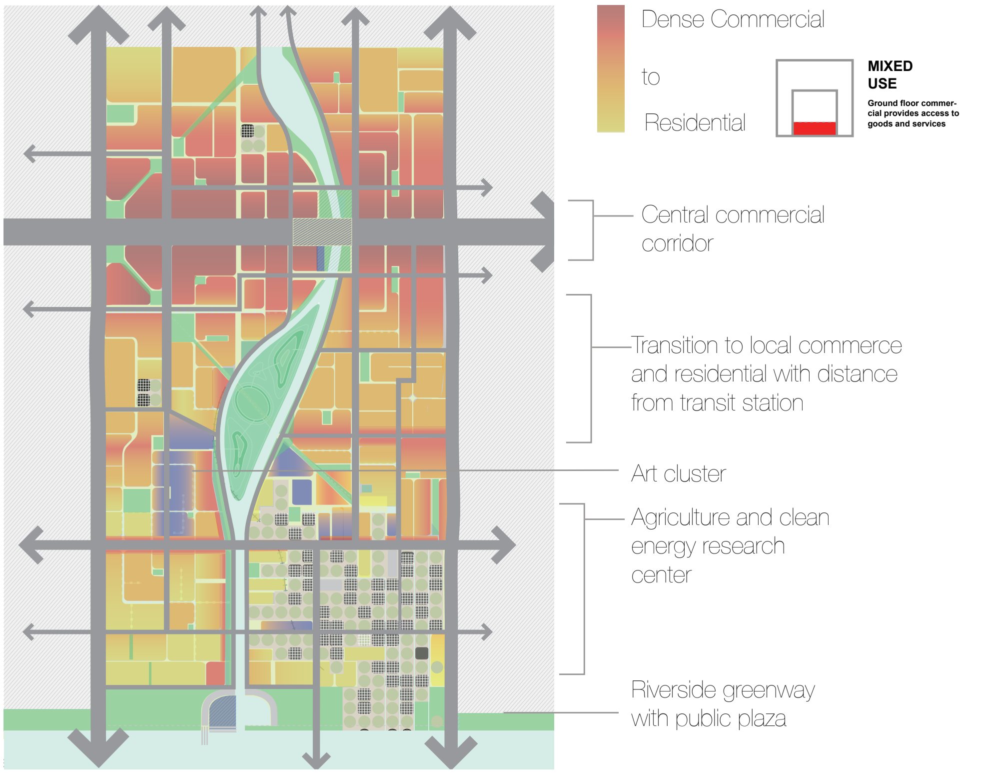


The project focuses on an urban waterfront, island, and park that are carved out of the center of the neighborhood. A network of activity nodes located

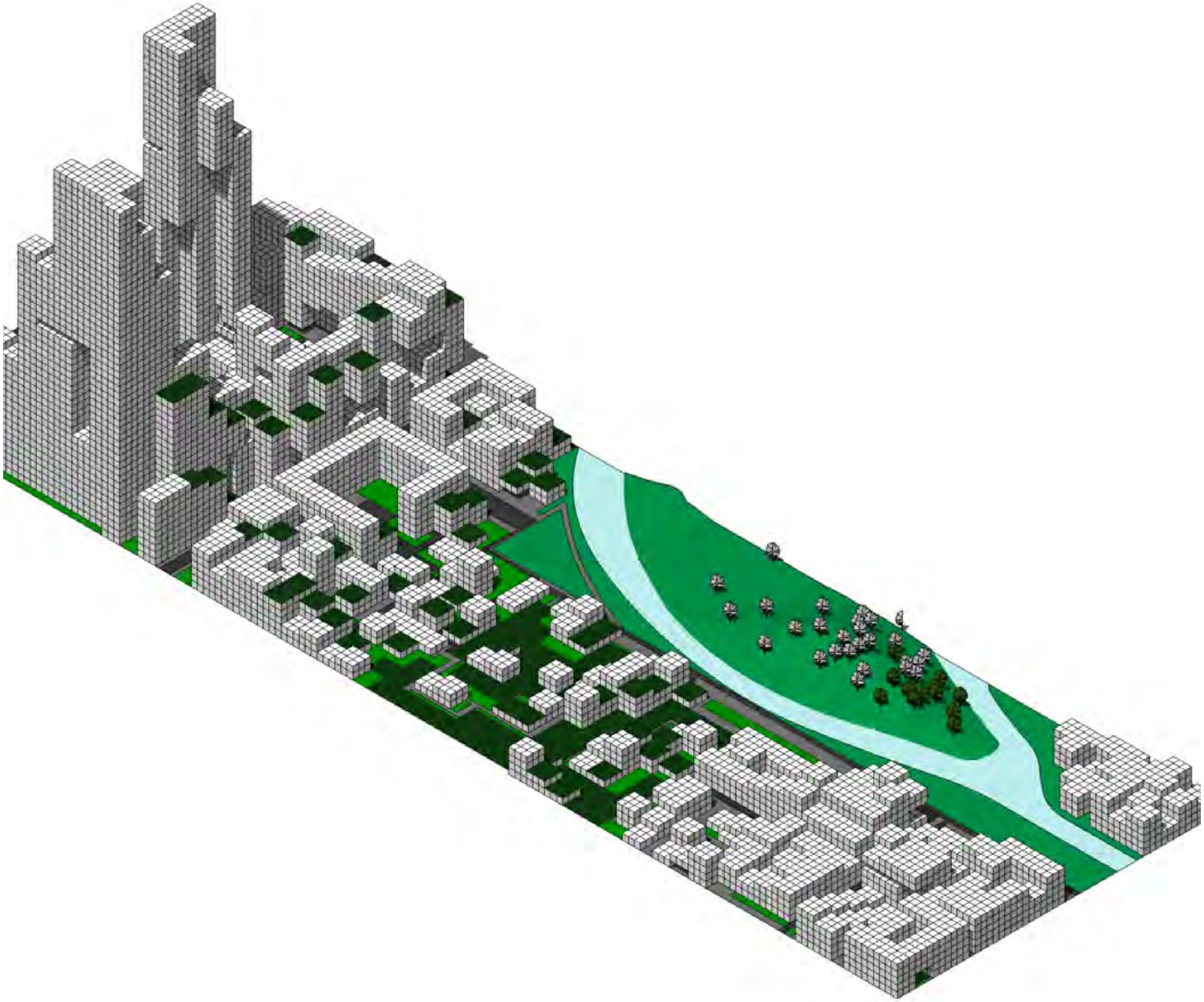
3.55. Rendering showing the typological gradient and the contrast between the built and the landscaped



3.56. Diagram presenting middle scheme as the decoupling of FAR and site coverage



3.57 Site plan showing land use as intensity of use gradients, general zones and circulation hierarchy.



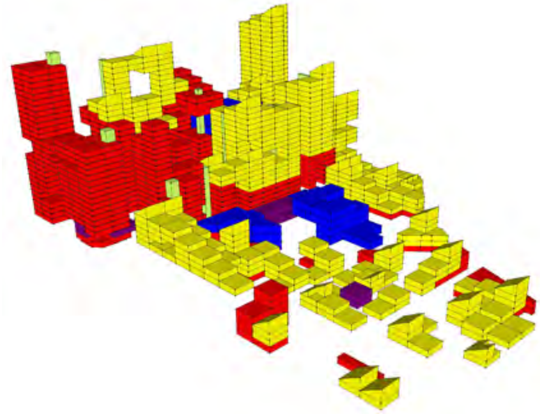
3.58. Isometric view showing sectional variation in height and coverage variation in plan around transit stations, small squares, and connecting pathways binds the community together. The network also disperses activity across the entire site. Both the overall urban form and individual building systems incorporate renewable energy forms.

ORGANIZING CONCEPTS

As shown in the site plan, the densest development is clustered to the north, around the intersection of a major transit station, arterial roadway and the canal —an area of tall buildings and commercial intensity. Building heights decrease moving south, where residential becomes the predominant use. Finally, major cultural, educational and research institutions are clustered at the bottom of the site, which opens onto a major natural preserve.

The fabric is composed of a polycentric system of hubs and connectors. Inserted natural features contribute to livability and reduce the urban heat island effect. These natural areas also include geothermal, wind, and solar energy production. Greenways throughout the area support pedestrian and bike circulation, accommodate for the geothermal system needs and mitigate air pollution. Ultimately, the master plan suggests a transit-oriented development by concentrating activity along the transit lines, and multiple means of circulation, including a bike or car sharing program, and a public electric bike charging scheme powered by solar energy.

