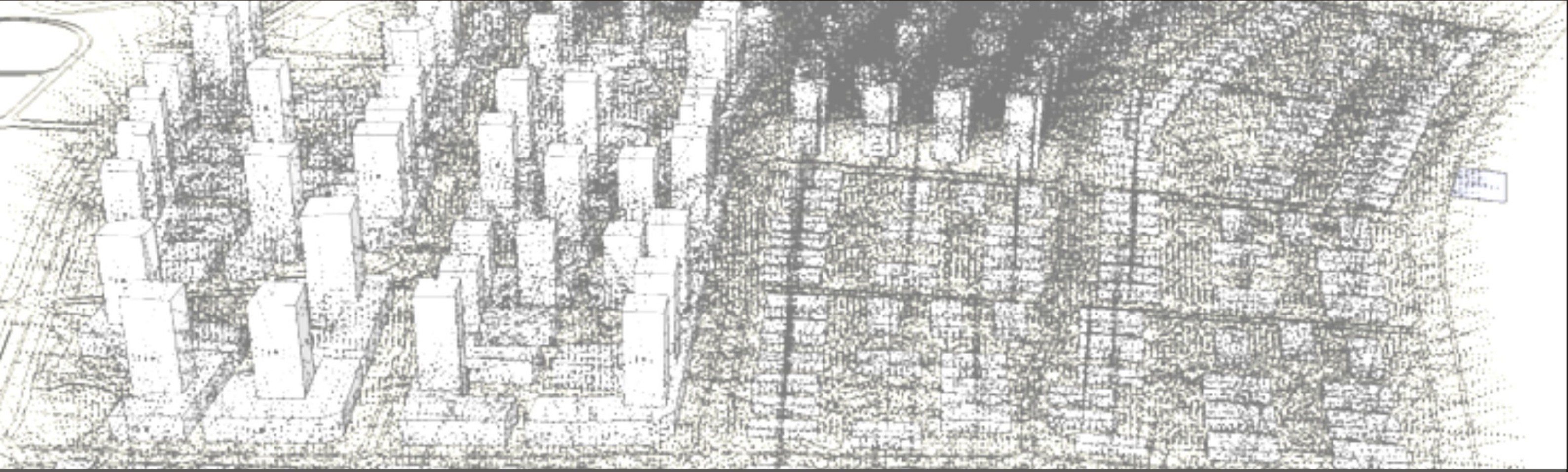

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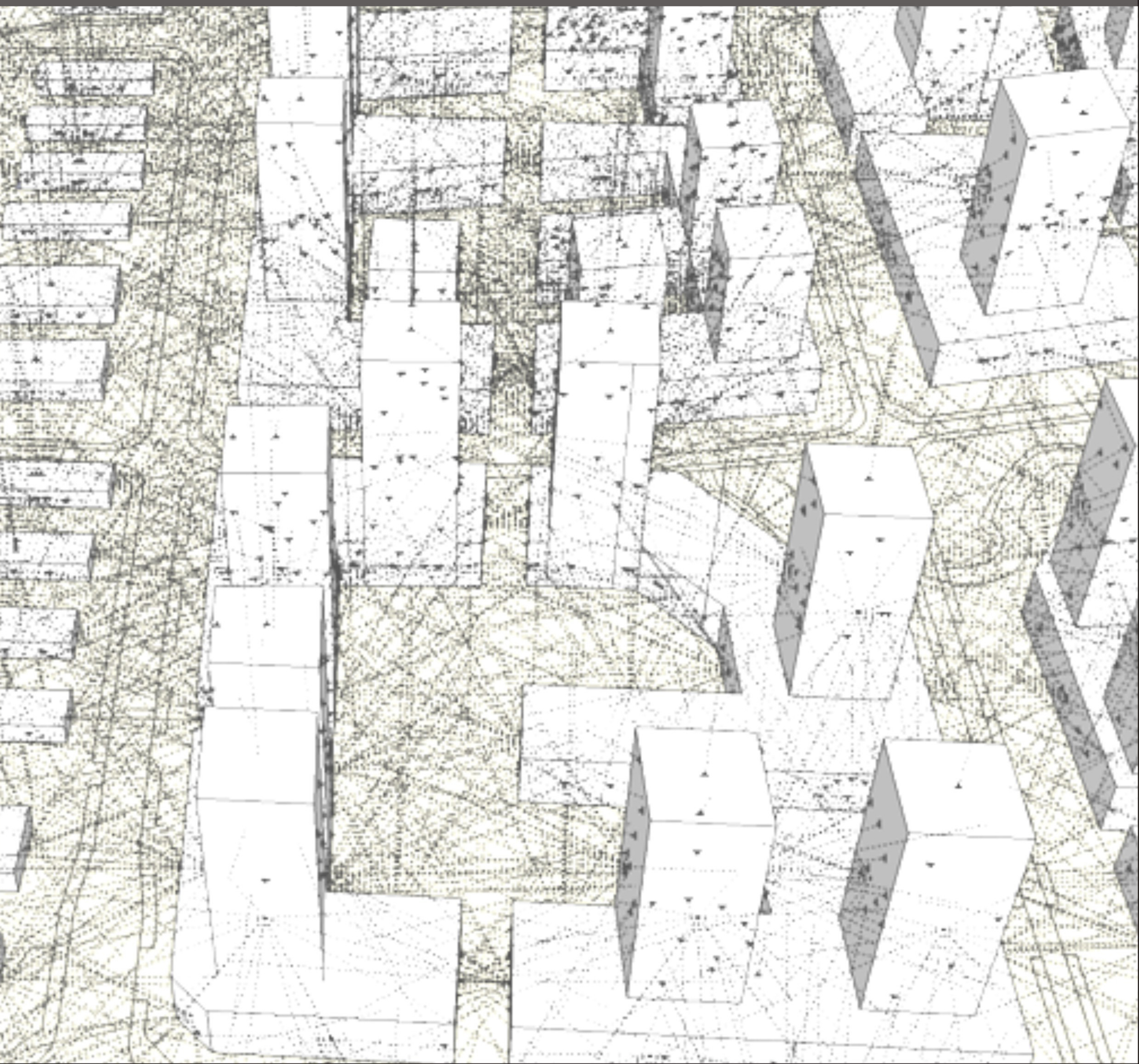
Low Carbon Master Plan Guidance



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Introduction

Structure of Guide

This 'low carbon master-planning' guide aims to provide guidance and modelling to significantly reduce carbon dioxide emissions for new developments. It is structured in two main parts:

Figure 1.0
The Ba'nan Project represented in Google Sketch-Up

Part 1: Low carbon approach and benchmarks
This section introduces the concepts of low carbon master-planning and presents results for the main sectors associated with energy use and carbon dioxide emissions, including, building energy use, embodied energy, renewable energy supply, transport and infra-structures.

Part 2: Low carbon model and application to Ba'nan
This describes the urban scale low carbon master-planning model developed at the Welsh School of Architecture, Cardiff University, and illustrates its application through the Ba'nan project. It is used to predict the operating energy, embodied energy and potential for using renewable energy for the project.

PART ONE
Low carbon approach and benchmarks

Purpose

PART 1 of the guide introduces the concepts of low carbon and sustainable master-planning and then presents benchmark information for the different sectors, and how this fits in to an evaluation framework. An evaluation framework needs to be closely aligned to the planning and design process, clearly identifying what outputs are to be assessed and against what criteria. Part 1 is presented in three sections:

- Low Carbon Approach
- Sectors and Benchmarks
- Process and Evaluation

Low carbon Approach

What is low carbon?

The definition of a low carbon building or a low carbon built environment is sometimes not fully understood. There is often confusion between low carbon and low energy. A 'low energy' building has its operating energy demand reduced, for example, through a more efficient fabric or a more efficient heating, lighting and ventilation system, using 'passive' and 'low energy' design. A low carbon building will have further energy demand reductions, and will then use renewable energy supply to meet this reduced demand.

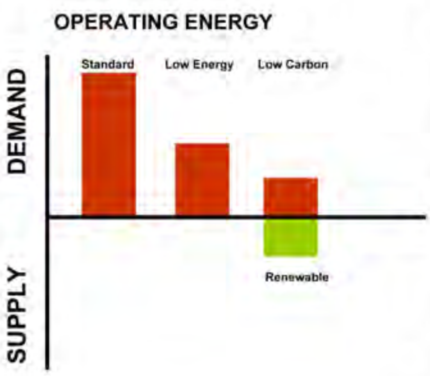


Figure 1.1
Low energy performance is typically 50% of standard performance. Low to zero carbon performance is further reduced and the supply met from renewable or low carbon sources.

This renewable energy supply can either be integrated into the building design or be located 'near-to' as part of a community system. Generally speaking, the renewable energy system should be part of the development and not, for example, be assumed to come from existing green energy sources.

Energy is used in buildings for cooling, heating, ventilation, and lighting. These energy uses are increasingly regulated by governments. Energy is also used for small power, including the electricity supply to computers, TV's etc. This energy use is generally not regulated at the moment. CO_2 emissions are associated with the use of fossil fuels to supply this energy, either delivered to the building, for example, oil, gas, etc., or used at the power station to generate electricity.

Sustainability

Figure 1.2
The sustainability 'triple bottom line' including environment, social and economics.

The planning and design associated with low carbon master-planning must be related to sustainability in terms of the so-called triple bottom line of environment / society / economics, and including governance issues. Several statements, concepts or consultation papers include a definition about sustainable development where all the comments embrace "that in the long term, economic growth, social cohesion and environmental protection must go hand in hand..." (Stockholm European Council). Furthermore it is the aim to better link between the involved stakeholders and include all important actors into the decision making and planning process.

There are many indicators and criteria in use, aiming to support sustainable development. The range of selected criteria depends on the context of a project or proposed development; in any case they should be understood as guidelines for the involved stakeholder groups to achieve a more sustainable development. A few of the many principles which contribute to sustainability are: to regard the precautionary principle, maintaining diversity, aiming for integrative solutions, creating scope for innovations, living the model of fairness and solidarity, enhancing knowledge and desire, assuring quality and health, supporting rationality and subsidiary, enhancing local identity.

Projects should demonstrate a socio-economic basis for their development rather than simply being property speculation without an identified socio-economic strategy. A sustainable approach will be based on a holistic systems approach.

Impact

The impacts of a development should be considered at a global, local and building scale. Factors include:

Building scale
This will include factors such as comfort, health, productivity.

Local scale
Outdoor air quality, accessibility to services, jobs, etc.

Global scale
Carbon dioxide emissions, use of resources, etc.

The impacts will relate to the measurable outcomes and should be determined through the evaluation process.

Figure 1.3
The built environment can impact at global, local and building scales in relation to the sustainability triple bottom line.

Sustainability issues relating to low-carbon urban master-planning

There are a number of basic decisions made during the early stages of master-planning which impact on sustainability and low carbon performance. These are introduced below:

Supply versus Demand
The first priority should be to reduce demand and then provide efficient and effective supply.

Local versus Central
Infrastructures should be an appropriate mix of building integrated, local and central, grid based, with any storage issues also considered. Where possible low-carbon renewable options should be used.

Accessibility versus Mobility
Accessibility to services should be considered before maximising mobility to ensure a low carbon, less congested, solution. Mobility should then be biased towards walking / cycling and public transport in preference to private motor vehicles.

Operating Energy versus Embodied Energy

The carbon agenda needs to be considered holistically including operating and embodied energy and associated carbon dioxide emissions, as well as maximizing the use of zero carbon energy supply.

High density versus Low Density Development

The appropriate density of development should be based on an appropriate balance of buildings and landscaping to reduce energy use (buildings and transport). The mix of buildings and green areas should be planned to minimise the heat island effect, pollution hot spots, and to ensure adequate breezeways through the development.

Community

Where buildings already exist, they should be considered for reuse and communities retained and developed on where appropriate. Local labour and supply chains should be used or developed where possible.

Costing

A life cycle costing approach should be used, based on CO_2 emissions. Subsidising non-sustainable approaches, such as transport systems and other infrastructures, at the cost of more sustainable solutions should be avoided.

Sectors and Benchmarks

Figure 1.4 identifies the main sectors associated with low carbon master-planning, including: base line conditions, setting targets and guidelines for achieving them, ensuring compliance through evaluation, learning from doing, and feeding to forward, adjusting procedures and targets over time where appropriate.

Figure 1.4
Low Carbon Master-planning framework

Low carbon master planning should adopt a holistic approach over the range of sectors. Guidance on benchmarks and target setting is presented. The process and need for evaluation is discussed at the end of PART 1. PART 2 of this guide presents an evaluation tool for predicting CO_2 emissions using Ba'nan as an example.

Site Analysis

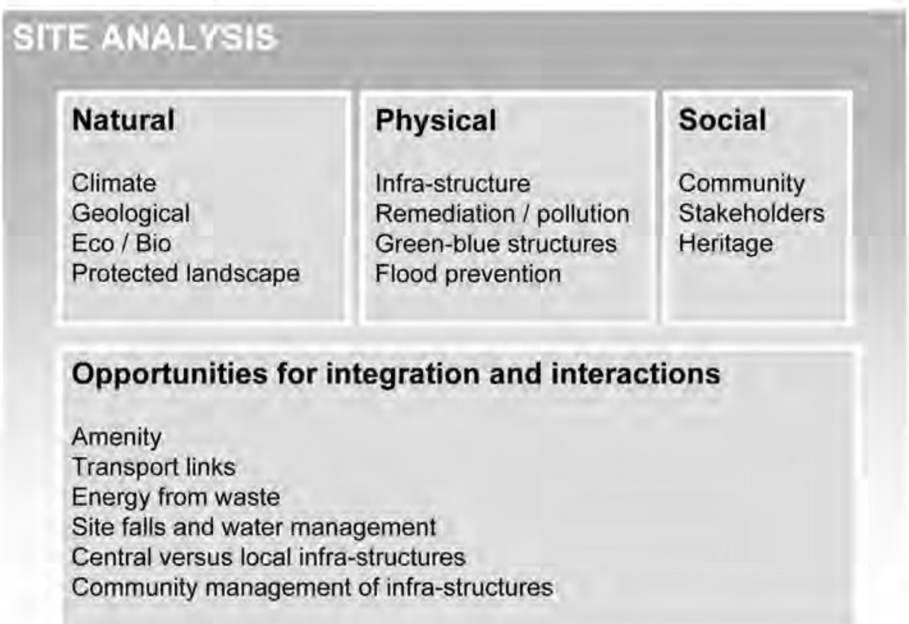


Figure 1.5
Site analysis data collection summary

The site analysis provides the context for low carbon approach. It is concerned with the given situation associated with the site and can be divided onto three areas, Natural, Physical and Social. Information on these three areas needs to be considered at the start of a project. Different projects will have different priorities and areas of emphasis. Figure 1.5 summarises the main factors that need to be considered. In addition to gathering data on the topics included in the table, consideration should be given to explore cross discipline opportunities offered by the site conditions to promote sustainability and low carbon performance.