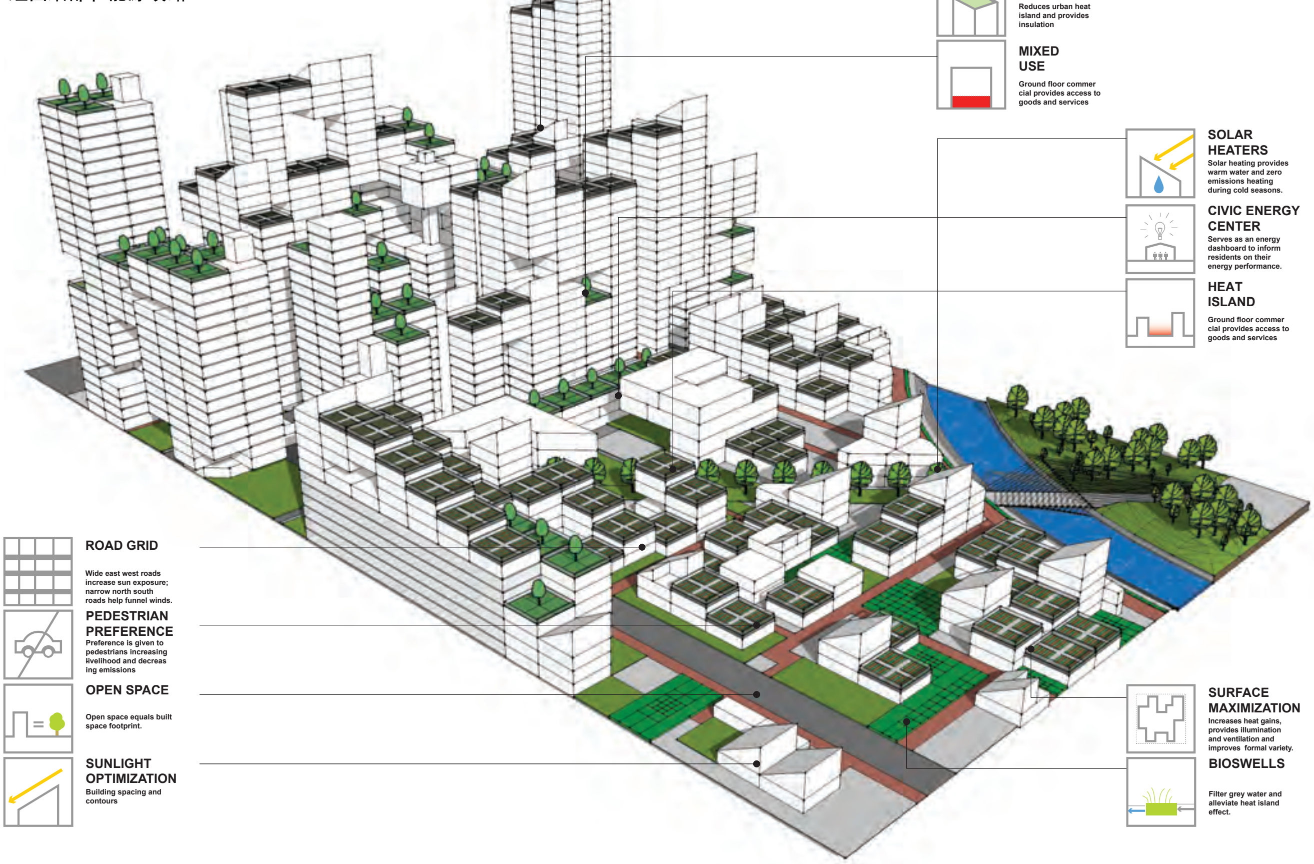
At the center, the canal splits to create an island (to the north it expand to create a lake). Commercial uses activate the banks with an artist gallery emphasis on



3.59. Cluster detail showing mix of uses

3.60. Bird’s eye view of deck over transportation hub

Cluster Detail and Energy Strategies
组团细部和能源战略

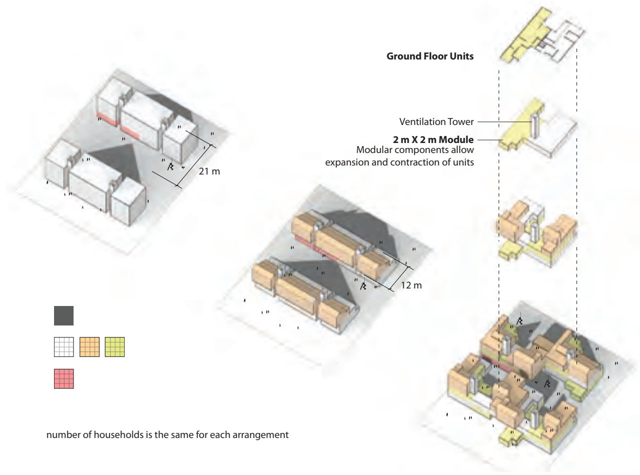


3.61. 3D model showing form - energy components the western shore and an agricultural and alternative energy research institution on the east. The waterfront edge becomes a unifying green space for the entire neighborhood.

CLUSTER SCALE DEVELOPMENT

The vertical diversity creates a variety of spaces from clustered tall office buildings to quiet residential streets and public spaces. The uses and forms are carefully balanced to enable sunlight penetration but still achieve density and diversity of form. This is possible by careful digital analysis of all the elements of the system during the process of design. The drawings illustrate the quality of permeable form that results from maximizing these complex interrelationships. The form is not only more energy efficient but also more livable than simple tower-in-park schemes, because it increases the opportunity to accommodate mixed uses and individual lifestyles. This approach can be translated to an entire city, where dense high-rise areas surround transit nodes or hubs of activity. Streets and pedestrian ways merge to transition to lower-rise environments farther away from the light rail stops. The variation of building types also allows for a high percentage of open space and public plazas as well as for the integration of geothermal wells and bio swales.

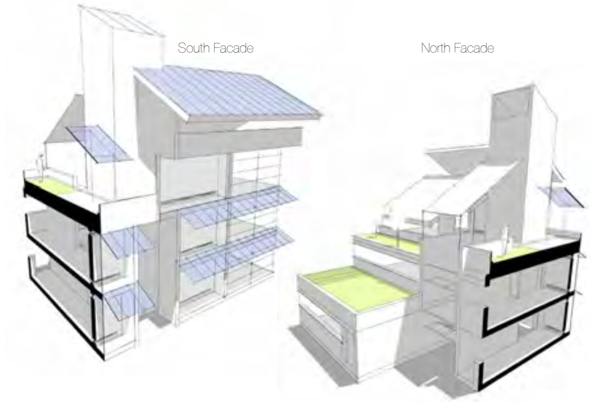
Residential units are aggregated into a range of types, including low-rise (1-3 stories), mid-rise (4-6 stories), and higher-rise (over 6 stories) configurations. In each case, residential units are combined in a way that allows them to share vertical ventilation towers and wet walls. The stacking is such that these vertical elements are



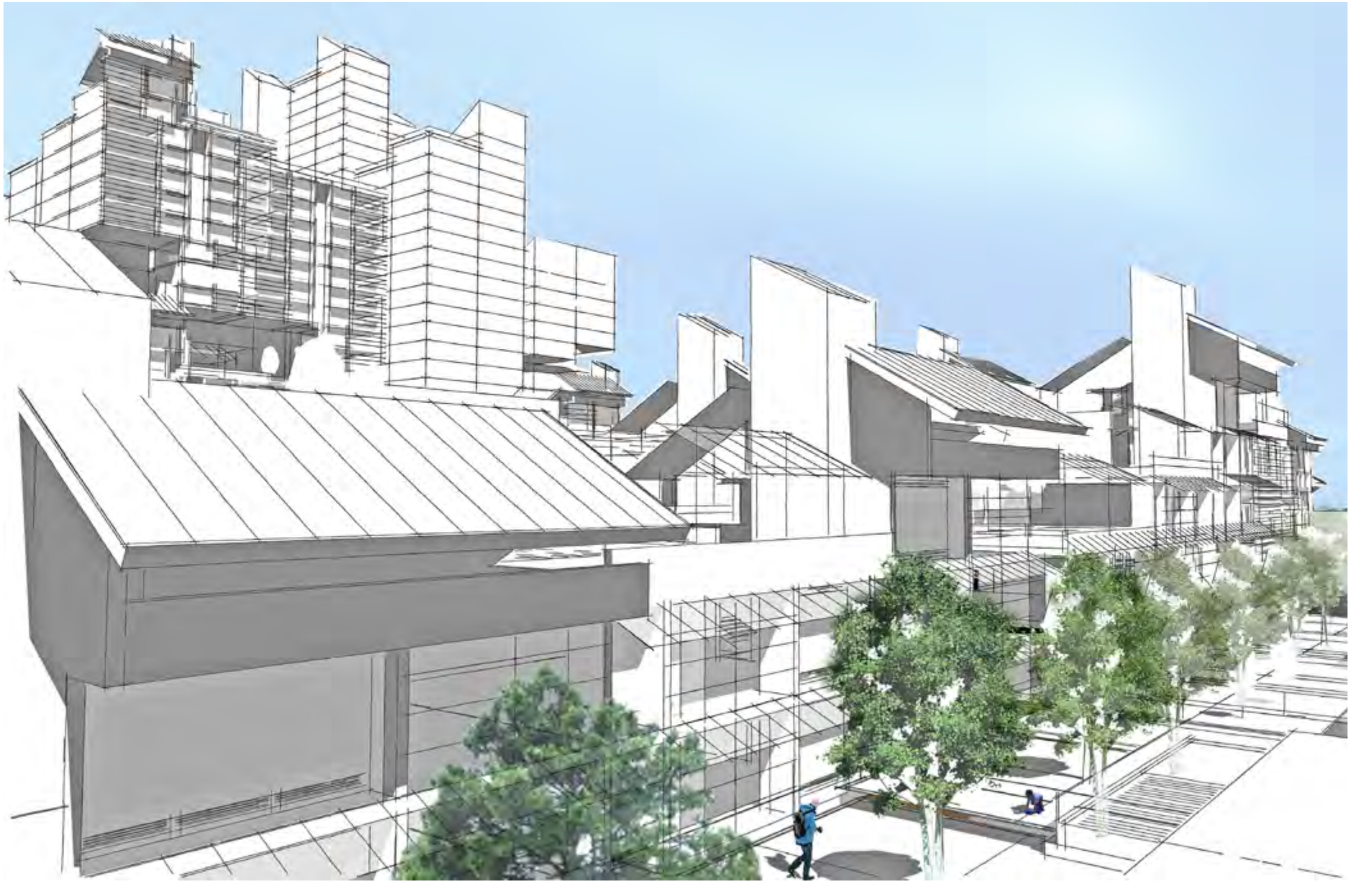
3.62. Individual unit components

continuous. Unit plans vary greatly in shape, creating an array of spaces designed to expand and contract over time and still meet sunlight requirements. Passive solar heating and adequate daylight are achieved through Trombe walls and south facing windows. An efficient unit size of approximately 100 square meters further contributes to decreased operational costs.

This new prototype achieves an energy performance comparable to that of a traditional Hutong with five times the density and twice as much open space allocation. The energy strategies contributing to this outcome emphasize natural ventilation, sunlight optimization, using roofs and un-built areas of the overall area for energy production, and a highly pedestrian environment. The Urban Sponge prototype proposes a new model of increased livability and energy efficiency that, although formed in this instance around a unique feature created by the canal island, can be abstracted and replicated elsewhere.



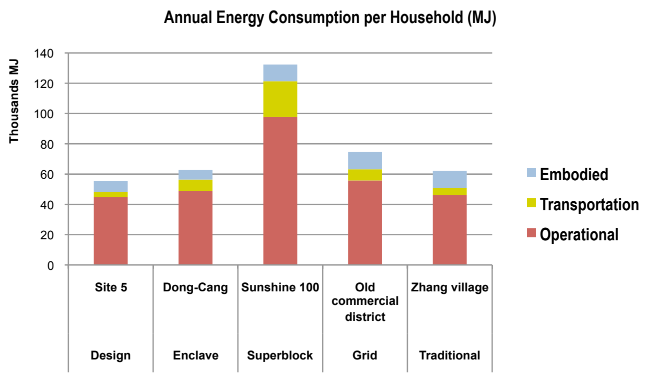
3.63. Unit facades



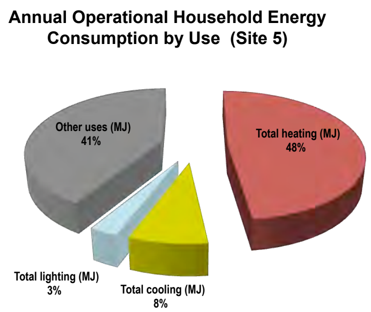
3.64. A pedestrian street in a majorly residential area overlooking mixed use highrises in the background

KEY FORM-ENERGY CONCPTS: URBAN SPONGE

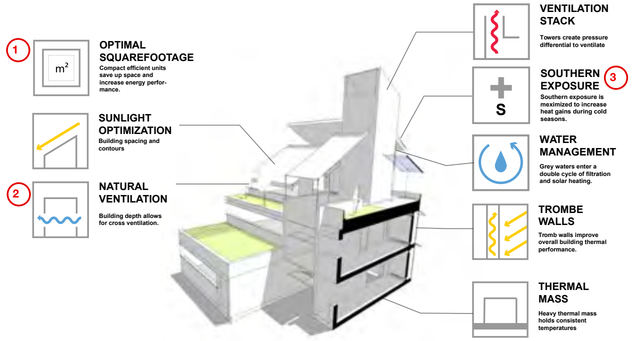
- The building height gradient and careful sunlight calculations that characterize this approach enables both high density and high site coverage and for clusters of high-rise structures and low-rise structures to be developed in appropriate areas of the site.
- The concentration of building frees up a high percentage of open space for major site features and public plazas as well as for the integration of geothermal wells and bioswales.
- The fabric across the site is composed of a system of open spaces, green pathways that link them, and activity nodes located around transit stations.
- Greenways and spaces also support pedestrian and bike circulation, accommodate for the geothermal system needs, and contribute towards the clean sky effect.
- Renewable energy forms are incorporated in both the overall urban form and in individual building systems. These are complemented by passive solar heating and daylighting achieved through trombe walls and south facing windows.
- A very efficient unit size design of approximately 100 square meters further contributes to decreased operational and embodied energy consumption.



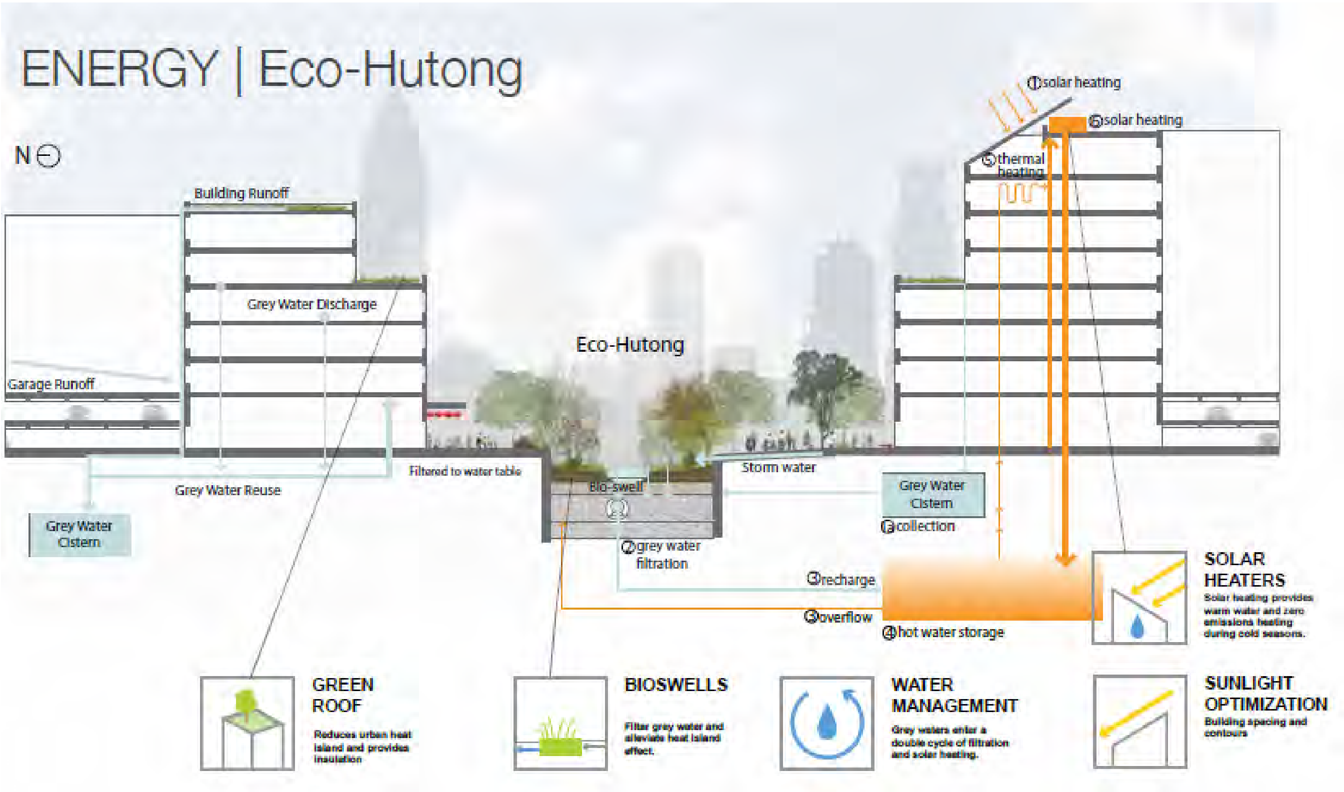
3.65. Annual energy consumption per Household (MJ)



3.66. Annual operational household energy consumption by use

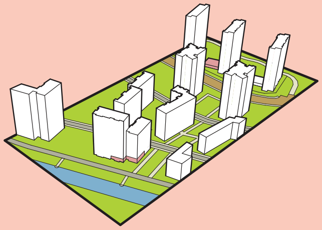


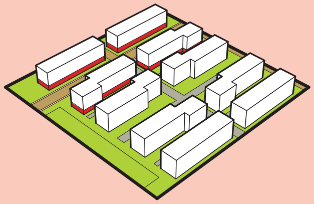
3.67. Energy strategies on the unit level