Natural Features

- Climate analysis includes consideration of seasonal temperatures, solar radiation, wind speed and direction, relative humidity and precipitation.
- Geological landscape: includes the study of the geology, geomorphology and hydrology of the area.
- Bio-diversity should be considered in relation to existing flora and fauna and the development of new systems.
- Ecology: considerations should include observations of diurnal cycles for vegetation and organisms, shelter and habitats for indigenous species, and sources of natural resources and local waste streams.Landscape Habitats: should consider the distribution of the vegetation and habitats and the basis for landscape ecology.
- Visual & Sensory: considerations should identify landscape qualities that are perceived through the senses in relation to the individual physical attributes of landform and land cover, and their visual patterns of distribution and sensory characteristics, and the relationships between them in a particular area.
- Historic Landscape: focuses on how archaeological and historical sites relate to each other and to the surrounding landscape.
- Cultural Landscape: evaluates the relationship that exists between people and places; how people have given meaning to places, how the landscape has shaped their actions and their actions have shaped the landscape.

Physical Features

- Existing infrastructure may include transport systems overhead power lines and underground utilities. These may produce constraints and opportunities.
- Remediation may be required to restore site conditions which may have been polluted from previous use.
- Green-blue structures may exist from previous developments or may be appropriate to consider in the light of the natural features of the site.
- Flood prevention measures may be necessary and these may use natural features and integrate with new green blue constructions.

Social Features

- A community may exist on the site and this may be included in the new development if appropriate, to provide services and labour.

- Stakeholders should be identified from all interested parties, including local communities, and they should participate in planning the new development.

- Heritage features may exist in the form of historic buildings which may
- need to be preserved.

Opportunities for integration and interactions

The early stages of a project should identify cross sector opportunities, including:

- Amenity
- Transport links
- Energy from waste
- Site falls and water management
- Central versus local infrastructures
- Community management of infrastructure

Building Operating Energy

This section presents benchmark data for building operating energy. This will vary with building type and location, so buildings in China will have different performance to those in other part of the world. There will also be a variation across China's different climate zones. However it is important to be aware of the range of benchmark data in order to develop criteria for Chongqing.

Low Carbon Energy Planning

The key point for low carbon energy planning is to reduce the amount of demand and thereafter plan to fulfil the required supply from renewable sources as much as possible. As a result the overall planning should provide balance between energy demand and energy supply (Figure 1.6). The term "energy" in this section mainly refers to building energy.

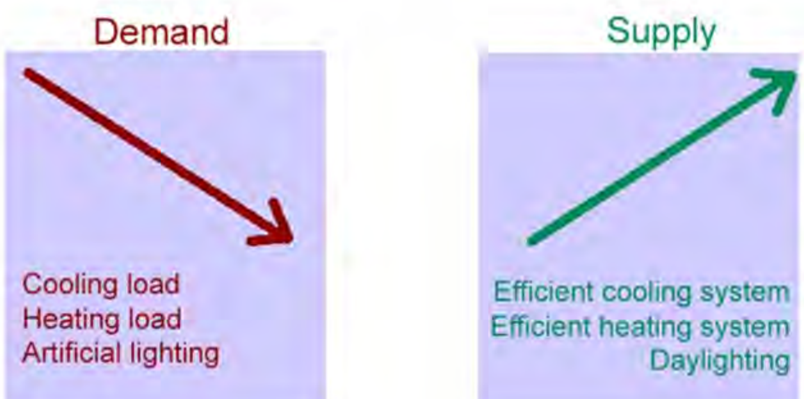


Figure 1.6
Reduce demand then provide efficient and effective energy supply

Benchmarks

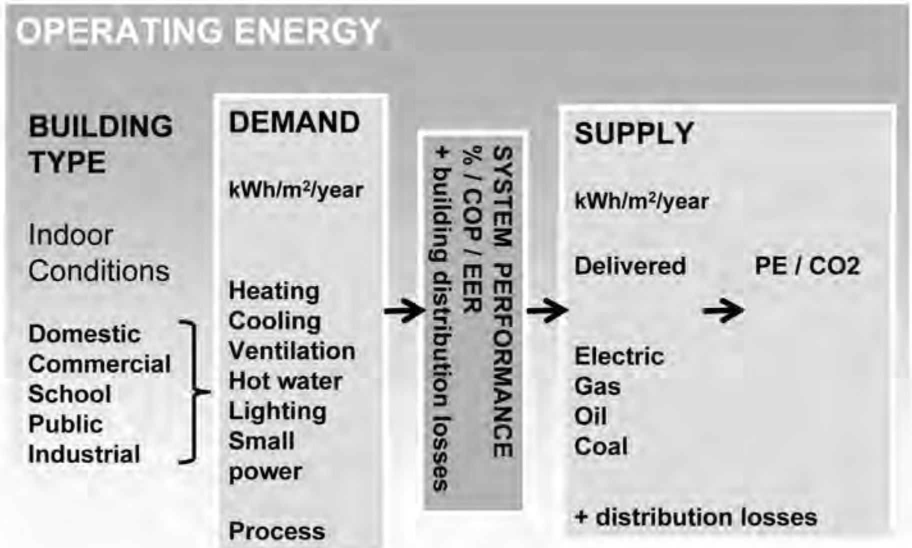


Figure 1.7
Summary of energy terminology

There are a range of benchmark criteria for building operating energy use, depending what is included, such as heating, cooling, ventilation, hot water, lighting, and small power. Some benchmark data include all, and some divide it into thermal and power. Any process energy used, such as for industrial buildings, is normally excluded from benchmark data. Figure 1.7 summarises the main terminology.

The Energy Demand relates to the thermal losses associated with heating, ventilation and cooling, and the electrical power consumption. The Energy Supply relates to the Delivered Energy and is the energy supplied to the building, for example the metered energy. The difference between energy demand and delivered energy relates to system performance factors, such as efficiency and COP (coefficient of performance), that are associated with heating, ventilation and cooling equipment. The energy supply is sometimes described in Primary Energy (PE) terms, which relates to the energy content in the fuel used, for example, gas, oil, coal, and fuels associated with electricity production at power stations. The CO_2 emissions are those associated with the primary energy use.

Benchmark data associated with the above definitions are presented below.

Indoor Conditions

Indoor conditions include:

- Environmental requirements for temperature, relative humidity (RH) and air speed.
- Internal heat gains from people and equipment.

Environmental requirements

Table 1.1 summarises the main conditions for design, based on typical conditions.

Parameter	Range
Air temperature	Winter 21°C Summer 26°C
Radiant temperature	Within 2°C of air temperature Internal internal surface temperatures, eg. glazing, <5°C above air temperature
Air speed	< 0.15m/s
Relative Humidity	40 to 60%
Fresh air ventilation	10l/s/person
Lighting	2% daylight factor/ 300-500 lux/ 9-15 W/m² lighting load

Table 1.1 Summary of internal design conditions

Internal gains from people and equipment

Tables 1.2 a-c summarises internal occupancy levels and energy gains from equipment for office type buildings.

Table 1.2a Internal heat gains for a typical office (UK)

Factor		Heat gains (W/m²)				
Density (m²/ person)		4	8	12	16	20
Sensible heat gain	People	20	10	6.7	5	4
	Equipment	25	20	15	12	10
	Lighting	12	12	12	12	12
Latent heat gain		15	7.5	5	4	3

Source: CIBSE Guide A: Environmental Design, 2006.

Table 1.2b Typical internal heat gains for office spaces (US)

Room type	Occupancy Density (m²/per)	Equivalent People Sensible W/m²	Lighting (W/m²)	Plug load (W/m²)
Office: light computer usage	18.58	3.85	11.84	5.38
Office: light computer usage	18.58	3.85	11.84	10.76
Office: light computer usage	18.58	3.85	11.84	21.53
Conference room	1.86	38.61	13.99	5.38
Lobby	9.29	7.72	13.99	2.69
Corridor	NA	NA	5.38	2.69
Kitchen/ break room	1.86	38.61	12.92	5.38

Source: ASHRAE: Advanced Energy Design Guide for Small to Medium Office Buildings

Table 1.2c Internal heat gains for a typical office (Switzerland)

Factor		Heat gains (W/m^2)		
Density (m^2/ person)		14	17	11
Sensible heat gain	People	5.0	4.0	6.5
	Equipment	7.0	3.0	15.0
	Lighting	15.9	11.6	15.9
Latent heat gain		5.5	4.5	7.5

Source: Standard-Nutzungsbedingungen für die Energie- und Gebäudetechnik 2006

Setting the benchmarks

Low Carbon design is an internationally known concept and therefore it can be approached in many different ways. Some methods measure their environmental credentials just by improving the energy consumption in comparison to what the specific building regulation standards requires in a given country or area; other designers compare the energy performance of similar projects across the globe and aim to improve those numbers. Hence many benchmarks and methods of comparison of final figures can be found, but very rarely is it possible to compare two projects fairly, because every project is different; however, due to the social need of urban scale design, attempts have been made to fit buildings into similar 'measuring moulds'.

The following information aims to provide an overview of various benchmarks available internationally. Nonetheless, keep in mind that the figures for the specifications of the different aspects of building design, should be dissimilar for different locations, in particular when comparing UK (or European) benchmarks to Chongqing, where the climate is significantly different.

This section provides various benchmarks given by different recognised standards. The figures represent the energy demand or supply (as stated) of buildings, including all the energy requirements (unless specified. i.e. as in the Passivhaus standard)

Energy Demand Benchmarks
The energy demand for a building can be divided into thermal (heating, cooling, hot water) and electricity (small power, lights and mechanical ventilation). For example, for a standard domestic building in Europe the thermal energy demand may be around 100kWh/m2. A low energy building might be half that at around 50kWh/m2, and a low to zero carbon building around 15kWh/m2.

The following tables show examples for general demand figures for buildings to be certified under the specific standards, in Germany (PassivHaus) and Switzerland (Minergie). The domestic electricity for PassivHaus standards might be typically 40 to 50kWh/m2.

PassivHaus originated in Germany and provide a standard for low to zero carbon energy demand. The emphasis is on reducing heat loss and usually incorporates mechanical ventilation heat recovery.

Standard	Domestic	Non-Domestic		
		Retail	Industrial	Office Buildings
	kWh/m2/a	kWh/m2/a	kWh/m2/a	kWh/m2/a
Passivhaus				
Heating only	15	15	15	15
Cooling only		15 (*)	15 (*)	15

Table 1.3 Passivhaus values. (*) when required

Minergie is the Swiss standard . It includes space heating, hot water, and (where needed) the energy required for mechanical ventilation. *[http://www.minergie.ch/minergie_fr.html]*
The Minergie-P standard generally relates to the integration of renewable energy systems.

Standard	Domestic		Non-Domestic					
			Retail		Industrial		Office Buildings	
	kWh/m2/a		kWh/m2/a		kWh/m2/a		kWh/m2/a	
	Post 2000 Buildings	Pre 2000 Buildings	Post 2000 Buildings	Pre 2000 Buildings	Post 2000 Buildings	Pre 2000 Buildings	Post 2000 Buildings	Pre 2000 Buildings
Minergie	38	60	40	55	20	40	40	55
Minergie - P	30	30	25	25	15	35	25	25

Table 1.4 Minergie and Minergie-P values.

System Performance

A building will have some form of environmental system for heating, cooling and ventilating, sometimes with humidity control. Heating systems will have an efficiency associated with them, cooling systems, a Coefficient of Performance (COP) and heat pumps a COP or energy efficiency ratio (EER). Systems may also have internal losses through pipework and ductwork (typically 5 to 10%). Table 1.5 presents typical system performance efficiencies, COP's etc for UK and Table 1.6 presents COP's for China.

System	%
Direct acting electric boiler	100
Ground-to-water heat pump (electric)	320
Ground-to-water heat pump with auxiliary heater (electric)	300
Water-to-water heat pump (electric)	300
Air-to-water heat pump (electric)	250
Gas-fired, ground / water source	120
Gas-fired, air source	110
Community boilers	80
Community CHP	75
Community waste heat from power station	100
Community heat pump	300
Community geothermal heat source	100

Table 1.5 Quoted System Efficiency in the UK

Types	Residential building		Commercial building	
	National standard	Local standard (Chongqing)	National standard	Local standard (Chongqing)
COP (Coefficient of Performance)	2.3	2.8	Depends on system types, 4.0 for average	Depends on system types, 4.1 for average
EER (Energy Efficiency Ratio)	1.9	2.8	Depends on system types, 3.0 for average	Depends on system types, 3.2 for average

Table 1.6 Quoted heat pump system efficiency in China

Energy Supply benchmarks

The following tables 1.7 and 1.8 show general supply figures commonly use in the UK: Table 1.9 refers to targets in Chongqing.

Standard	Domestic		Non-Domestic					
			Retail		Industrial		Office Buildings	
	kWh/m2/a		kWh/m2/a		kWh/m2/a		kWh/m2/a	
CIBSE- Guide F	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice
	291	496	209	259	96	103		
office types								
naturally ventilated cellular							112	205
naturally ventilated open plan							133	236
air conditioned standard							225	404
air conditioned prestige							348	568

Table 1.7 Energy supply values from CIBSE
Figures for CIBSE (F): 'Energy consumption benchmarks for existing buildings.' These benchmarks are from the latest publication (2004).