3.68. Section showing the bio swale as the heart of gray-water management strategy

The Energy Proforma 4





The Energy Proforma

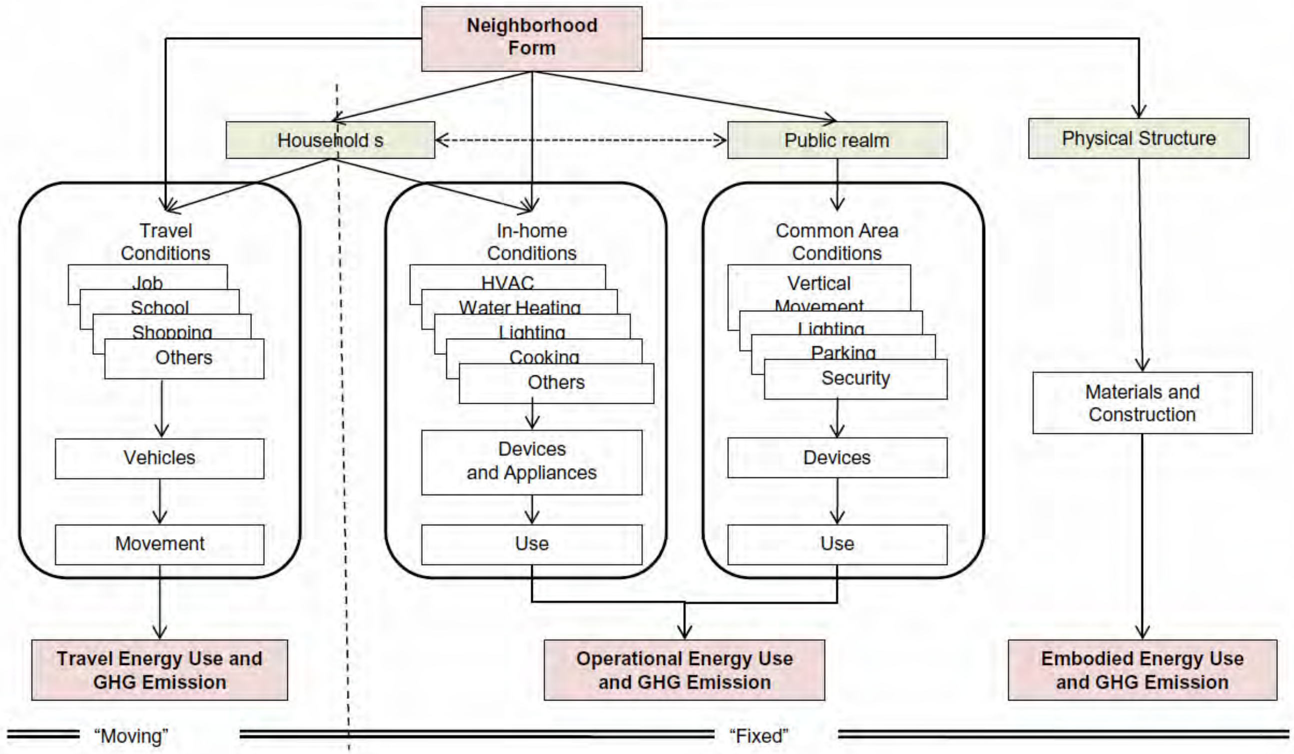
THE NEED

This chapter summarizes the initial development and application of the Energy Proforma ©, a tool being developed at MIT to enable researchers, designers, developers, and policy makers to evaluate the energy performance of neighborhood scale projects. The first part of the chapter summarizes the concept of the Proforma and research underway to develop it. Following that is a brief guide to use of the Proforma and the outputs it provides. Finally, we present outcomes from the first application of the Proforma in Jinan by the MIT-Tsinghua Joint Urban Design Studio, discuss lesson learned, and next steps. The chapter provides only a synopsis of the Energy Proforma research to date. More detailed information can be found in *Making the 'Clean Energy City' in China*: Year 1 Report (Frenchman and Zegras 2010)

The need for a means to assess the energy performance of urban development was discussed in Chapter 1: Clean Energy and Urban Patterns. Despite the growing consumption of energy by cities in China, and evidence that urban form is a key determinant, currently there exists no means or even common standards of measurement for assessing the energy performance of development, or neighborhood scale projects. The lack of these tools has inhibited research, since it is very difficult to compare the performance of different projects in different locations. More importantly, it has inhibited practice and the invention of more energy efficient urban forms, since designers and developers cannot measure the performance of their projects in the process of design. Finally, enlightened public policy on urban form is impossible without a commonly accepted protocol to measure its performance and establish standards.

Lack of progress to date can be attributed partly to the complexity of the problem. The energy performance of a neighborhood is the resultant of complex interactions across four key dimensions:

- the construction, maintenance, and eventual demolition of buildings and sites, which embody energy over their life cycle;



4.1. Neighborhood form and energy

- the operation of the environment, including common areas as well as individual households and uses which consume energy;
- the need for those residents and users to travel for the daily necessities of living such as food, services, friends, and employment which consumes more energy;
- the capability of the environment to support production of renewable energy on-site, to offset consumption.

All of these dimensions, and the interactions among them (which can have compounding effects), are affected by the neighborhood form, or to be more accurate, its design.

It is important to stress that by urban form, or design, we mean more than general characteristics like density, land use, and roads. Rather, we are referring to the specific characteristics such as configuration, orientation, horizontal and vertical circulation, location of uses, types of uses, and patterns of human behavior that exist within clusters of structures and spaces. Furthermore, these clusters involve more than the performance of individual buildings added together, since depending on how the same buildings are arranged, they can have different impacts on the energy performance of one another and the behavior of the people who inhabit them. Urban design establishes the matrix in which all of these elements come together, and each neighborhood, district or project has its particular signature as a "form-energy system".

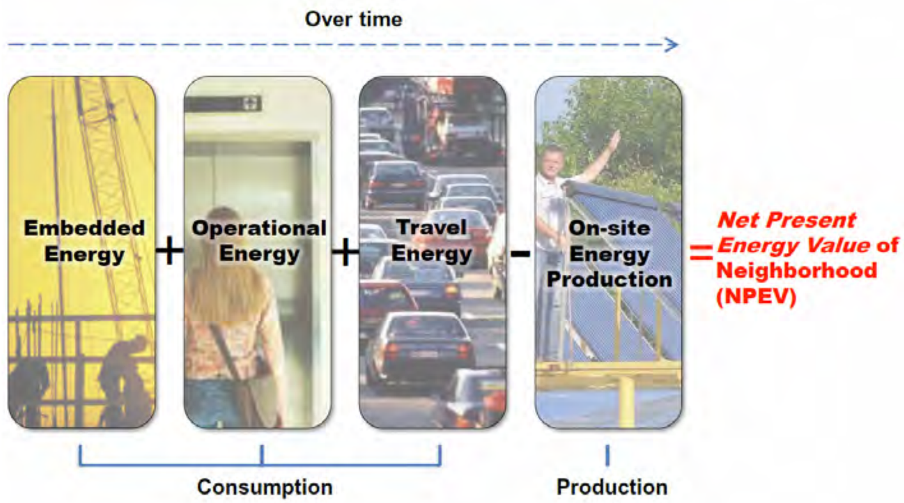
> "The goal is not to develop the most ideal energy efficient form and repeat it endlessly, but to guide design and development decisions towards neighborhood designs that may be highly diverse but are relatively more energy efficient than what would otherwise be produced."

To date efforts to encourage more sustainable, energy efficient urban form have focused on learning from best practice and applying models that have seemed to work well elsewhere. In the LEED-ND rating system (US Green Building Council), for example, the more closely a project fits the model, the higher the rating it receives. Our research, and others', have highlighted limitations to such an approach, the most significant being that it is not a method of measuring energy performance or based upon empirical evidence. More significantly, it does not take into account interactions among various design elements. As a consequence, a project can receive a high LEED rating, and still consume a lot of energy. Rating systems do have a role in promoting sustainable development, but to make significant progress on the energy front a more effective approach is needed.

The Energy Proforma offers a fundamentally different route to clean energy neighborhood design in China. The goal is not to specify an ideal model or specific practices, recognizing that at the neighborhood scale energy consumption is affected by a huge number of variables and performance may be improved using different strategies. Furthermore, development models can be problematic in China, where they tend to be repeated endlessly because of the top-down planning system. With the Proforma, decisions and trade-offs among the many options for saving and producing energy in a neighborhood can be left to individual designers and developers operating in the local context. The aim is to guide their design and development decisions towards projects that may be highly individualized but relatively more energy efficient that what would otherwise be built. From a public policy perspective, the Energy Proforma enables the relative performance of projects to be understood, compared to each other, and standards established that are sensitive to local climate and culture.

THE APPROACH

To develop the Energy Proforma we used the concept of a financial pro forma as a model. The financial pro forma is commonly accepted tool of real estate development, which measures the economic value of a development project. The financial proforma collapses many complex variables—size, construction systems, costs, market demand (rents), time, value of money, design, liability—into a single measure: the "net present value" of the project (or the "internal rate of return"). Presented as a spread-sheet model, the proforma is easily accessible to designers and



4.2. The Energy Proforma

developers who can use it to adjust and test multiple features of their project in the process of achieving a target value. These same terms and protocol are also widely understood by banks, public agencies and investors who can set their standards for the financial performance of the project and decide whether or not to approve it, or invest.

To be useful in practice, however, the financial proforma needs to be tuned to local conditions. Developers must investigate what people like and need, rents, the cost of materials, construction practices, availability of capital at what rate, all of which may vary a great deal depending on the location. Once these factors are entered into the proforma, it can then be used to readily assess the financial value of numerous complex options for a particular site in that context.

These same basic concepts are applied in the Energy Proforma. In theory, once it has been tuned by entering local factors related to form and energy, the Proforma can be used to calculate the energy value of a particular design in that context. However, unlike real estate where "form-money" relationships are constantly being surveyed, analyzed and indexed using many available data sources, data on form-energy relationships is not readily obtainable. We predict this will change in the near future as the value of energy data becomes increasingly apparent. Meanwhile in Jinan, as noted before, these local factors were determined through the survey and statistical analysis of 27 neighborhoods involving about 7500 respondents.

Chapter 2: Learning from Jinan presents some of the key findings from the initial survey of nine neighborhoods representing four prototypical urban forms. The analysis demonstrated significant relationships between their design and energy consumption. In turn, the coefficients relating to embodied, operational, and travel energy were incorporated in to the beta version of the Energy Proforma. An additional 18 neighborhoods have now been surveyed to provide a broader set of data that, hopefully, will reveal more nuanced form-energy relationships.

USING THE ENERGY PROFORMA

As a decision support tool, the Energy Proforma is designed primarily to meet practical needs. Specifically, it enables users (e.g. urban designers, developers, and policy makers) to explore and compare energy performance across existing or proposed development projects and patterns. Formatted as a spreadsheet, it helps users to estimate and forecast the potential energy consumption and CO2 emissions of urban development plans that have different project forms and physical typologies.

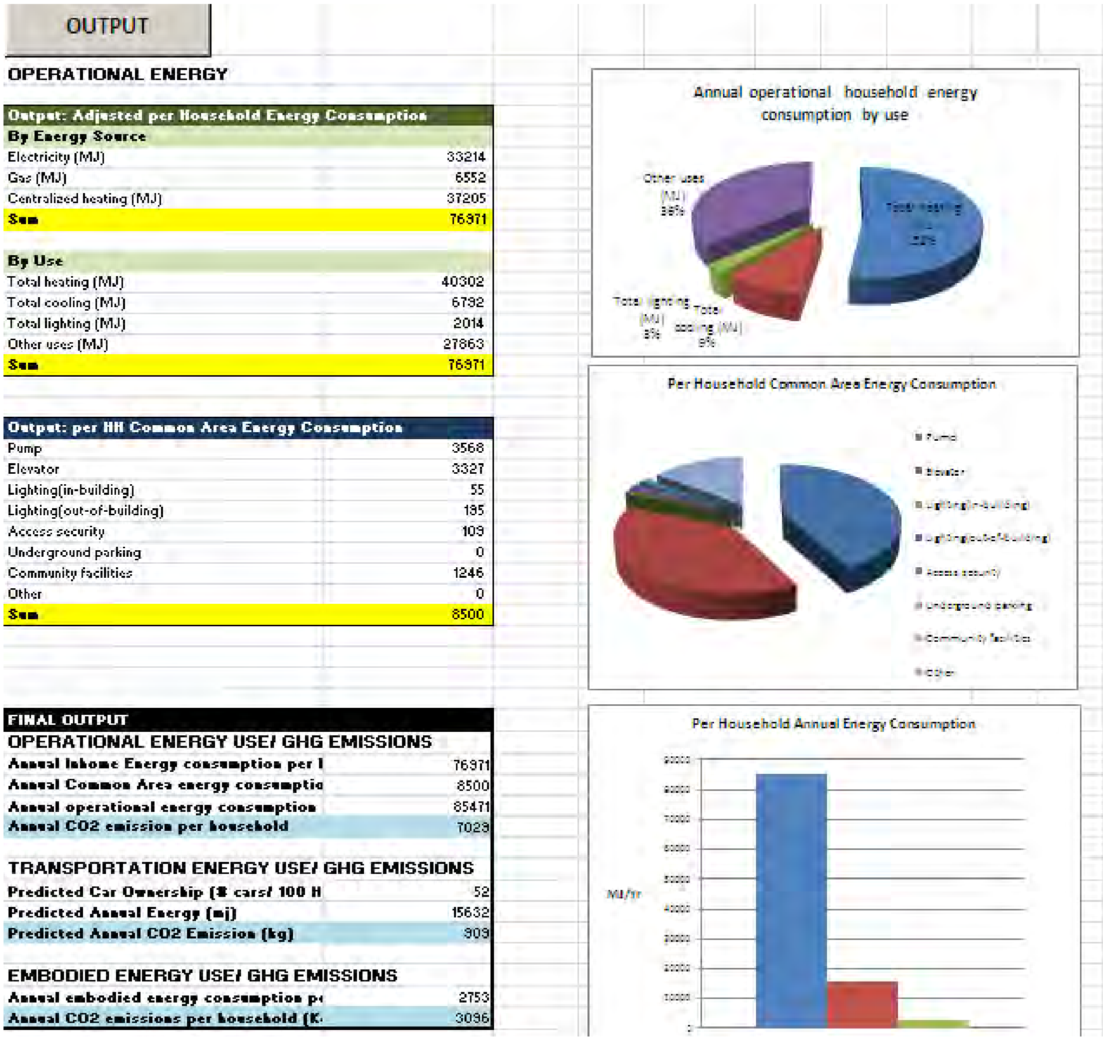
As discussed above, the beta version of the tool has been developed based on the life cycle analysis of typical urban neighborhoods in Jinan, China. It contains

INPUT						
NEIGHBORHOOD FORM CHARACTERISTICS						
LAND USE AND LOCATIONAL CHARACTERISTICS						
	These variables are used in the calculation of travel behaviors and related impacts on energy consumption. The calculation can be provided in "Intermediate Calculation" section.					
			Units	**Sector**		
	Neighborhood (cluster) size	0.20	Sq. km	E, O, T	*Total gross area of the neighbourhood/community/development*	
	Distance to Central Business District	10.00	km	T	*Distance from approximate centre of development to centre of nearest downtown*	
	Brt Corridor	1	if yes	T		
	Building coverage	0.28	%	O, T		
	Average Home construction area	120	Sq. m	O, E		
	Road construction area	12895.96	Sq. m	E		88371.899
	Road density	644.798	m2/sq.km	O, T		*6.63719*
	Land use mix	0.25		T		
	Building function mix	0.0774		T		
	Green space coverage	0.24		O, T		
2nd	Parking (# of parking lots/100 HHs)	57	#	T		
1st	Surface parking space	7296	Sq. m (1 parking lot=10sq.m)			
1st	Undergroundparking space	0	Sq. m	O_common area		
	Community facility space	10000		*O_common area*		
CLUSTER DESIGN CHARACTERISTICS						
	Total # of households	**1280**		E, O, T		
	Population Density	**43.27**	(# of 1000ppl/sq km)	T		
	Total # of buildings	**28**		E		
	F.A.R.	**2.12**		T		
	Average buidling heights	**7.47730443**	Avg. # of floors	E, T		
Heights						
	Percentage in super-high rise (19+)	50%	%	O_common area		
	Percentage in high-rise(13-18)	30%	%	O_common area		
	Percentage in mid-rise (4-12)	20%	%	O_common area		
	Percentage in low-rise (1-3)	0%	%	O_common area		
	Low rise (1-5)			E		
	Mid-rise (6-10)			E		
	High-rise (10-15)			E		
	Building parameter		m	E		
	Floor area	**896**	Sq. m	E		
	Residential buidling with street-level shops	**0**		T		

4.3. Screenshot of Part of the Energy Proforma Input Sheet three sub modules: (1) embodied energy use, (2) operational energy use, and (3) transportation energy use. Users can explore how much is the total energy consumption and GHG emission of each neighborhood, or cluster, they chose to analyze, as well as the share of different sources of energy consumption attributable to the above components. A fourth component of the Energy Proforma, renewable energy production within a neighborhood, will be added in future versions of the tool.

Use of the Proforma involves three steps:

1. Input—First, users insert quantified values of variables listed in the input sheet. The listed



OUTPUT

OPERATIONAL ENERGY

Output: Adjusted per Household Energy Consumption	
By Energy Source	
Electricity (MJ)	33214
Gas (MJ)	6552
Centralized heating (MJ)	37205
Sum	76971
By Use	
Total heating (MJ)	40302
Total cooling (MJ)	6792
Total lighting (MJ)	2014
Other uses (MJ)	27863
Sum	76971

Output: per HH Common Area Energy Consumption	
Pump	3568
Elevator	3327
Lighting(in-building)	55
Lighting(out-of-building)	185
Access security	109
Underground parking	0
Community facilities	1246
Other	0
Sum	8500

FINAL OUTPUT	
OPERATIONAL ENERGY USE/ GHG EMISSIONS	
Annual Inhome Energy consumption per I	76971
Annual Common Area energy consumptio	8500
Annual operational energy consumption	85471
Annual CO2 emission per household	7023
TRANSPORTATION ENERGY USE/ GHG EMISSIONS	
Predicted Car Ownership (# cars/ 100 H	52
Predicted Annual Energy (mj)	15632
Predicted Annual CO2 Emission (kg)	909
EMBODIED ENERGY USE/ GHG EMISSIONS	
Annual embodied energy consumption p	2753
Annual CO2 emissions per household (K	3096

4.4. Screenshot of Part of the Energy Proforma Output Sheet variables are chosen from our empirical analysis and are used to estimate embodied energy, operational energy, and transportation energy. The input variables are grouped in two categories: neighborhood form characteristics and socio-demographic characteristics. The variables that represent neighborhood characteristics are mostly related to the physical condition of a neighborhood whereas those that represent socio-demographic characteristics represent the human behavior and attitudes. The input variables in the first category represent the following: (1) Land use characteristics, (2) cluster/ neighborhood design characteristics, (3) road characteristics and (4) material characteristics. While some values (e.g. neighborhood size, residential floor area,) can be obtained from the design plans, other values (e.g. land use mix, surface-volume ratio) may require secondary calculations based on the first order variables.

2. Calculations—The input variables provided by users are then calculated based on the coefficients and functions developed from our early empirical analysis of neighborhoods in Jinan. As such, the intermediate calculation uses coefficients on embodied energy use, operational energy use and transportation energy use derived specifically from the Jinan context, taking in to account its climate, local behaviors, and other factors. These intermediate calculations are not visible on the input sheet, but nonetheless transparent to the user. If the user clicks each cell in each "intermediate calculation" sheet, they are able to see the functions and follow the logic of how the final output is driven. However, the calculations shown in each sheet are provided not for deterministic purposes but more as benchmarks. As the goal is to enhance the transparency and legitimacy of the tool, users are able to verify and modify calculations as they explore the energy performance of various urban designs.

3. Output—Results are displayed on an "output" sheet. First, the annual operational energy consumption per household, which shows the largest share of the total energy consumption, is presented. It includes the annual in-home operational energy consumption (per household) both by energy source and by use. An accompanying diagram shows the annual operational household energy consumption by use. A second table presents the annual common area energy consumption per household. A second graph illustrates how the common area energy is used for different purposes. A third table presents the share of energy consumption by three sub sectors: embodied, operational, and transportation energy consumption. Along with the energy consumption per household, the values for the annual CO_2 emissions per household for each sector are also presented. The third graph illustrates this final output.

The accompanying figures shows a partial glimpse of the current form of the input and output sheets for the Proforma.