Standard	Domestic		Non-Domestic					
			Retail		Industrial		Office Buildings	
	kWh/m2/a		kWh/m2/a		kWh/m2/a		kWh/m2/a	
Carbon Trust	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice
office types								
naturally ventilated cellular							89	150
naturally ventilated open plan							88	148
air conditioned standard							115	210
air conditioned prestige							130	245

Table 1.8 Energy supply values from Carbon Trust
Figures for Carbon Trust: 'Energy consumption guide,' these benchmarks are from the 2000-2003 publication

Standard	Domestic	Non-Domestic		
		Retail	Industrial	Office Buildings
	kWh/m2/a	kWh/m2/a	kWh/m2/a	kWh/m2/a
Chongqing University Research		260		135

Table 1.9 Energy supply values from a Case Study in Chongqing

Office building data: TAN Xiaoyan. Survey and Research on Energy Consumption of Office Building in Chongqing. Chongqing University, 2008;
谭晓艳，重庆市办公建筑能耗调研及节能对策研究.重庆大学硕士学位论文, 2008年
Research on Energy Consumption Status and Energy Consumption Simulation of Emporium in Chongqing. Chongqing University. 2008;
王树健.重庆大型商场建筑能耗调研与能耗分析.重庆大学硕士学位论文, 2008年

Primary Energy and CO_2 emissions

Primary Energy relates to the energy content of the materials used, such as fossil fuels, either used directly in the building or converted to electricity at the power station. Typical values for the main fuels are given in Table 1.10.

CO_2 emissions associated with energy use also relate to the type of fuel used. These are summarised for China in table 1.11.

Fuel	United Kingdom	China
Electricity	2.5	3.3
Natural Gas	1.1	1.24

Table 1.10 Emission factors for main fuels

Fuel	Kg CO_2 / kWh
Raw coal	0.354
Coke	0.385
Crude oil	0.264
Gasoline	0.249
Diesel oil	0.267
Fuel oil	0.279
Liquified petroleum gas	0.227
Natural gas	0.202
Coal oil	0.259
Fuel gas	0.227
Electricity	0.694

Table 1.11 Quoted emission factors in China

Urban energy distribution must consider the different aspects about locally sourced or grid sourced energy, since they both provide different efficiencies and emit different carbon emissions. For instance in China there are different carbon emission indicators for different grid systems, see Table 1.12 and 1.13.

Power Grid	Provinces and Cities Covered
North China Power Grid	Beijing, Tianjin, Hebei, Shanxi Province, Shandong Province, Neimenggu Autonomous Region
Northeast China RPG	Liaoning Province, Jilin Province, Heilongjiang Province
East China Power Grid	Shanghai, Jiangsu Province, Zhejiang Province, Anhui Province, Fujian Province
Central China RPG	Henan Province, Hubei Province, Hunan Province, Jiangxi Province, Sichuan Province, Chongqing
Northwest China RPG	Shanxi Province, Gansu Province, Qinghai Province, Ningxia Autonomous Region · Xinjiang Autonomous Region
Southern China RPG	Guangdong Province, Guangxi Zhuang Autonomous Region,Yunnan Province, Guizhou Province
Hainan Power Grid	Hainan Province

Table 1.12 Regional Power Grid

Power Grid	EFgrid,OM,y (tCO_2/MWh)	EFgrid,BM,y (tCO_2/MWh)	EF (tCO_2/MWh)
North China Power Grid	1.0069	0.7802	0.89355
Northeast China RPG	1.1293	0.7242	0.92675
East China Power Grid	0.8825	0.6826	0.78255
Central China RPG	1.1255	0.5802	0.85285
Northwest China RPG	1.0246	0.6433	0.83395
Southern China RPG	0.9987	0.5772	0.78795

Table 1.13 Regional Power Grid Baseline Emission Factor in China 2009
Zhao Guan-wei, Chen Jian-fei, Cui Hai-shan, Chen Ying-biao (2010), Carbon Emission in Energy Consumption in Guangzhou During 1997 to 2007, Resources & Industries,12, Issue 6, 179-184.

Setting Operating Energy Targets

China has an energy target of 65% savings for new buildings compared to those constructed in the 1990's. 50% of this is achieved through fabric improvements and 15% through efficiencies in the HVAC systems.

Targets for 'low carbon' new build compared to existing standards are considered below in relation to three levels:

1. ***General improvements from regulations***: Typically for the European situation energy or CO_2 targets are being improved by about 25% every 5 years.
2. ***Environmental assessment methods*** such as LEED and BREEAM require about 50% savings over national standards to gain maximum credits.
3. ***Passivhaus*** (Germany) type standards requires about a 75% saving over national standards.

The above provides a typical set of targets for buildings as presented in Table 1.14, and based on the following strategy:

Level	*Standard*	*CO2 reductions*
Level 1	Basic level of improvement	25%
Level 2	Low carbon performance	50%
Levels 3	Zero carbon performance	75%

Office building	Current standard (kWh/m²/year)	basic level (kWh/m²/year)	low carbon performance (kWh/m²/year)	zero carbon performance (kWh/m²/year)
EU	130	98	65	33
China	135	101	68	34

Table 1.14 Targets for low carbon design

Electrical power for lights and small power for offices are presented in Table 1.15.

Use	Electrical power (W/m²)
Lights	12
Small power	10

Table 1.15 Targets for small power and lighting in offices (based on table 1.1a)

Power for domestic properties in the UK are currently on average about 4700 kWh/year and have the potential to be reduced to about 2400 kWh/year. While on average Chinese households use only about 160kWh/year, modern houses in China probably have the same potential for energy use as Western households and so these targets may be suitable.

Embodied Energy

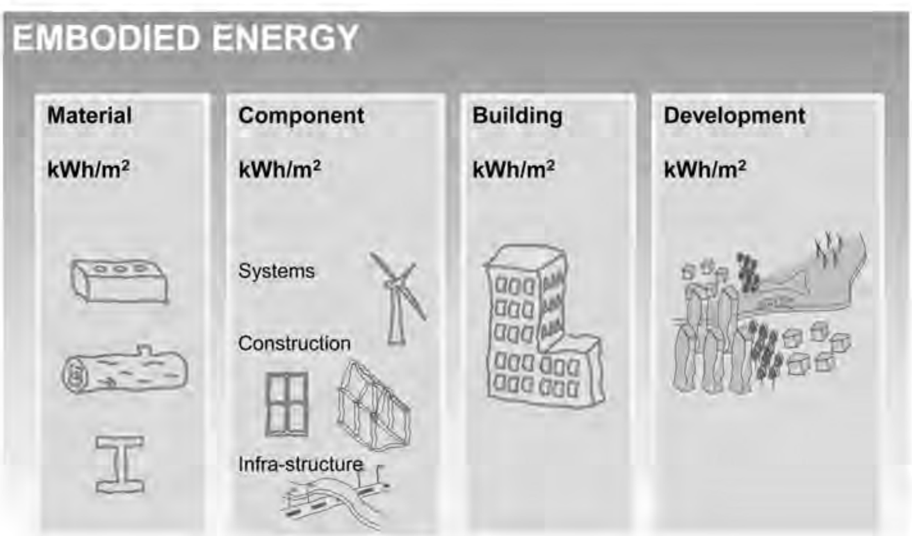


Figure 1.8
Summary of embodied energy

The embodied energy is that associated with processed materials and products used during a building's construction and fit-out (Figure 1.8). This includes the process energy to acquire natural resources and to produce the materials and components, and the transport energy associated with their production and delivery to site. As the delivered energy is reduced through a more energy efficient design, the embodied energy becomes of increasing significance. In some low carbon buildings the embodied energy is equal to the lifetime delivered energy. The embodied energy is closely linked with the life-cycle and environmental costs of raw materials and material manufacture, lifetime durability, and end of use disposal. In sourcing a building material or component the embodied energy is a major factor in determining its sustain-ability. Embodied energy can be reduced by:

- The use of local materials is favoured as transportation energy costs are reduced.
- The use of less highly processed materials which generally have higher embodied energy.
- The use of reclaimed materials, or materials with a high recycled content such as metals (although the process of recycling adds to their embodied energy.)
- Sustainable design should encourage construction systems which use fewer materials. Some construction types are inherently more wasteful than others.
- Standardisation, the use of less packaging and using more locally sourced off-site construction methods should be encouraged.
- Transportation of materials also plays a significant role in embodied energy calculations, especially where buildings are remotely located.

Materials

Values of embodied energy for specific materials are summarised in Table 1.16, below.

Materials	Embodied energy (MJ/Kg)	Embodied carbon (KgC/Kg)
Bricks		
General	3	0.060
Limestone	0.85	–
Cement		
General	4.6+/-2	0.226
Portland cement, wet kiln	5.9	0.248
Portland cement, semi-wet kiln	4.6	0.226
Portland cement, dry kiln	3.3	0.196
Portland cement, semi-dry kiln	3.5	0.202
Fibre cement	10.9	0.575
Mortar (1:3 cement : sand mix)	1.4	0.058
Mortar (1:4)	1.21	0.048
Mortar (1:0.5:4.5 cement : lime : sand mix)	1.37	0.053
Mortar (1:1:6 cement : lime : sand mix)	1.18	0.044
Mortar (1:2:9 cement : lime : sand mix)	1.09	0.039
Soil-cement	0.85	0.038

Concrete		
General 91:2:4 as used in construction of buildings under three storeys	0.95	0.035
Precast concrete, cement: sand: aggregate		
1:1:2	1.39	0.057
1:1.5:3	1.11	0.043
1:2.5:5	0.84	0.030
1:3:6	0.77	0.026
1:4:8	0.69	0.022
Autoclaved aerated blocks (AACs)	3.5	0.076—0.102
Fibre-reinforced	7.75	0.123
Road and pavement	1.24	0.035
Road example	2.85MJ/m2	51KgC/m2
Wood-wool reinforced	2.08	–
Glass		
General	15	0.232
Fiberglass (Glasswool)	18	0.417
Toughened	23.5	0.346
Steel		
General, 'typical' (42.3% recycled content)	24.4	0.482
General, primary	35.3	0.749
General, secondary	9.5	0.117
Bar & rod, 'typical' (42.3% recycled content)	24.6	0.466
Bar & rod, primary	36.4	0.730
Bar & rod, secondary	8.8	0.114
Engineering steel, secondary	13.1	0.185
Galvanised sheet, primary	39	0.768
Pipe, primary	34.4	0.736
Plate, primary	48.4	0.869
Section, 'typical' (42.3% recycled content)	25.4	0.485
Section, primary	36.8	0.757
Section, secondary	10	0.120
Sheet, primary	31.5	0.684
Wire	36	0.771
stainless	56.7	1.676
Timber		
General	8.5	0.125
Clue laminated timber	12	–
Hardboard	16	0.234
MDF	11	0.161
Particle board	9.5	0.139
Plywood	15	0.221
Sawn hardwood	7.8	0.128
Sawn softwood	7.4	0.123
Veneer particleboard (furniture)	23	0.338

Source: Authors: Hammond, G. P. and Jones, C. I. Embodied energy and carbon in construction materials. In Proceedings of the ICE - Energy, 161/ 2, p. 87 –98, ISSN: 1751-4223, E-ISSN: 1751-4231

Table 1.16 Embodied energy for common building materials

A comparison of the embodied energy of some common building materials are presented in Figure 1.9.

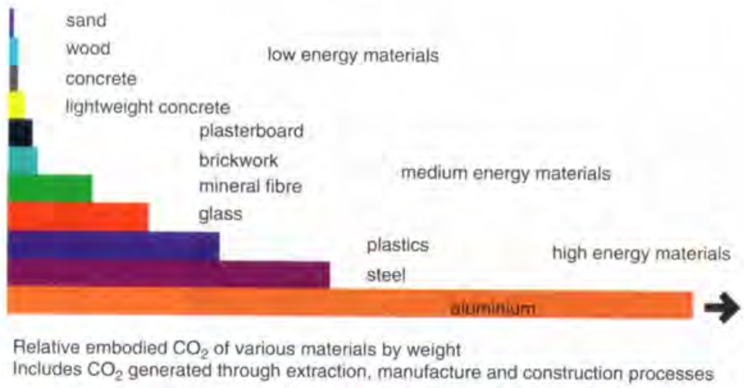


Figure 1.9
A comparison of embodied energy for common building materials.

Building Components

To calculate appropriately the embodied energy of a project, it is not only important to consider the distances required to transport building materials from their origin to the site, but also to account for the variation of EE amongst different building materials.

Although concrete seems relatively small in the above CO2 emissions graph (Figure 1.9), this material is widely used in construction, hence between 5-10% of the global man-made CO2 emissions are due to concrete manufacture. There are ways of reducing the CO2 emissions associated with concrete by using different contents as illustrated in Figure 1.10. A comparison of embodied energy associated with different components of construction is presented in Figures 1.11 and 1.12. The structure and in particular the foundations often have large values for embodied energy.

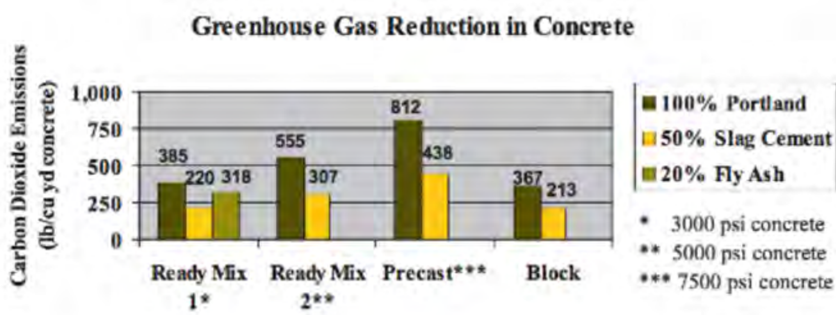


Figure 1.10
Variation in CO2 emissions associated with different types of concrete.

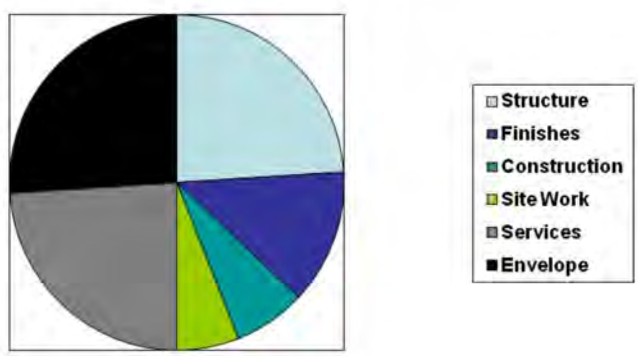


Figure 1.11
Proportion of lifecycle energy associated with different building components
Raymond J. Cole, Paul C. Kernan Life-cycle energy use in office buildings. Building and Environment, Volume 31, Issue 4, July 1996, Pages 307-317]

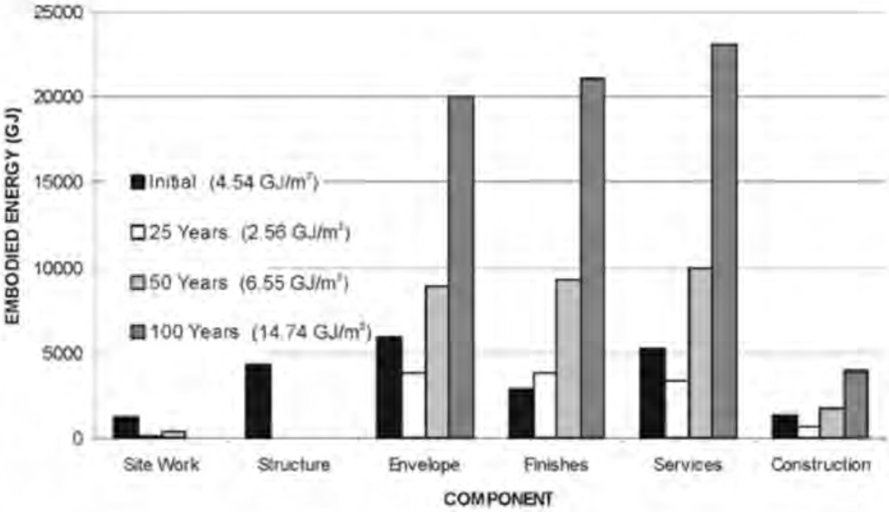


Figure 1.12
Comparison of embodied energy associated with different components of construction

Buildings

Different types of buildings and uses will incur different amounts of embodied energy. As previously mentioned, as structures become increasingly efficient and operational energy consumption levels are driven downward, attention will turn to the energy demand necessary to supply the structures. A low- or zero-carbon building – arguably – is neither if the energies consumed in creating the structure are not accounted for. In future the embodied energy should also consider the energy input that may be required to maintain, repair and replace buildings during their lifetime.

Embodied energy can vary with the type of structure (Industrial, Commercial, or Residential) and the type and method of construction and materials (steel vs concrete frames). Due to their design, residential buildings generally require more material per square metre - and therefore more embodied energy per square metre - than their commercial and industrial counterparts. Furthermore, all materials vary in their energy intensity per volume. The largest contributors to a project's embodied energy are steel, concrete, brick, and aluminium. In all cases, the re-use and recycling of these materials can lead to significant reductions in embodied energies.

Example embodied energy for different building types are presented in Figure 1.13. As embodied energy can vary depending upon the development, these figures can be used as a comparison to compare developments and construction types.

Building type Normalising the data to the total floor area (gross internal floor area) of the building	Embodied CO2 kgCO2e/m²
Supermarket	
CFA concrete piles (1,144 Nr 13m x 380mm nominal diameter)	376
CFA concrete piles (1,144 Nr 13m x 380mm nominal diameter)	384
Steel H-piles (641 Nr of various sizes)	395
Mixed use (office, residential, hotel, car park)	
Slimdek1	480
Concrete fl at slab: 260mm thick slab in office floors 250mm thick slab in hotel floors	467
Cellular steel beams supporting lightweight concrete slab on profiled steel decking²	395
Office	
Cellular steel beams supporting lightweight concrete slab on profiled steel decking	452
350mm thick post-tensioned concrete fl at slab	506
School	
390 precast concrete piles	309
450 precast concrete piles	344
248 steel H-piles	301
Warehouse	
Steel portal frame	234
Glulam beams and purlins supported on concrete columns	266
Steel portal frame with north lights	251

Figure 1.13
Embodied carbon associated with different building types.
target Zero

Developments

The embodied energy associated with whole developments includes buildings, roads and other infrastructures. Some values are provided in Tables 1.17a for roads and 1.17b and c for renewable energy systems.

Roads	Embodied Energy kWh/m²
Asphalt road – Hot construction method – 40 yrs	700
Construction	300
Maintenance – 40 yrs	130
Operation – 40 yrs	270
Asphalt road – Cold construction method – 40 yrs	840
Construction	230
Maintenance – 40 yrs	430
Operation – 40 yrs	270
Concrete Road – 40 yrs	580
	250
	65
	270

Table 1.17a *Embodied Energy in kW/m2 for Roads*

PV Modules	Embodied Energy kWh/m^2
Monocrystalline	1320 (720 - 2400)
Polycrystalline	1130 (540 – 1570)
Thin Film	360 (215 – 500)

Table 1.17b Embodied Energy in kW/m2 for photovoltaic systems

Turbine Size	Embodied Energy (EE) (GWh)	Annual Produced Energy (GWh)	Lifespan of Turbine (years)	Time to offset EE (years)
850 kW [d]	8.16	8.571	20	0.95
1.8 MW [c]	1.89	3.27	20	0.58
2.0 MW [c]	3.1	5.98	20	0.52
3.0 MW [d]	25.6	29.743	20	0.86

Table 1.17c Embodied Energy in GWh for wind turbines

Low Carbon Transportation Planning

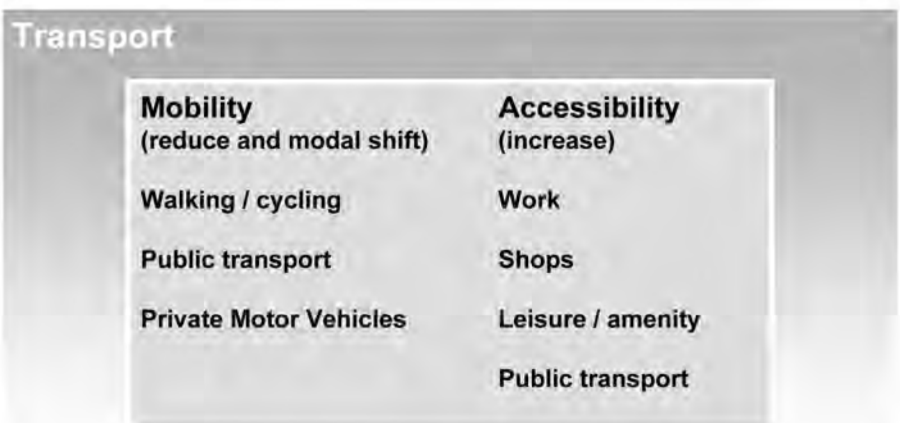


Figure 1.14
Summary of transport considerations

A sustainable transportation system provides for the mobility needs of individuals and communities whilst minimising the impact of energy use, environmental harm, socio-economic problems and hazards. The emphasis should be on reducing the need to travel by improving accessibility to everyday destinations such as work place, shops, recreation and other necessary services. It should promote health through provision for walking and cycling, whilst reducing air pollution and traffic hazards. It should be affordable and minimise socio-economic problems associated with congestion.

A sustainable transport system should be multi-modal, in that it provides an appropriate mix of walking / cycling, public transport and private motor vehicles (PMVs), and, inter-modal, allowing convenient connections for transferring between modes.

The main factors associated with different modes are:

Walking

Access to basic services, including, shops, recreation, social services and public transport nodes should be within 0.4km (maximum of 0.8km) based on an average walking speed of 4 to 6km/h. So, the time taken to reach a destination should be typically within 6 to 10 minutes. Typical access distances and times are presented in Table 1.18.

Facility	Recommended distance
Postbox	250m (2-3 mins)
Newsagents	400m (5 mins)
Local shops, bus stop, health centre and primary school	800m (10 mins)
Local park	250 – 400m (3-5 mins)
Regional park and open space	3.2km – 8km
Metropolitan park	3.2km
District park	1.2km (15 mins)

Table 1.18 Typical walking distances and times to amenities
Llewelyn Davies, 2000. Urban Design Compendium

Streets should connect to allow access, with a clear pattern joining key destinations along direct routes. Where there is no or limited PMV access safety and security should be ensured.

Cycling

The effective range of cycling should be between 2 and 5km, at typical speeds of 12 to 25km/h. So, for example, a distance of 2km would take less than 10 minutes to travel. Key destinations should be linked without major interruptions to allow consistent cycling and should be well maintained.

Public transport

The performance of public transport is greatly affected by other road users, so consideration should be given to separation of public transport, or providing 'right of way' privileges.

Encouraging people to use public transport requires a system that is convenient, comfortable, safe and affordable. Encouraging people to walk and cycle should also consider safety and separation from PMV's, although in many cities walking and cycling share routes with public transport systems, such as trams and Mass Transit Railway (MTR) access routes.

It is recognised that PMV will continue to play an important role in local transport, particularly for multi-point journeys, and that the development of Ultra-low Emission Vehicle market will address this over the long term. The EU has set a target of 10% of transport fuel consumption coming from renewable energy sources by 2020. However, planning to reduce dominance of the PMV can include reducing the number of parking spaces at both start and end points of journeys.

The energy use associated with different transport systems is summarised in following table 1.19.

Transport mode	Person-Miles Per Gallon (PMPG)	Passenger capacity
Scooter	75	1
Motorbike	60	1
Small car	30 to 40	1
SUV (Sport Utility Vehicle)	15 to 21	1
Bus	78	25
Tram	92	30
LRT (Light Rail Transit)	887	65
Express coach	180	20
Train	115	30

Table 1.19
Summary of energy use and capacity for transport systems

Market and pricing is often distorted in favour of PMVs and mobility, at the cost of more sustainable options. The costing of a development should consider subsidies on land development in relation to the balance between walking / cycling, public transport and PMV. Very often PMVs are unfairly subsidised in relation to other modes and are treated as a priority within the planning process. The socio-economic costs associated with pollution and congestion from PMVs is also often ignored. PMV levels could be limited through financial penalties such as road pricing which would reduce congestion and enable road based cyclists and road based public transport to move more freely.

Consideration should be given to car free zones, traffic calming and flow reduction, and the concept of complete streets, which are multi-purpose in nature and not simply 'traffic sewers'.
Well linked spaces, where people can move from place to place easily in an attractive environment are critical for a successful sustainable transport system. Direct routes for pedestrians and cyclists should be considered from the outset as they will be difficult to add at a later date. The quality, interest, connectivity and speed of nearby traffic can all contribute to the appeal of space for walking and cycling. 'The more direct the links between main streets, the greater the potential for mixed use' (Llewellyn-Davies, 2000).

Development should take place where possible in areas where successful public transport mechanisms are already in place and infrastructure is already provided. Density should be high around transport nodes such as railway stations to encourage maximum use. Dedicated public transport routes which are clearly visible with obvious connection points will encourage more users. Transport plans need to be integrated at the planning stage to reduce dependency on the PMV from the outset.

To summarise, a sustainable transport system (EC (2001) in DGENV(2005)):

- Provides for basic access and development needs
- Supports safety and human and ecosystem health
- Promotes equity within and between successive generations
- Is affordable, fair and efficient
- Offers choice of transport mode
- Supports a competitive economy and balanced regional development
- Limits emissions and waste within the planet's ability to absorb them
- Uses resources at rates which permit renewal or substitution
- Minimises impacts on the use of land and the generation of noise

Figure 1.15
Summary of suitability of renewable energy supplies
☆ Low
☆☆ Medium
☆☆☆ High

RENEWABLE ENERGY	Building Integrated	Community	Grid
Solar PV	☆☆☆	☆☆	☆☆
Solar thermal	☆☆☆	☆	☆
Wind	☆	☆☆	☆☆☆
Biomass	☆☆	☆☆☆	☆☆☆
Hydro	☆	☆☆	☆☆☆

Renewable energy systems may be integrated into a building design, community or development based or from off-site grid sources. The more common systems are summarised below:

Solar PV

Photovoltaic panels are most applicable to building integrated design, and can provide energy at an efficiency between 10%-15%. The panels have a high embodied energy (58gCO_2eq/kWh), but this maybe reduced using thin film technologies.

Solar thermal water

Where hot water is required solar thermal water heating can be integrated into wall and roof systems. They can provide typically 40% of a buildings water heating demand. The efficiency of the panels varies according to their type and ranges from 22% for flat panels to 39% for evacuated tubes.

Wind

Wind turbines have a maximum theoretical efficiency of around 60%. They are considered to have one of the lowest embodied energy of all renewable (apart from nuclear power and hydro) at 4.64gCO_2eq/kWh. They are most appropriate at a community or grid scale as they can be difficult to install in the urban environment.

Biomass

Wood based biomass fuels come in wood chips or pellets, the energy output of these depends upon the moisture content of the processed wood, generally wood chips give 3.5 MWh/tonne and wood pellets give 4.8 MWh/tonne (17 GJ/tonne). The land required for growing biomass fuels for a typical dwelling is between 0.3 to 2 hectares depending on type of wood and if it is the by product of timber production.

Energy Supply

After significant efforts to fulfil the energy requirements of the site with renewable sources, it is imperative to consider how much of the energy would be thereafter obtain by fossil fuels, which would help to strategically choose the most environmentally friendly fuel possible. In order to reduce the use of fossil fuels ,various 'low carbon' technologies exist to make energy distribution systems more efficient. Some options are presented below:

Combined Heat and Power (CHP)

Combined Heat and Power (CHP) provides on-site electricity using the benefit of heat recovery, hence improving the efficiency of the conversion process from primary energy to end-use. "The conversion of primary fossil fuels, such as coal and gas, to electricity is an inefficient process. Even the most modern Combined Cycle plants can only achieve efficiencies of between 50-60%. Most of the energy is wasted in this conversion process is released to the environment as waste heat. UK power stations typically reject more energy as waste heat than is consumed by the entire domestic sector." 《Ref: 《The Institute of Engineering and Technology. CHP Fact files, 2008.

The efficiency of CHP plants are typically over 80%: CHP can be run from a variety of fuels, including natural gas, landfill and sewage gas, fuel and gas oils, coal, biomass and biogas, solid waste, waste gases and waste process heat.