STUDIO RESULTS AND LESSONS

The 2010 MIT-Beijing Urban Design Studio provided an opportunity to test application of the Proforma in practice for the first time, as described in **Chapter 3: Five New Clean Energy Neighborhoods**. There were two aspects to this experience. First, each team conducted a reconnaissance of one of the study neighborhoods in Jinan, representing one of the four form prototypes. The energy performance of these neighborhoods was known, across all dimensions, based on the extensive surveys and analysis done prior to the studio. This enabled the teams to intuit in the field what aspects of the design and use of each neighborhood were contributing to its energy performance, and how they compared and contrasted. This ability to see form-energy relationships with greater intelligence is one benefit of the Energy Proforma research that we had not anticipated.

Second, using their field experience as a platform, the teams designed their own schemes using the Energy Proforma as a tool. Being well aware that the values contained within the Proforma were derived from some of the very projects they studied in Jinan, gave a sense of reality to the exercise that would otherwise have been impossible. Many of the teams made use of successful characteristics they had observed in the neighborhoods as a starting point for their designs. At the end, designers were able to compare the performance of their projects with neighborhoods in Jinan and also with each other. This was another powerful learning experience.

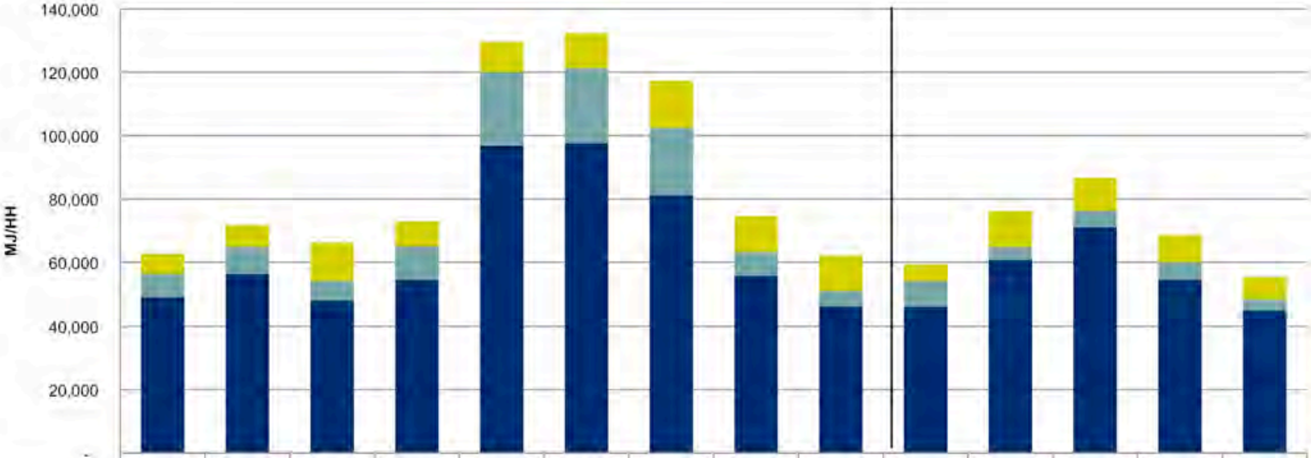
Results of the five individual designs are compared in the accompanying tables, along with all of the study neighborhoods in Jinan. It must be noted that during the studio it became evident that providing operational energy per household (MJ/HH) alone, has limitations in assessing the efficiency of highly mixed-use environments characterized by large amounts of commercial and office space. Hence, operational energy was also calculated as annual operational energy per square meters of total floor area (MJ/sq.m).

The Energy Proforma introduced a method of urban form evaluation unfamiliar to many designers. Much of design is based on intuition, inspiration, and qualitative evaluation of previous knowledge and experiences. The Energy Proforma is highly quantitative and offers the potential for more objectively comparable results. Although still under development, the early version of the tool enabled the five teams to assess the energy performance of their urban design interventions during the conceptual design process. It also ultimately allowed the five teams to compare the outcomes of their work with the cases they studied at the beginning of the summer studio as well as with the proposals of the other teams in a rigorous and consistent fashion.

The introduction of the tool to the students during the early stages of the workshop, and an understanding of the studies that had been undertaken in order to develop the tool, contributed significantly to the form and variety of design solutions. The very nature of the Energy Proforma encouraged exploration, since it does not imply prescriptive guidelines or standards for the generation of energy efficient urban design. To the contrary, it reveals the impact of various design moves and alternatives, serving as a decision-making support tool. In the studio, it enabled the teams to validate or question their initial assumptions and subsequently launch more intense investigations about how different forms and characteristics affected energy consumption.

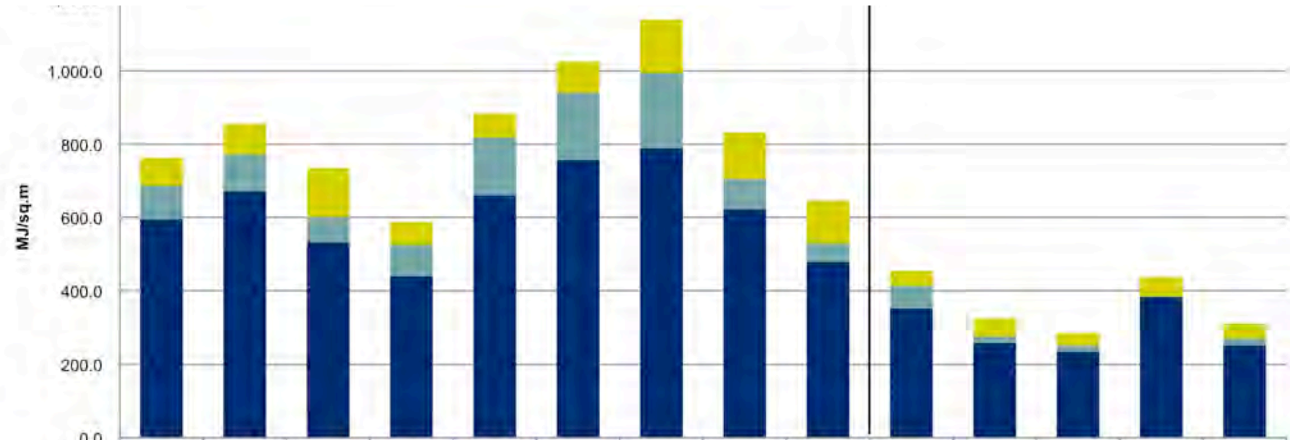
Discussions with the design teams following the studio experience provided interesting insights that will be used to advance the Proforma:

- Engagement—In general, designers enjoyed working with the Proforma, because it gave them concrete results—“something to hang their hat on”.



	Dong-Cang	Wuying-Tan	Foshan-Yuan	Yanzi-Shan	Lv-Jing	Sunshine 100	Shanghai Garden	Commercial District	Zhang Village	Site 1	Site2	Site 3	Site4	Site5
Embodied	6,348	6,979	12,147	7,766	9,605	11,055	15,021	11,435	11,245	5,365.6	11,310.5	10,412.3	8,788.4	7,098.3
Transportation	7,439	8,484	6,175	10,633	23,170	23,657	21,179	7,352	4,852	8,066.2	4,077.3	5,208.8	5,362.2	3,543.0
Operational	48,953	56,362	47,968	54,505	96,833	97,645	81,174	55,785	46,122	45,937.5	60,735.1	71,069.1	54,573.8	44,749.8

4.4. Annual Per Household Energy Consumption (MJ/HH)



	Dong-Cang	Wuying-Tan	Foshan-Yuan	Yanzi-Shan	Lv-Jing	Sunshine 100	Shanghai Garden	Commercia l District	Zhang Village	Site 1	Site2	Site 3	Site4	Site5
Embodied	77.3	83.1	134.8	62.6	65.5	85.7	146.0	127.6	116.6	41.1	48.3	34.4	53.5	40.0
Transportation	90.6	101.0	68.5	85.7	158.0	183.3	205.8	82.1	50.3	61.7	17.4	17.2	1.3	19.9
Operational	595.9	670.9	532.3	439.1	660.4	756.7	788.8	622.6	478.3	351.6	259.2	234.7	383.0	251.9

4.5. Annual Energy Consumption per sq. meters of Building Construction Area (MJ/sq.m)

However, it took a while to become comfortable with the tool. Teams expressed a desire to be able to jump in more quickly, so there could be a more integrated process between design and assessment. Multiple iterations give a better understanding of form-energy relationships and should be easy to do. This might be addressed by organizing better training sessions or making the tool more friendly. Designers expressed interest in having a structured feedback loop that would allow them to trace design changes and their impact in the Proforma.

- Expectations—Teams noted that certain design moves made because of their perceived energy implications had far less or far more impact than was expected. In this way, the Proforma served as a kind of reality check, exposing the actual impact of design decisions. Elements which had a strong impact on energy consumption were such aspects as window coverage ratio, FAR, and unit size. Design features that had less impact than the teams expected were characteristics such as natural wind ventilation, sun exposure, unit flexibility, rain water collection and grey water remediation, all considered to be good management practices.
- Sensitivity—In particular, the Proforma did not seem to be sensitive enough to pick up on some important moves that should result in reduced consumption. For example, in Site 1: Re-Invented Enclave, retaining existing rubble on the site did not affect the embodied energy results. In a similar way, recycling rain and grey water, which dramatically reduces water consumption, was not accounted for. Finally, it is assumed among designers that urban environments and the characteristics they posses are closely correlated with human behavior. The way human behavior may impact energy consumption, beyond transportation choices, was unclear.

The Energy Proforma created, at a minimum, high levels of interest; it urged the teams to think of their design solutions in different ways and to debate their own assumptions. Further development and refinement of the Proforma is currently underway that aims to address among other things some of the key points that the designers raised.

NEXT STEPS

The research to date has opened up a rich field of inquiry—the relationship between urban design and energy—that in many ways was previously unexplored. We look forward, first, to expanding the robustness and sensitivity of the Energy Proforma to better address factors such as the effects of sun and wind and potentials to support on-site renewable energy production. Studies of these topics are now under way. We also wish to better incorporate the energy consumed by commercial, institutional and other uses that increasingly will be mixed in with residential development. Finally, we hope to streamline the Proforma to make it a more accessible and flexible tool.

These are important steps but means to an end. The underlying goal of our work is to advance the design of cities in China, making them more energy sustainable and livable at the same time. To the degree that Proforma leads designers and developers to invent new, more effective urban environments, the project will be successful.

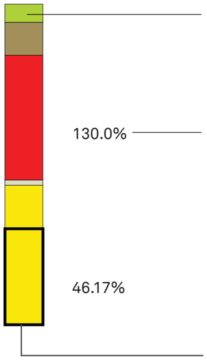
Appendix: Urban Form Patterns and Reference Cases

As part of the research on Making the 'Clean Energy City' in China, close to 100 international cases of clean energy development projects were examined, as discussed in **Chapter 1: Clean Energy and Urban Patterns**. Considering the most successful projects, several repetitive design patterns became evident. These prototypes represent very basic ideas about urban form including relationships among buildings, sites, routes of access, and the surrounding city. They capture the essence not only of physical form, but also activities and patterns of behavior engendered by the form, and finally, strategies for saving and producing energy. In all, six prototypes with several variations on each were identified.

The case projects most representative of each prototype were studied in more detail to provide the foundation for a pattern book of reference cases now under development. Collectively, the projects stand out for their comprehensive energy goals and/or performance, although the degree of documentation varies. They also represent a range of scales and types of development; the aim was to highlight projects that were relatively successful within their prototype category. Finally, the projects stand out as examples of livable, high quality design. The prototypical patterns, variations on each, and key representative cases are presented on the following pages.

NOTE! Red indicates that certain clusters are neighborhoods within Jinan, China, and were not necessarily designed with clean energy in mind. These cases are for comparison purposes only.

USE BREAKDOWN

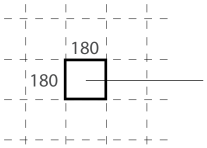


Colored Bars - represent total use area of a given use relative to a clusters total land area. Note how multiple floors result in total use areas that exceed land area

Percentages - represents the total built area of a given use relative to the total land area of a cluster. In this case, residential built area is 129.25% of the total land area available. (Note that only built areas have the percentage shown, as these are the only numbers factored into FAR) See pages 38 and 39 to view other uses as percentage of land area.

Heavy Black Box - represents relative total land area of a given unit cluster. All of the boxes are the same size graphically, but keep in mind that each cluster's absolute total land area may vary, and the box should only be used for relative comparison

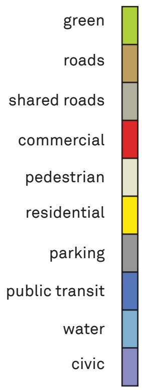
CLUSTER SIZE



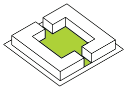
CLUSTER AREA

32400 sq. m

Cluster Grid - as much as possible, clusters are reduced to units that fit into simple multiples of a 180mx180m grid.

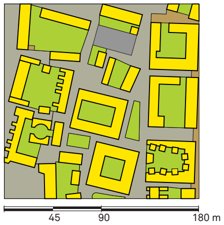


Small Perimeter Block,
Simple
based on Bo01
Malmo, Sweden

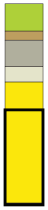


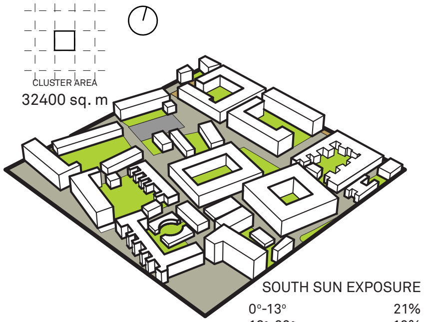
1A

FAR	1.32
LAND COVERAGE	33.0%
UNITS/HECTARE	172



129.25%

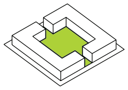




SOUTH SUN EXPOSURE

0°-13°	21%
13°-90°	19%
0°-90°	40%

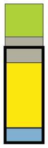
Small Perimeter Block,
Complex
based on Ecolonia
Alphin, Netherlands

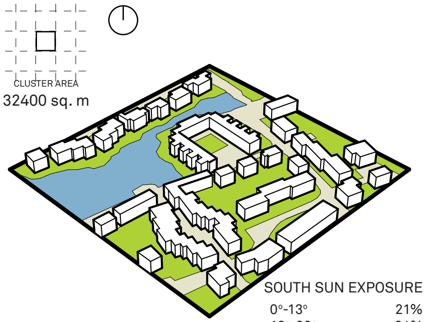


1B

FAR	0.63
LAND COVERAG	21.2%
UNITS/HECTARE	39

68.33%

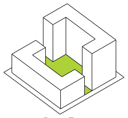




SOUTH SUN EXPOSURE

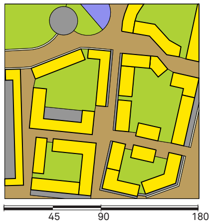
0°-13°	21%
13°-90°	24%
0°-90°	45%

High Density Perimeter Block,
Simple
based on Greenwich
London, UK



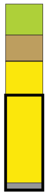
2A

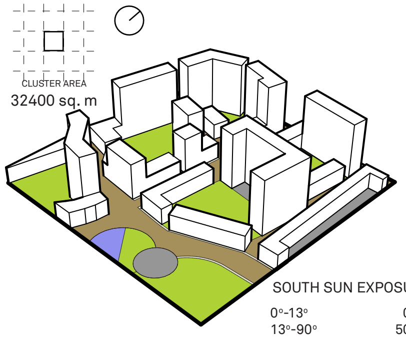
FAR	1.25
LAND COVERAGE	32.1%
UNITS/HECTARE	105



127.80%

1.21%

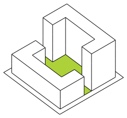




SOUTH SUN EXPOSURE

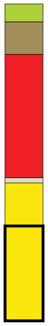
0°-13°	0%
13°-90°	50%
0°-90°	50%

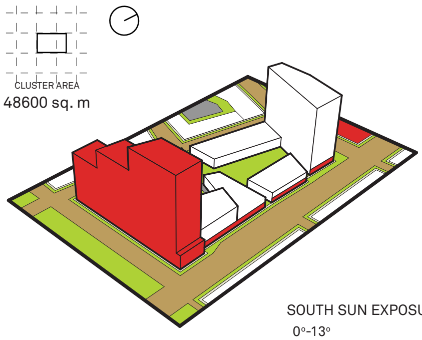
High Density Perimeter Block,
With Towers
based on Symphony Park
Las Vegas, NV, USA



2B

FAR 2.40
LAND COVERAGE 35.7%
UNITS/HECTARE 72

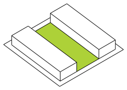




SOUTH SUN EXPOSURE

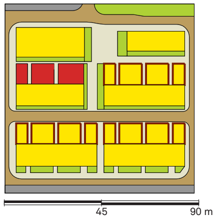
0°-13°	0%
13°-90°	53%
0°-90°	53%

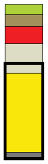
Low-rise Slabs,
Alighed
based on Bedzed
Wallington, UK

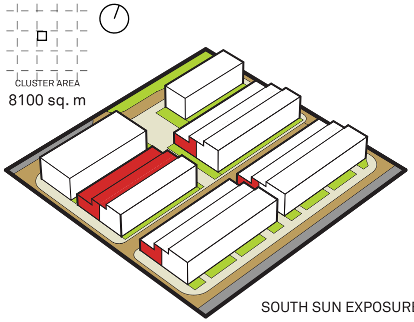


3A

FAR 1.14
LAND COVERAGE 44.0%
UNITS/HECTARE 104



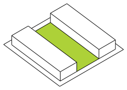




SOUTH SUN EXPOSURE

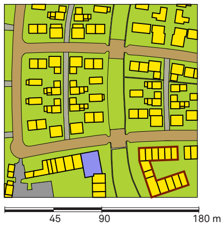
0°-13°	0%
13°-90°	49%
0°-90°	49%

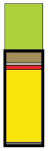
Low-rise Slabs,
Staggered
based on Geos
Denver, CO, USA

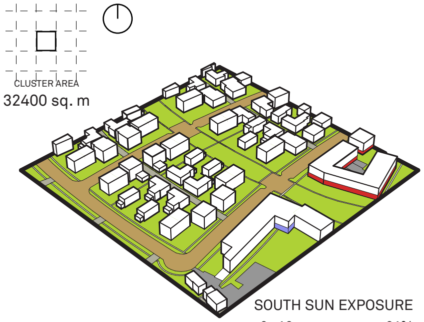


3B

FAR 0.81
LAND COVERAGE 29.4%
UNITS/HECTARE 46



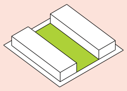




SOUTH SUN EXPOSURE

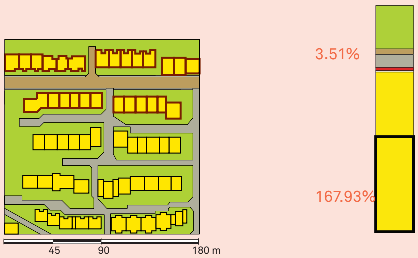
0°-13°	21%
13°-90°	21%
0°-90°	42%

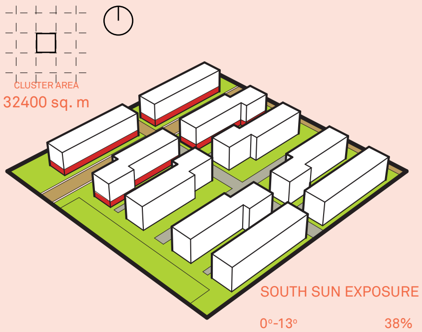
Low-rise Slabs,
Enclave
based on DongCang
Jinan, China