District Heating and Cooling

District heating and cooling systems provide heat and cooling based on an underground network of mains conveying cold, hot water or steam throughout the site; this is supplied by a single generation plant which ideally utilises CHP (heat recovery) to produce the energy required to run the distribution pump.

Its efficiency is based mainly on two factors:

- Type of equipment (i.e chillers) and technology used, and its high efficiency operation and maintenance.
- The use of and environmentally sound heat source (CHP, river and sea water as heat sink/source of heat pump, etc)

Building and environment.

Successful implementation highly depends on the capacity of the system to obtain high temperature differentials between the supplied and return water. Typical differential temperature of the hot water based district system: $\Delta Ts \geqslant 40$ oC

Minimum supply temperature for ice-based systems with thermal storage and ice chillers: 1oC. "The corresponding return temperature of cooling systems is at best 12oC at peak operating conditions. The maximum system ΔT , is thereby only 11 oC at peak conditions for ice based systems and 8oC for conventional chiller based systems." The pipe sizing of the DH&C systems should be determined based on :

- The system ΔT (typical values are from 8-11 oC
- Maximum allowable flow velocity (avoid velocities higher than 2.5-3.0 m/s unless the system design allow it. The velocity should depend on pressure drop constrains and critical systems disturbances caused by transient phenomena (i.e water hammer effect)
- Distribution network pressure at the design load conditions.
- Minimum differential pressure requirements to service remote locations.

International Energy Agency. IEA District Heating and Cooling.

Large scale storage

According to the type of use and the capacity there are a variety of electricity storage options. The amount of energy it can store and the rate at which it can deliver that energy is the power rating.

Underground Thermal Energy Storage
Underground Thermal Energy Storage is the thermal storage system which utilises seasonal excess heat or coolth to be used at a later season. It is usually coupled with ground source heat pump so that the earth can be used as a 'source' or 'sink' of heat.

Geological storage technologies
Compressed air energy storage (CAES) involves storing air at high pressure, often in a large underground space, before using it to power a turbine. This is a high power system, capable of providing significant reserve services.

Pumped hydroelectricity storage
The use of reservoirs, building two of them with a large height difference. During low-peak periods (cheap) water is pump from the lower reservoir to the higher. In peak demand periods, water is then allowed to flow from the upper reservoir back to the lower through large turbines which generate electricity. Approximately 75-80% of electricity used can be recovered.

Large scale water or ground thermal storage
These can provide inter-seasonal storage of heat from summer to winter. It is the same principle as the underground thermal energy storage explained above, but in some larger scale developments they may use large volumes of water or earth to storage significant amounts of thermal energy.
Parliamentary Office of Science and Technology. Post Note. 'Electricity Storage Report. 2008

Infrastructures

Providing sustainable Infra-structures is a major part of low carbon planning and design. Figure 1.16 summarises the main infra-structures. Opportunities for cross sector systems should be considered at an early development stage, for example, such as energy from waste.

INFRA-STRUCTURES

Water	Sewage	Waste	Energy supply
Potable supply Irrigation Rainwater	Local treatment Biogas	Construction Waste arisings Energy from waste	CHP District H / C Large scale storage

Opportunities for integration and interactions

Figure 1.16
Summary of the main infrastructures

Water

Urban development's require

- Clean water supply
- Safe transport of waste water and storm water
- Hygienic and environmentally conscious waste water treatment.

Nonetheless to claim sustainability credentials a building site should consider:

- Efficient methods of water distribution (supply and removal)
- Classification of different water uses
- Local efforts to manage pollution and storm runoff
- Planning methods to include the most sustainable alternatives of water use across the whole site. For instance:
  - Rain water collection
  - Separation of clean/gray/dirty water
  - Encourage the reuse of water where possible
  - Implementation of low water consumption features in the design.

Water for Chongqing

The maximum daily water consumption per person is given in Tables 1.20 and 1.21 for different building types.

Residential building style		Setting standard for sanitary ware	Water quota (Litter/p.day)
Normal residential	I	Stool, sink	85-150
	II	Stool, wash basins, wash basin, washing machines, water heaters and shower	130-300
	III	Stool, wash basins, wash basin, washing machine, central hot water supply (domestic hot-water heaters) and shower	180-320
Villa		Stool, wash basins, wash basin, washing machines, sprinkler bolt, and domestic hot water shower unit	200-350

Table 1.20
Maximum daily water consumption / person in Residential Building

Code for design of building water supply and drainage,GB50015-2003

No.	Building type	Water quota (L/p. day)
1	Dormitory * I、II III、IV	 150～200 100～150
2	Apartment	200～300
3	Hotel Rooms guests employees	 250～400 80～100
4	Public bathroom shower shower、bathtub	 100 120～150
5	Canteen	20～25
6	Commercial building Employees and visitors	 5～8
7	Office building	30～50
8	Fitness centre	30～50
9	Meeting rooms	6～8
10	Parking ground cleaning water	2～3

* Classification for dormitory – Type I for PhD candidates, teachers, scientific and technological personnel, one person per room, with bathroom; Type II for master students in universities, two persons per room, with bathroom; Type III - for University undergraduates and College students, 3-4 persons per room, with relative centralized bathrooms; Type IV - for students in secondary school and factory workers, 6-8 persons per room, with centralized bathroom.

Table 1.21
Maximum daily water consumption / person in dormitory, hotel and other public Building

1. 《Code for design of building water supply and drainage》 GB50015-2003.
2. Daily water quota of other type of building can be decided according to the value of Tab. 3.1.10 in 《Code for design of building water supply and drainage》 GB50015-2003.

Sewage

The treatment of sewage and wastewater has usually been tackled by its threatening to health characteristics rather than by its potential to generate electricity through Anaerobic Digestion.
There are a variety of alternatives to handle and use the by-product of sewage to create energy, various cases have been investigated where sewage sludge can be use in incineration plants to recover energy or simply used as an alternative fuel to run certain industrial processes, such as the production of cement . These should be investigated for a development.

Waste

Urban waste production per capita indicators
A common urban indicator for sustainable developments is the 'urban waste production per capita'. Urban waste can be classified into different categories according to their origin and end (cradle-to-grave). Particular care must be taken when handling hazardous and toxic materials. Common benchmarks can be found in Table 1.22 for non-hazardous/toxic waste.

	Waste generation rates (kg/per capita/day)		
	Low-income country	Mid-income country	High-income country
Mixed urban waste Large city (>500000)	0.50 - 0.75	0.55 - 1.1	0.75 - 2.2
Mixed urban waste small to medium city (<500000)	0.35 - 0.65	0.45 - 0.75	0.65 - 1.5
Residential waste only	0.25 - 0.45	0.35 - 0.65	0.55 - 1.0

Table 1.22 *Waste in kg/capita/day*
Urban Waste Planning. Guidance on Urban Waste Generation and Classification: Guidelines for Municipal Solid Waste Management in the Mediterranean Region

The most common means of disposing urban solid waste is landfill despite being the least environmentally recommended and its finite availability of spaces for this practise. The other common options are recycling, composting and incineration; the latter one being also of high environmental concern.

Within an industrial park it would be recommended to establish an industrial symbioses plan, which would encourage the exchange of by-products amongst industries that may be able to re-use what would otherwise end wasted. "Industrial symbioses (ISs) and eco-industrial parks (EIPs) are key concepts of industrial ecology (IE). The aim of ISs and EIPs is to minimise inefficient material and energy by utilising by-product and energy flows."
Ref: 27 Ong, B.L., Green plot ratio: an ecological measure for architecture and urban planning. Landscape and Urban Planning, 2003.

Process and Evaluation

Process

The process is all-important! There is a need to change what to do and how to do it, probably not in a single step, but rather in a series of managed changes, learning at each stage and feeding forward into the process. For a large-scale sustainable master plan it can be less ambitious in the first phase, setting easily achievable targets and concentrating more on how to integrate sustainability into the process. This will ensure that, not only will the built environment be physically more sustainable, but it will also be socially and economically acceptable. After all, the ultimate goal should be to provide a built environment that is a healthier, cleaner, and more productive, for the most efficient and effective use of resources.

So the first stage should be to develop the context of sustainability and culture in the planning and design process. Costs, skills and training needs, the role of stakeholders, all need to be better understood. Some projects will last a long time, typically, 5 to 20 years and the technologies available in the future do not yet exist. It is therefore not appropriate to prescribe too much detail at the early phases. Figure 1.17 and Table 1.23 present some guidance on process.

Evaluation

The evaluation must identify outcomes that can be tested at the various stages of planning, design and construction. Most of our low carbon design and planning is focussed on what might be termed inputs. We might typically have a 'shopping list' of items to consider in the design (related to the brief in 1 above). These tend to be prescriptive in nature and often building specific. However, we also need to consider the outcomes for a project (related to the impacts in 3 above), which will be more performance based. Both inputs and outcomes are essential for low carbon sustainable design. An evaluation and feedback activity is essential not only from planning through design, etc, but also to feed forward from project phase to phase. Lessons learnt should be disseminated to the industry in order to promote a better understanding of sustainable planning and design.

In developing an evaluation process for sustainable master planning, the focus needs to be on outcomes at all stages of planning, design, construction and operation. We need to set clearer goals for what we want to achieve for a specific project, how we will assess the outcomes, and what are the criteria for judging success. These will be different for different projects, but the generic process of setting clear aims and evaluation methods must be established.

Very often an eco-city will be labelled 'eco' but with no clear aims. There may be a 'shopping list' of ideals, such as, low carbon, healthy, low car use, green, etc, but when it gets to the process of 'doing', if these ideals cannot be bolted on to our existing methods, they tend to disappear during the more detailed planning and design stages.

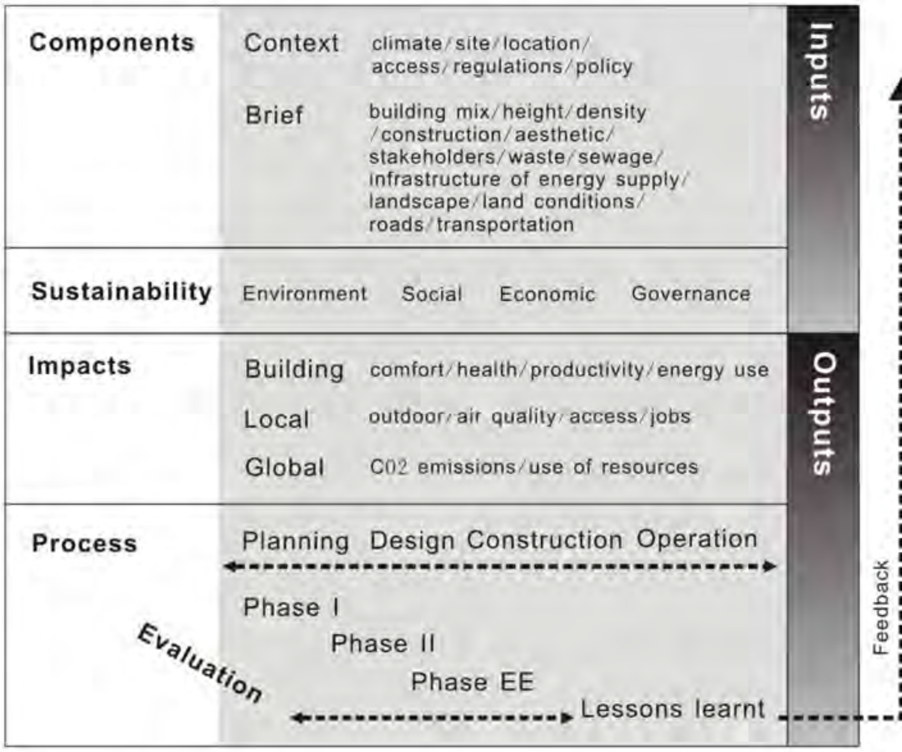


Fig.1.17
An evaluation framework for sustainable master-planning.

There are checklist approaches to urban scale, generally developed from building scale assessment methods, such as BREEAM Communities (http://www.breeam.org/page.jsp?id=117) and LEED Neighbourhood (http://www.2011usgbc.org/DisplayPage.aspx?CMSPageID=148). They provide a valuable approach to sustainable master-planning, however, they tend to deal with inputs rather than outcomes. Web based approaches such as PETUS (http://www.petus.eu.com) provide reference sources and a checklist approach based on sustainable environmental impact assessment as well as identifying suitable evaluation tools.

We need an evaluation framework that not only identifies the components of master-planning, but also clearly separates these inputs from the impact related outcomes. The flow diagram in Figure 1.17 above suggests how the process could be constructed, from the specification of the aims, identifying base line conditions, setting targets and guidelines for achieving them, ensuring compliance through evaluation, learning from doing, and feeding to forward, adjusting procedures and targets over time where appropriate.

Two types of information are required at the start. The first is contextual information, which includes details of the climate, site, location, access, regulations and policy. This relates to the physical and other aspects of the location. The second set of information relates to the project brief, including the mix of buildings, their density, height, local construction standards, stakeholders, etc. It also includes the infrastructures of energy supply, water, sewage, waste, landscape and land condition, and, roads and transportation. The initial stages of master-planning will need to assemble as much of these details as possible.

1. Survey The development zone should be surveyed at the start of the planning/design process	• Topographical survey. • Identify all private and public stakeholders involved. • Identification and recording of existing functions and communities • Identification and recording of existing buildings, green/blue structures and heritage cultural value • Identification and recording of existing road and other transport systems • Climate analysis of site, including annual variation of temperatures, wind velocity, relative humidity, solar radiation and rainfall – now and in future. • Identification of existing infra-structures for energy supply, water/sewage and waste. • Develop brief for mix of buildings and infra-structures. • Meeting to consider issues and prepare for concept planning/design stage.
2. Concept Planning/Design The concept planning/design stage should identify sustainability objectives and how they can be evaluated	• Zoning for use, including density and number of units against each use type. • Seek views of stakeholders. • Retention of existing communities and built environments. • Assess opportunities for communities, jobs, etc. • Location of public transport systems and links with existing systems, and locating major transport hubs. • Car use and roads. • New infra-structures for energy supply, water/sewage and waste. • Set targets for energy use, material use, water use, recycling of material waste, etc. • Set targets for the type and use of renewable and 'low carbon' energy systems. • Set targets for transport use and modal mix between public, private, cycle and pedestrian flows. • Meeting to consider concept design and prepare for detailed planning/design stage.
3. Detailed Planning/Design The detailed planning/design stage should include:	• Building layouts, density, and orientation and view, to take account of solar gains in winter, solar overheating in summer, access to daylight and use of renewable energy systems, noise and pollution from traffic flow. • Integration of new build with existing structures. • Location and concepts for green/blue structures, public spaces and water side developments. • Road and rail transport layouts and pedestrian and cycle routes. • Infra-structure location and layout, including any district/heating/cooling, water sewage treatment, waste treatment. • Evaluate (life-cycle approach where possible) against targets for energy use, renewable/low carbon systems, material use and waste management, water/sewage systems, transport systems. • Provide three-dimensional design options for major areas of site. • Meeting to review detailed stage.