3C

FAR	1.82
LAND COVERAGE	33.5%
UNITS/HECTARE	253



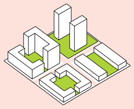


32400 sq. m

SOUTH SUN EXPOSURE

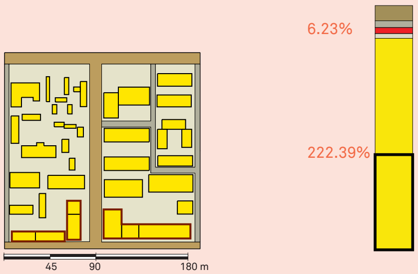
0°-13°	38%
13°-90°	0%
0°-90°	38%

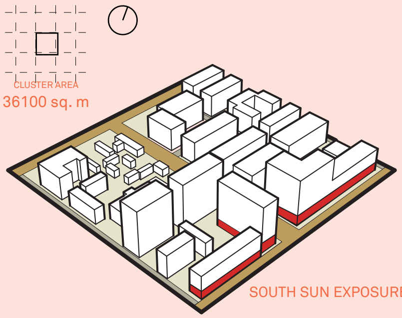
The Grid,
Regular
based on Old Comm. Ctr
Jinan, China



4A

FAR	2.72
LAND COVERAGE	46.1%
UNITS/HECTARE	374



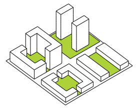


36100 sq. m

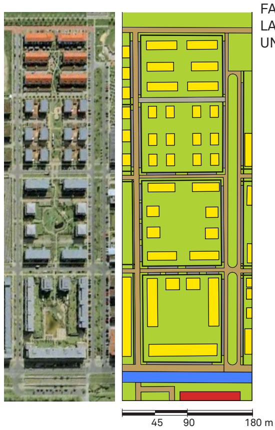
SOUTH SUN EXPOSURE

0°-13°	0%
13°-90°	49%
0°-90°	49%

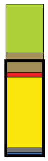
The Grid,
Regular
based on Kronsberg
Hanover, Germany

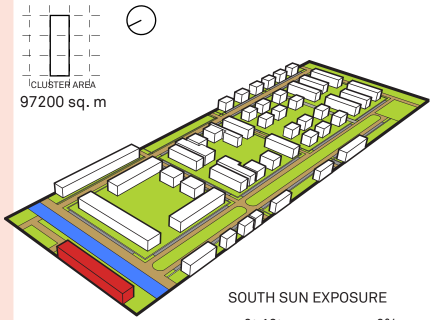


4A



FAR	0.73
LAND COV.	18.2%
UNITS/HECTARE	106



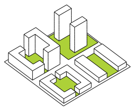


97200 sq. m

SOUTH SUN EXPOSURE

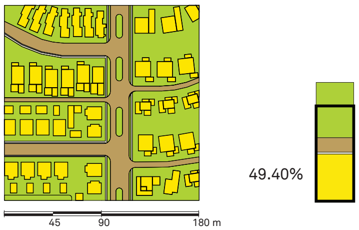
0°-13°	0%
13°-90°	50%
0°-90°	50%

The Grid,
New Urbanist
based on Civano
Arizona, NV, USA



4B

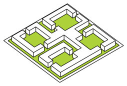
FAR	0.60
LAND COVERAGE	29.7%
UNITS/HECTARE	40



SOUTH SUN EXPOSURE

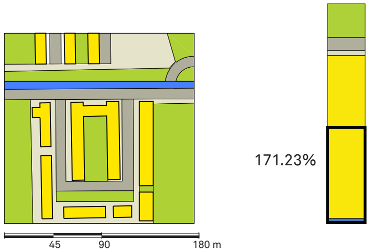
0°-13°	19%
13°-90°	10%
0°-90°	30%

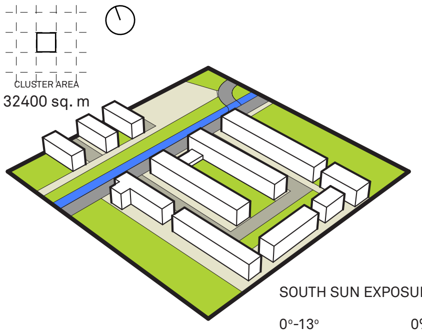
Low-rise Superblock,
Pedestrian Cluster
based on Vauban
Freiburg, Germany



5A

FAR	1.97
LAND COVERAGE	49.1%
UNITS/HECTARE	257

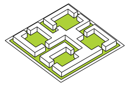




SOUTH SUN EXPOSURE

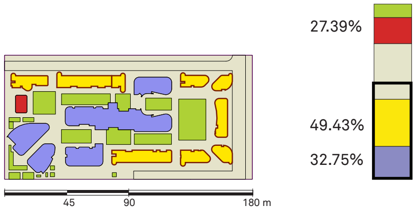
0°-13°	0%
13°-90°	51%
0°-90°	51%

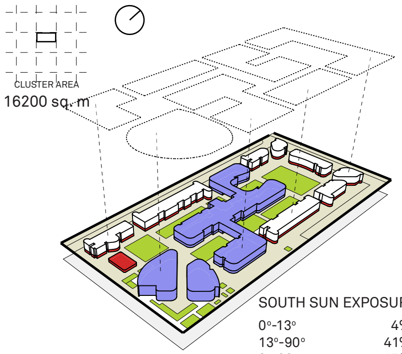
Low-rise Superblock,
Pedestrian Matrix
based on Masdar
AbuDhabi, UAE



5B

FAR	1.10
LAND COVERAGE	27.4%
UNITS/HECTARE	47

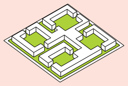




SOUTH SUN EXPOSURE

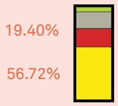
0°-13°	4%
13°-90°	41%
0°-90°	45%

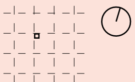
Low-rise Superblock, Traditional Form based on Zhang-Jia Village Jinan, China



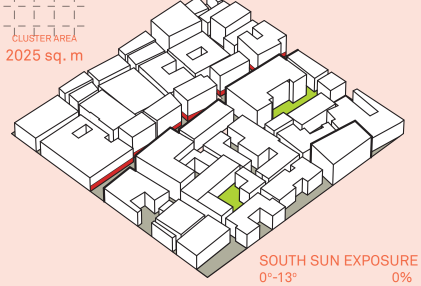
5C

FAR	0.75
LAND COVERAGE	76.1%
UNITS/HECTARE	121





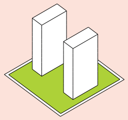
2025 sq. m



SOUTH SUN EXPOSURE

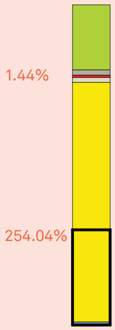
0°-13°	0%
13°-90°	50%
0°-90°	50%

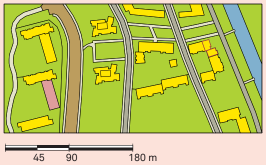
High-rise Superblock, Towers in Park based on Sunrise 100 Jinan, China

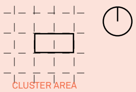


6A

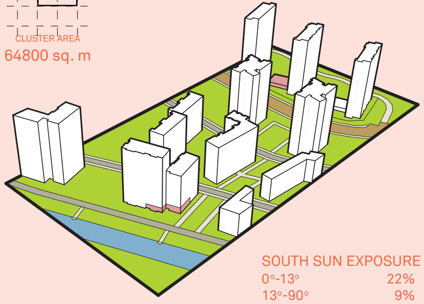
FAR	2.37
LAND COVERAGE	15.4%
UNITS/HECTARE	222







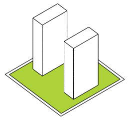
64800 sq. m



SOUTH SUN EXPOSURE

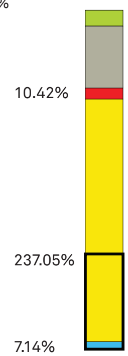
0°-13°	22%
13°-90°	9%
0°-90°	31%

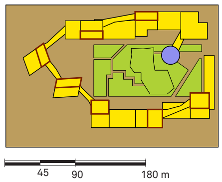
High Density Perimeter Block, Linked Towers based on Linked Hybrid Beijing, China

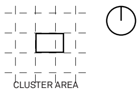


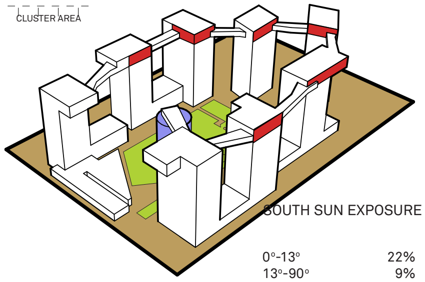
6B

FAR	3.00
LAND COVERAGE	39.4%
UNITS/HECTARE	222









SOUTH SUN EXPOSURE

0°-13°	22%
13°-90°	9%
0°-90°	31%

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