Table 1.23 Process

PART TWO
Low Carbon Industrial Park Project
Ba'nan District, Chongqing

Low Carbon Industrial Park For Chongqing

Structure of Case Study

- Introduction to the software and Low Carbon Master Planning
- Road Map and basic zoning – Site, location and design
- Construction of case study, detailed description of the analysis and tools.
- Results
- Appendices

Figure 2.1 An overall image of Low carbon industrial park for Chongqing

Introduction to the software and Low Carbon Master Planning

The analysis method presented in this case study is a novel software modelling approach currently under development and improvement. The parameters applied to this project are based on the provided "Ba'nan Guidance", where benchmarks can provide performance indicators an urban model.

Existing modelling software work well with single structures; applying benchmarks to an urban region quickly and efficiently has previously proven elusive. Generally, modelling was either limited to spreadsheets and GIS software, or a single modelled building (either in Transys, HTB2, Ecotect, or EnergyPlus, to name a few) replicated multiple times to simulate an urban area. Our approach has been to link Google Sketch-Up and HTB2: the former a simple, powerful modelling tool for early stage analysis, the latter a powerful yet complex energy modelling tool for structures and volumes.

Using Google Sketch-Up instead of other modelling tools is three-fold in scope:

Simplicity

Sketch-Up is a volumetric modelling tool which, through extrusion, allows a user to create a model of simple, thermal-modelling ready building envelopes quickly and easily over an area or region from a 2-D plan. Details superfluous to energy modelling are automatically excluded with Sketch-Up; when matched with HTB2, a simple volumetric shell is all that is required for simulation, which is attained through Sketch-Up's extrusion tool from a flat surface. Ecotect, DesignBuilder, IES, and other energy modelling programs require both a licence and a working knowledge of how to model in each program, and require (to some extent) complex modelling of more than a mere shell to achieve appropriate outputs. Sketch-Up is intuitive, simple, and free to use.

Figure 2.2 Urban Design Approach proposed

Accessibility

Sketch-Up is currently used by over half of all architectural practices. It is a free program, available for download globally, and widely used by professionals at an early stage in a project to view how the finished structure(s) may look.

Flexibility

Sketch-Up has its own programming language - Ruby - which allows a user to create custom Plug-Ins to achieve specific outputs within Sketch-Up. This allows the program to be used for virtually any task analysis, and has allowed for seamless communication with HTB2.

Marrying Google Sketch-Up and its Ruby scripting language with HTB2 creates a powerful tool for energy analysis on an urban scale. Once the model of the urban area is sketched, HTB2 can be invoked from within Sketch-Up, creating all the required files for HTB2 thermal analysis. These files, in turn, can be manipulated to create comparative outputs relatively quickly (glazing ratios, wall constructions, occupancy types, etc.) Furthermore, **this tool is directly applicable to the Low Carbon Master Planning proposed in the guideline** as it will be explained here:

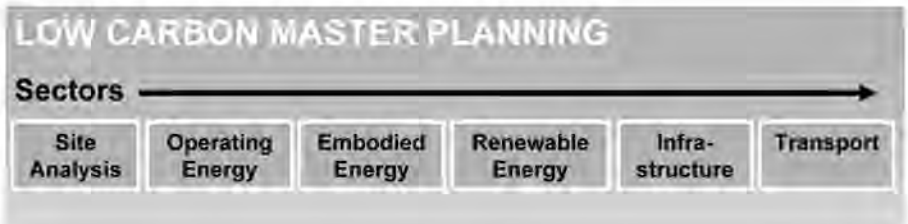


Figure 2.3
Low Carbon Master-planning proposed in the Ba'nan Guidance.

Diagram 2 shows the Low Carbon Master Planning process established in the previously issued Ba'nan Guidance. Following, there is a brief introduction on how this case Study follows the principles of the Guidance.

Site Analysis

Google Sketch-Up works in tandem with Google Earth. Communicating between the two allows a user to perform detailed site analysis to assess a site's location, topography, area, and understand factors which may play a role on the microclimate through visual inspection. Physical features are immediately visible on Google Earth, and can be considered directly by the client or energy analyst. Social features can typically be highlighted using Google Maps or via queries through Google's search engine. Additionally, the terrain of the site may be directly imported into Sketch-Up to aid in structural layouts, placements, and with solar analysis. Weather data can be obtained from the U.S. Department of Energy's website directly, and a conversion tool has been created to input these files into HTB2 for thermal studies.

Operating Energy

Operating energy, divided between supply and demand, is handled separately within the tool. Operating energy demand on an urban scale can be calculated by using low carbon benchmarks directly. Once structures have been modelled in Sketch-Up, the Ruby script allows them all to be attributed quickly into industrial, commercial, domestic, educational, etc. These categories carry with them benchmark figures (typically per square metre) for water consumption, lighting demands, ventilation rates, small power consumption, etc. Approximate population numbers (either by benchmarks or available from the client directly) can also be attributed to the occupancy schedules to aid in internal gain calculations. Combined with a construction library for the structures' fabrics, these numbers and figures enable a simple running of HTB2 to calculate heating, cooling, and small power demand rates.

Following this analysis, which can be run many times by varying different HTB2 files (construction types, occupancy schedules, ventilation rates), a final energy demand can be realised for the urban area. At this point, energy supply can then be discussed. Accessibility to heat and power infrastructures can be located using Google Earth. Various system performances can be compared, and ultimate energy supply rates can be calculated, based on demand.

Embodied Energy

Embodied energy is another aspect of the low carbon master planning which can be calculated easily with the tool. By appending an index of construction materials and their accepted embodied energies to the model with the Ruby script, embodied energy on an urban scale can be readily calculated, by element, façade, building, block, or over the entire model. By changing the construction file within the model, embodied energy values can be directly compared for the same volume(s). Areas of pavements and roads taken from a 2-D model can be used to calculate infrastructure embodied energy rates across and urban area.

Renewable Energy

Finally, renewable energy supplies on the urban scale can be analysed with the tool. Terrain can be directly analysed for the appropriate use of ground-source heat pumps/ exchangers. A location can be specified or discussed within the model for community co-heating plants or heat and power plants. Most importantly, using the data generated through the solar analysis Plug-In developed with Ruby, solar access and potential solar hot water (SHW) and photovoltaic (PV) panel outputs can be generated for each façade and building, allowing for the contribution of renewable solar solutions to be calculated for the energy supply on an urban scale.

Future Research

Low Carbon Master Planning in regards to Infrastructure and Transport is the goal of future research with the tool, and outputs under these headings can be anticipated in future releases of the tool. Existing benchmarks can be used temporarily in calculations on an urban scale.

Road Map and basic zoning - Site, Location and Design

Site's Characteristics: Climate, Location and layout.

In order to design a site holistically, the first stage of the process should consider the geographic location of the site, its topography and climatic characteristics, in order to establish the design features required to harmonise the whole construction with the given conditions.

During the first stage of the Low Carbon Industrial Park for Chongqing (the conceptual stage), information on the area has been gathered (Figure 2.4, Graphs 2.1-2.4). This climatic variation has been considered when modelling the current case study.

Some of the main characteristics that affect this site (located in the Ba'nan District) are the extreme temperatures, the high cloud cover and the relative humidity. The impact of these issues over the complex can be mitigated by analysing the sensitivity of the proposed design. As a result simple re-orientation of building facades or a variation of the glazing ratio can work to advantage of the design, hence the importance of early stage computer modelling as an important tool to reduce carbon emissions.

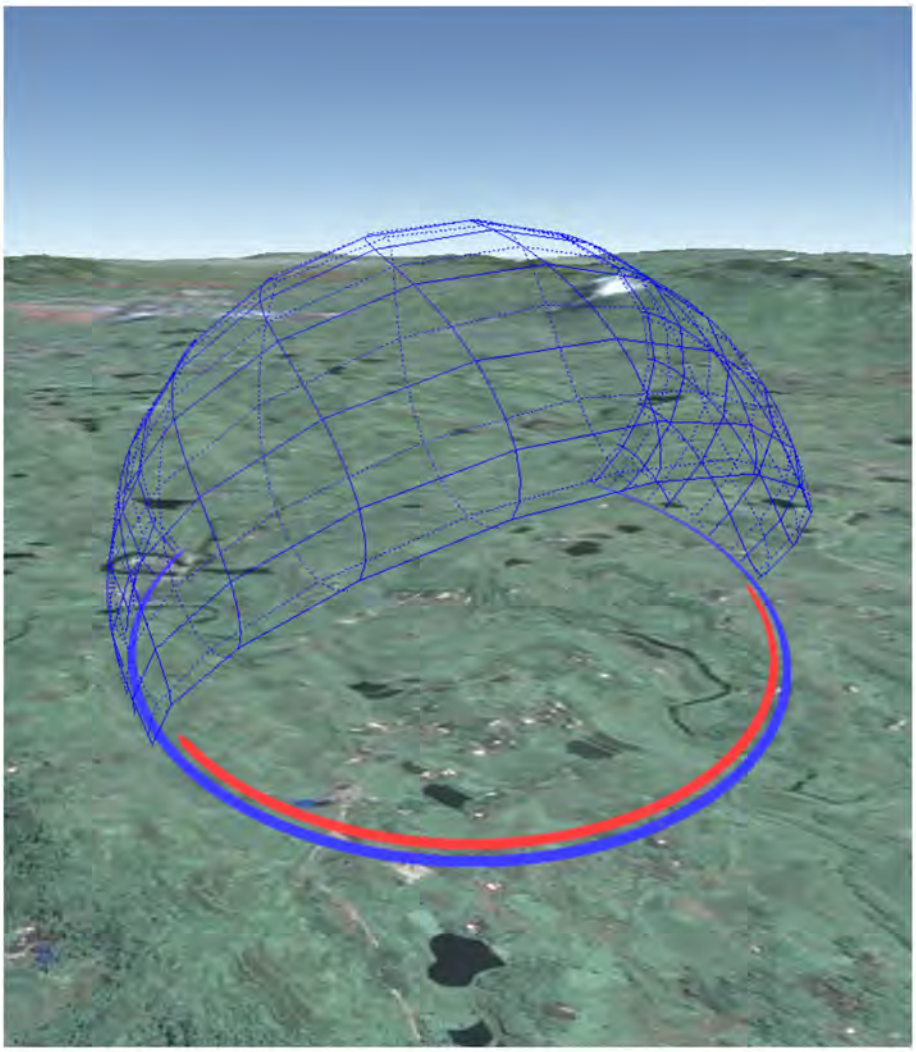
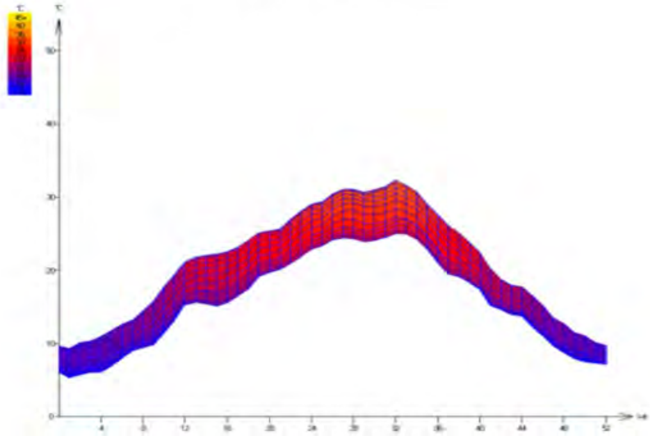
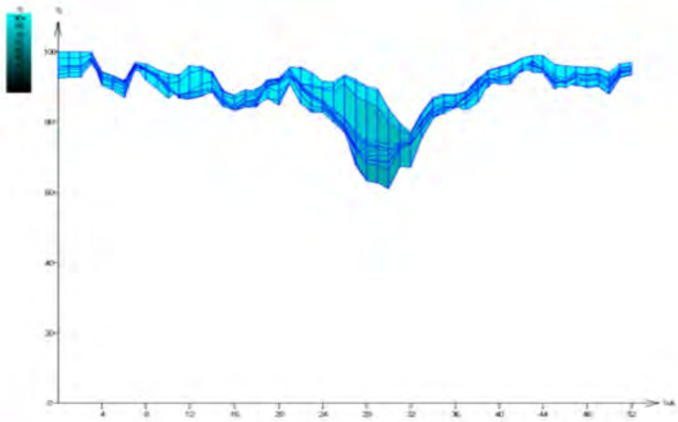


Figure 2.4 Sunpath diagram Chongqing

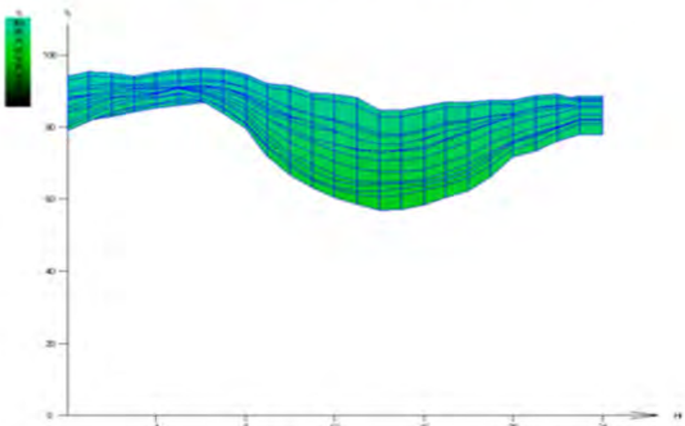
Climate conditions of Chongqing



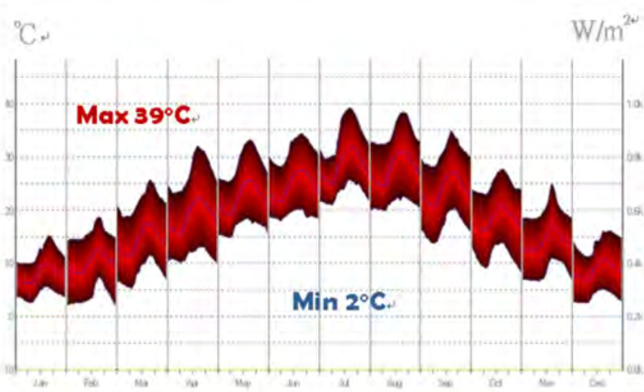
Graph 2.1 Temperature (℃)



Graph 2.2 Cloud Cover



Graph 2.3 Relative Humidity (%)



Graph 2.4 Detailed temperature data for Chongqing

Specifications of site and zoning

The client of this project expressed the desired of having a relatively mixed use of buildings, nonetheless the final design of the project has not been provided (specific number of buildings and uses), and therefore for the purpose of this guidance project, we have selected a mixed composition of buildings, in order to consider the various issues that may arise when dealing with buildings of different nature.

The zoning used for this case study has been based on the following common general zones (Figure 2.5):

- Industrial
- Residential
- Commercial

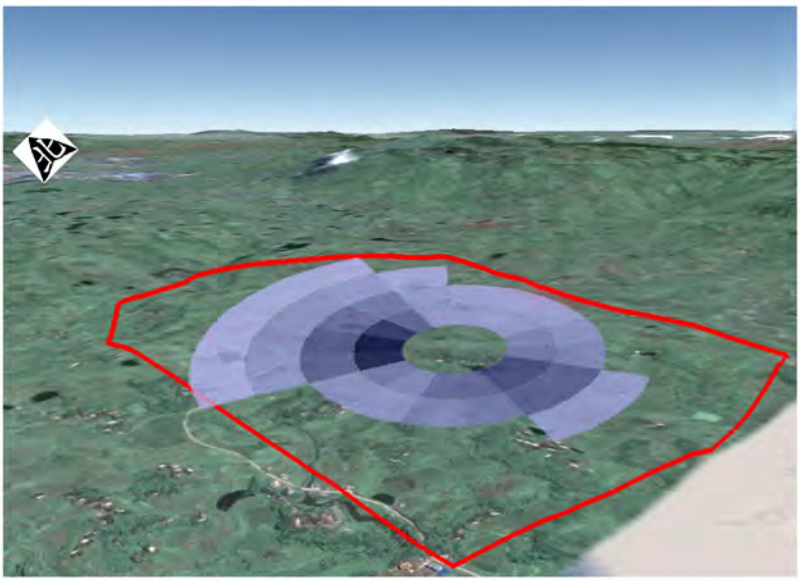
The approximate total area of the site is of 2.8 km^2. The complex has been located in the geographical reference given by the client (Figure 2.6), allowing us to display some weather analysis on the site (Figure 2.7 & 2.8).

Figure 2.5
Case study site layout and zoning
Key: Industrial
Residential
Commercial

Site's topographic context

Figure 2.6
The master plan for Chongqing

Wind analysis of site and case study layout



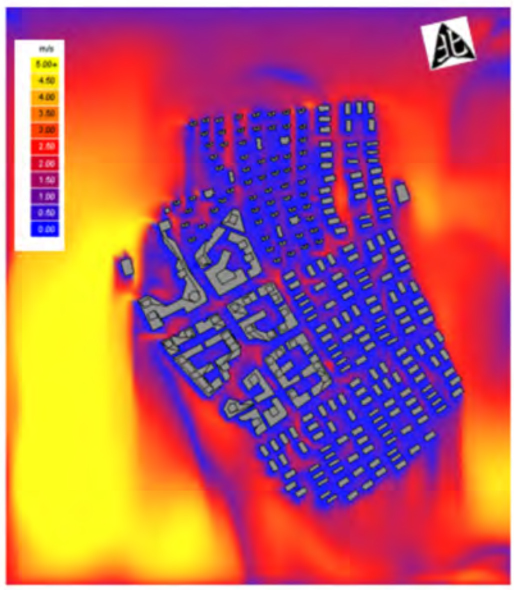


Figure 2.7
Boundary of site on the location, Chongqing

Figure 2.8
CFD analysis of the proposed project

Construction of Case Study

Building the Case Study

The layout and buildings of the site are assumed to follow the standards and parameters provided in Part 1 of this project (Ba'nan Guidance).

As previously mentioned, new software tools have been developed focusing on early stage urban design. The chosen interface and engine used for calculations (Google Sketch-Up and HTB2) were chosen after a thorough research on the area. It was found that Google Sketch-Up is popularly used amongst architects and designers mainly as an early stage 'sketching' tool. Nonetheless such software has much further design capabilities other than rough early stage design of buildings. During the background research it has been found that this software already plays a considerable role within the design process, with over 50% of all architects using it at some point on projects *[Reference: Attia, S. 2009, "Architect friendly: a comparison of ten different building performance simulation tools", Eleventh International IBPSA Conference]*. As a result, the proposed calculation method can be easily applicable for any project that considers the use of this platform.

Furthermore, HTB2 has been widely used across the world, to reliably obtain specific figures of the thermal behaviour of buildings. This is a pioneer attempt to use such tools together, a lot of research and modifications have been putted into making this possible, and final calculations are being compared to previously researched benchmarks in order to confirm the reliability of results.

Google Sketch-Up includes an embedded application programming language called Ruby which enabled us to create custom Plug-Ins for use within Sketch-Up. Our recently developed Plug-Ins allow for calculations on any Sketch-Up model, including:

- Operational Energy Consumption
- Embodied Energy Totals
- Renewable Energy Potential
- Shading Masks
- Façade Areas
- Structural Volumes

Details of the Analysis

When running building simulations, different approaches should exist when analysing an individual building or a whole urban site. In this case, the urban scale scope led the analysis to simplify the simulation conditions (as it has been recommended), by setting standard models for different types of buildings. In this case, the following classification has been used: **Residential**, **Commercial** and **Industrial**.

Simulation conditions for our standard models are set according to national and local design standards, and based on basic documents about Ba' nan Low Carbon Industry Park Project, together with related project examples provided by the client. The main references are listed in **Appendix A**.

Appendix B contains details about the simulation conditions for the standard model, where details of the construction and materials are shown, as well as the Design' s indoors conditions and the overall areas of the site.

Overview of the software tools and processes

Following is an overview of the capabilities of the VirVil Plugin for Sketch-Up:

Importing Buildings

In order to use the tool, the first thing the user needs to have is a basic knowledge of Sketch-Up. Normally, the project architect or site designer should be able to provide a Sketch-Up model of the site. Once the model is open in Sketch-Up, it is important any part of the model which is not to be thermally modelled must remain a part of a component or group. Un-grouped (or 'exploded') geometries will be modelled in HTB2.

Figure 2.9 and 2.10, below, show the removal of geometries and components prior to invoking the Plugin.

Figure 2.9
*Visualization of the site **before** it has been 'exploded'*

Figure 2.10
*Visualization of the site **after** it has been 'exploded'*

Site Location

After making sure the model is on its simplest forms, the site should be given a geographic location. Google Sketch-Up includes links with Google Earth for the selection of almost any location on the globe (Figure 2.11).

Area Measurement and Surface Normal Verification

The Plugin allows for façade area and orientation calculations. Once the site location has been specified and all the structures to be thermally modelled with HTB2 have been 'exploded' (ungrouped), the user can invoke the 'Area Totals' calculation in the Plugin, which will calculate the areas of all the façades facing a given direction. All façades facing in similar directions will be automatically coloured according to their orientation.

This calculation also offers the user to verify all surface normals are facing 'outward,' a quality essential for the creation of shading masks further in the process. If a façade is uncoloured after running the Area Totals calculation, a tool in the Plugin called Final Flip is invoked, and the Area Totals calculation is run for a final time to ensure all façades are coloured and all surface normals are facing outward (Figure 2.12-2.15).

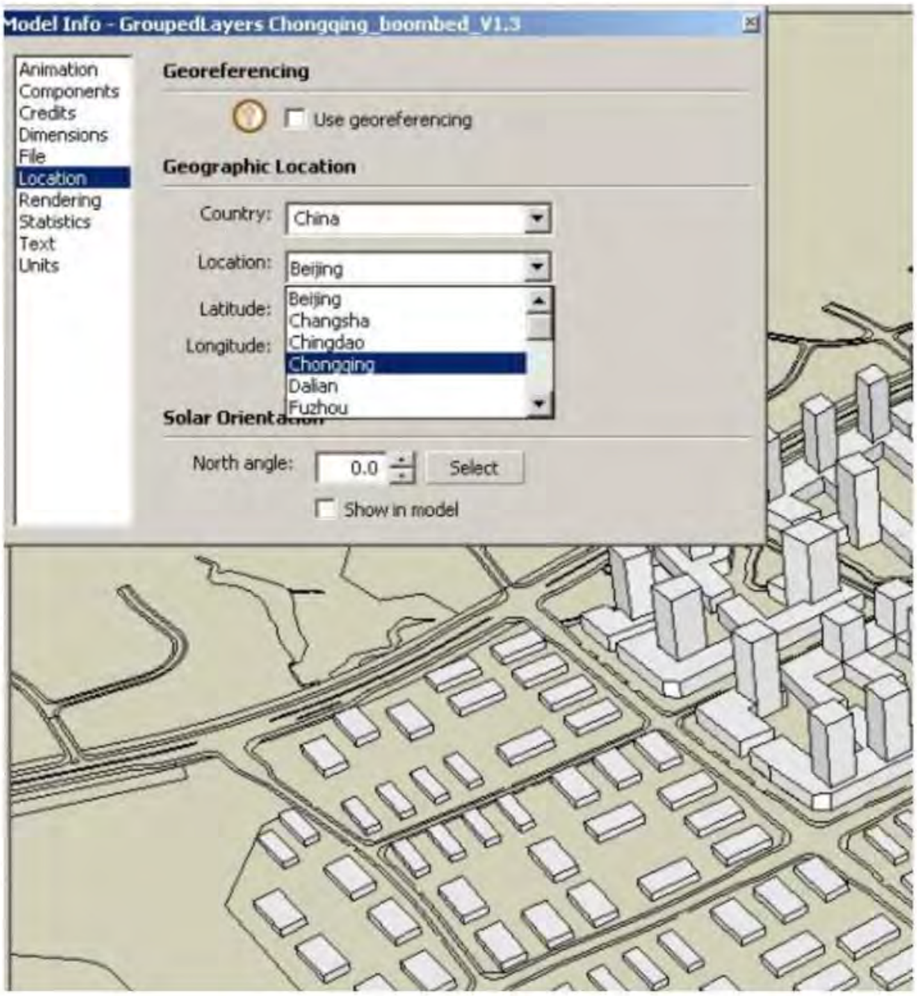


Figure 2.11
Attributing geo-location to the site

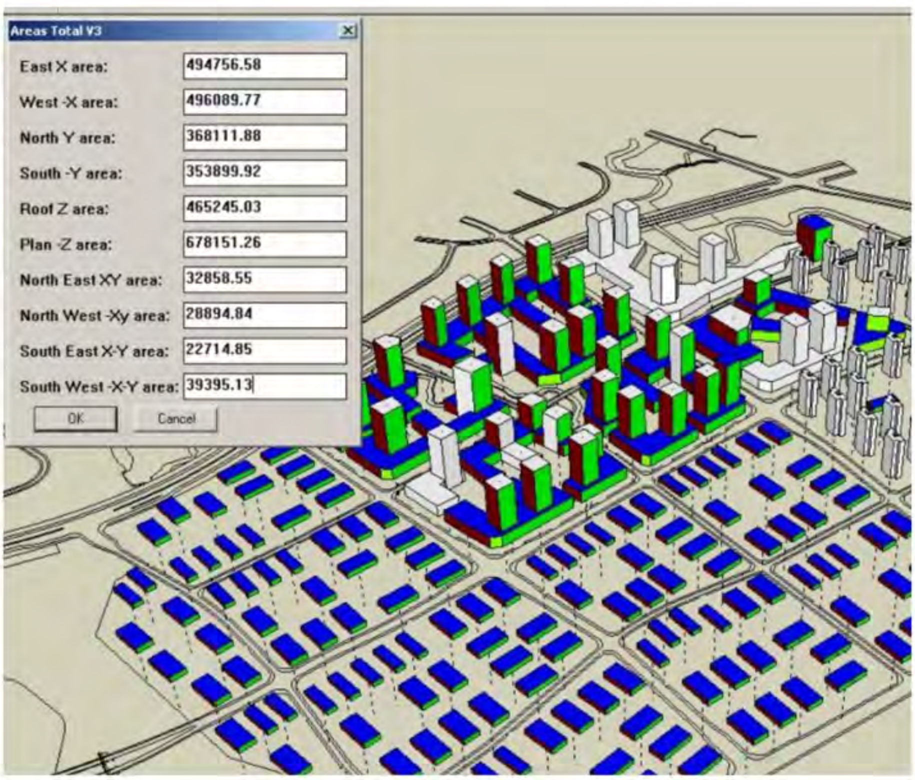


Figure 2.12
Result of the Surface Areas plugin

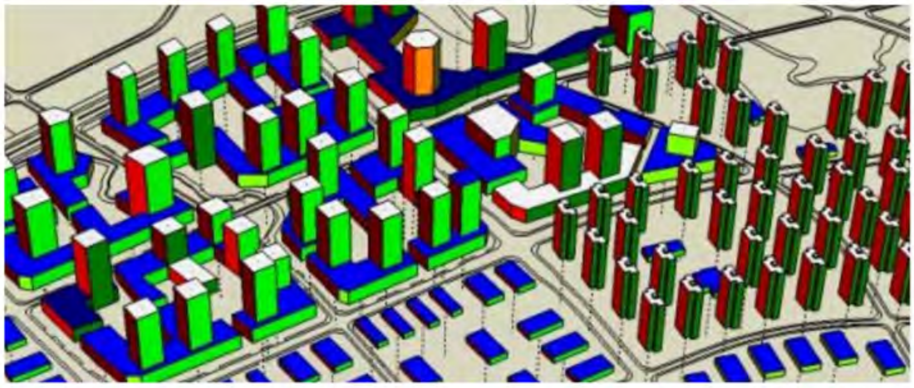


Figure 2.13
Model after the Final Flip, some of the surfaces still colourless

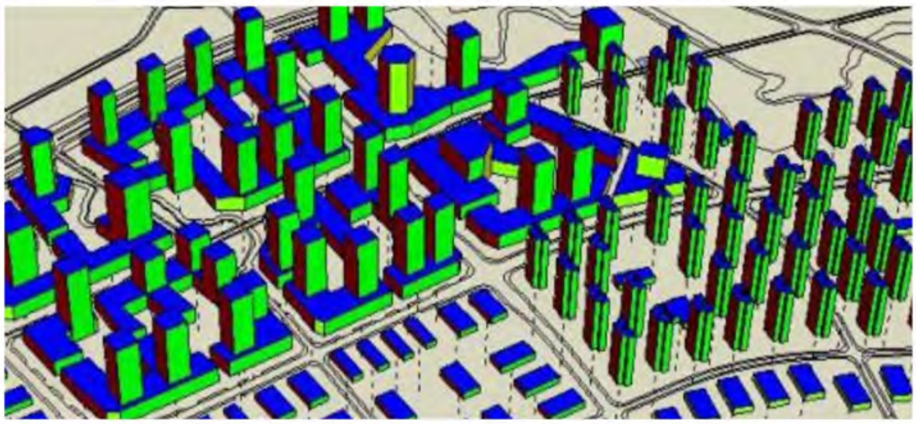


Figure 2.14
All surfaces coloured after final flipping process

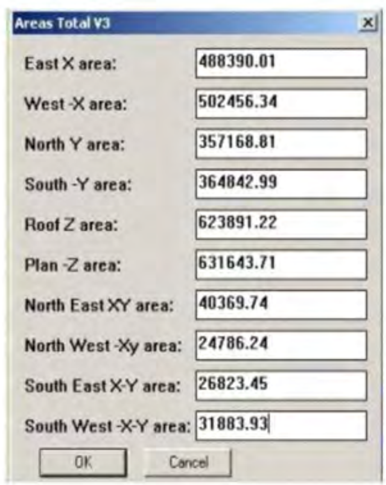


Figure 2.15
Final area totals

Attributing buildings

Attributing buildings through the VirVil Plugin for Sketch-Up is a critical step. It assigns the physical location and time zone of the model to each building, assigns a typology to each building (residential, industrial, and commercial, for example), and gives each building and façade a unique label for future analysis and computations.

After being run, the following message displays in the Ruby window (which is opened in the Sketch-Up environment) the data that the model will be using for the thermal calculations (Figure 2.16) : the time zone, latitude, longitude and the total number of buildings.

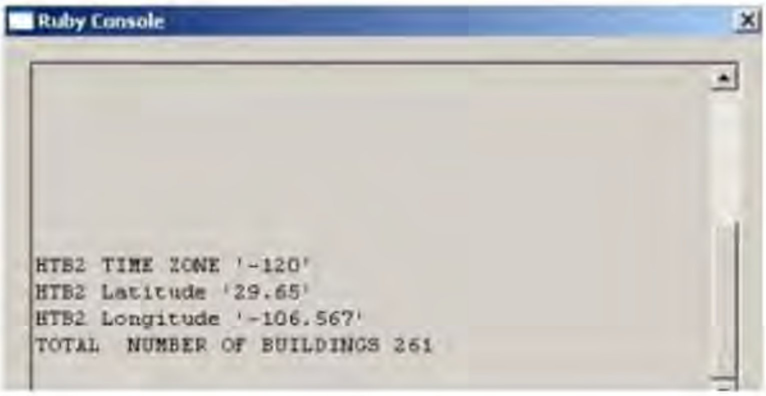


Figure 2.16
Initial attributes of the model, which will be used to run the thermal calculations using HTB2

New attributes can be given to the different parts of the model. By using the Building Properties menu in Sketch-Up, the list of attributes of the buildings can be seen and/or modified. Changes in attribution can be done for a single or multiple buildings (Figure 2.17)

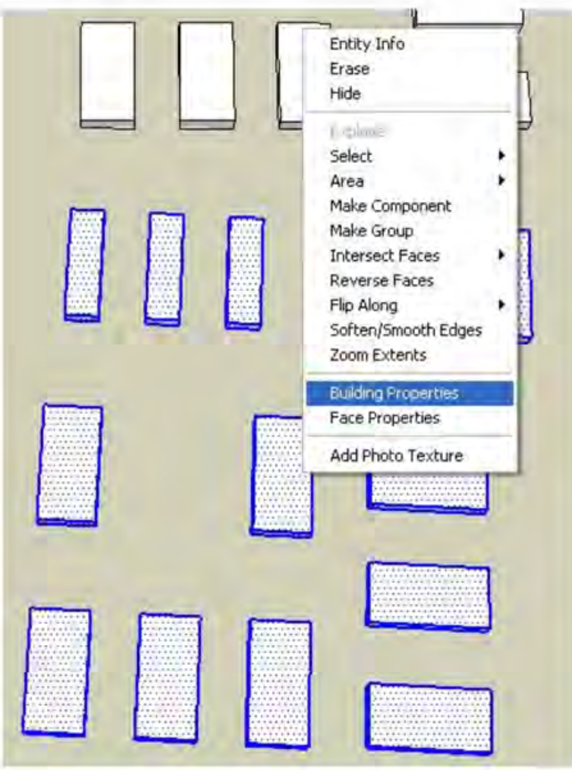


Figure 2.17
Selecting buildings to assign different attributes

When the option Building Properties is selected from the right-click menu, a dialog-box is opened (Figure 2.18), where various aspects of the building or the elements selected are displayed. This Building Type classification will be used during the thermal modelling for occupancy patterns, impacting on cooling and heating calculations; the default instance is Residential if no selection is made.

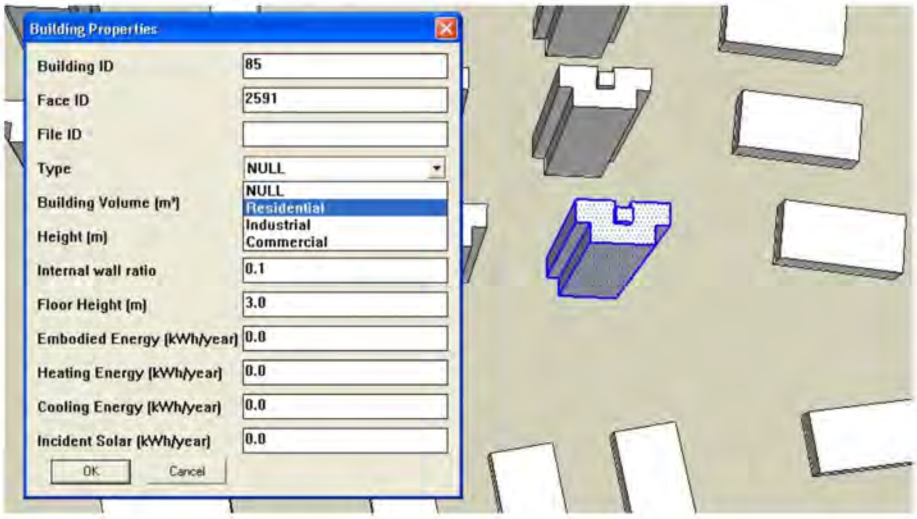


Figure 2.18
Viewing the properties of the building, where they can be altered.
*Note: if the Type of building is not specified, **Residential is default***

Embodied Energy

Using the VirVil Plugin for Sketch-Up, the Embodied Energy of every building can be calculated.

Currently, the Plugin provides figures in MJs of the Embodied Energy of a whole building or any selected face (façades, roofs or floors). The figures appear in the Building and Face Properties lists (Figure 2.19).

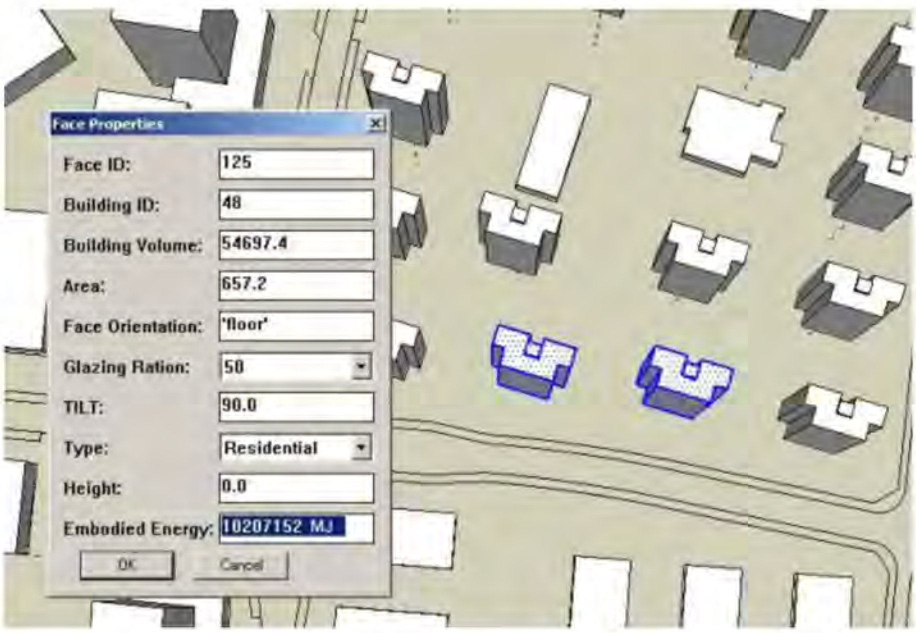


Figure 2.19
Embodied Energy Value (of the selected buildings) displayed in the Building Properties menu

The tool uses embedded data to calculate the embodied energy values across the entire model. This data has been gathered after extensive research and investigation into urban scale embodied energy. Principles of the calculations used for this Plugin can be found in the 'Embodied Energy' section of Part 1 of the guide.

Creating HTB2 files

This step readies the model data to be exported to HTB2 whilst also creating a shading mask for every façade. The VirVil Plugin automatically creates the files needed to make the connection to HTB2. Such files are created according to the information obtained from the shading mask analysis and the other attributes given to the entire model.

The technique used by the Plugin to create shading masks for each façade is to shoot lines from each façade of each building, finding which obstacles obscure visual access to the sky dome. This process can be done more accurately according to the separation angle of each line being shot from each façade.

The intervals used to decide the accuracy of the shading mask calculation has been set to be 10°, 5°, 2° and 1° (lower degrees of separation mean more lines being shot from each façade, resulting in higher accuracy, with longer running calculation times (Figure 2.20). Research on the sensitivity of such degrees of accuracy provided enough confidence to recommend a 5 degree separation of the arrows as accurate enough for this case scenario.

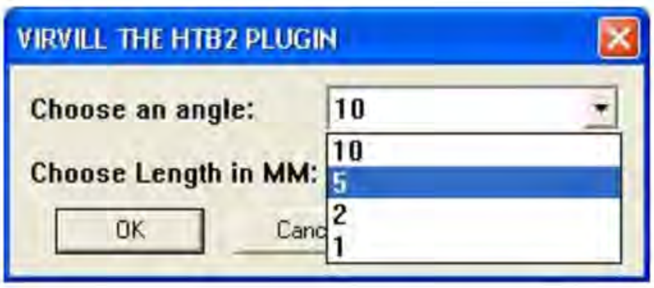


Figure 2.20
Selecting accuracy of shading mask

Figure 2.21 and 2.22 represent the principle behind the model calculations. They show how each element of the buildings 'collects' the data of the surrounding obstacles to the sky vault.

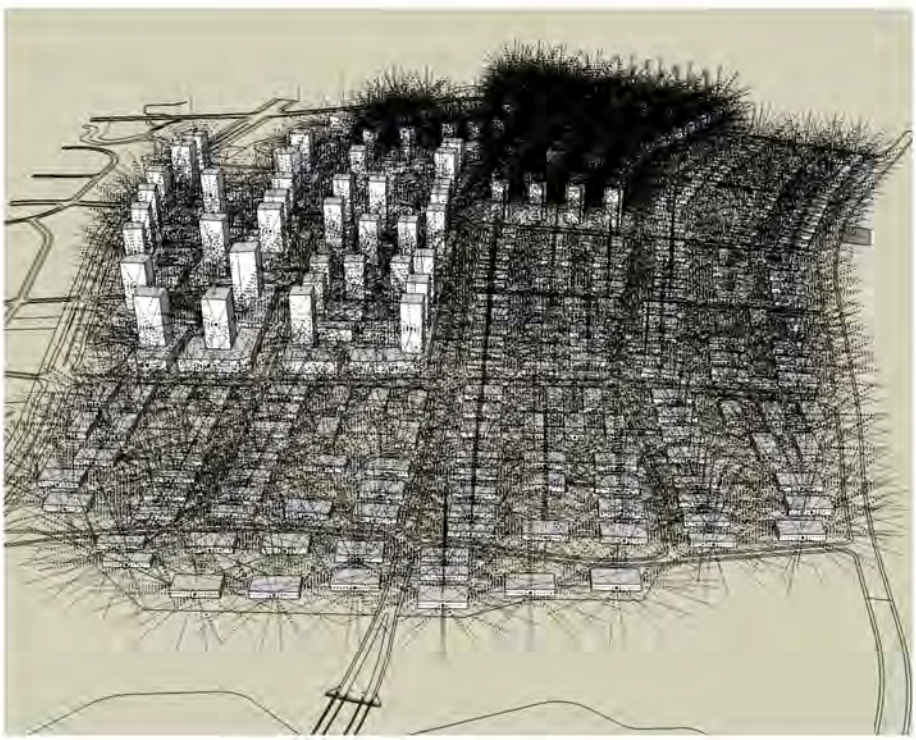


Figure 2.21
Urban façade shading being developed by the plugin

Note that for faster results the plugin has been upgraded from displaying all this rays in the model. The version we are now using does not display these rays visually in order to reduce calculation times. Displaying the rays is still possible by invoking the ' Sky View' calculation in the Plugin menu.

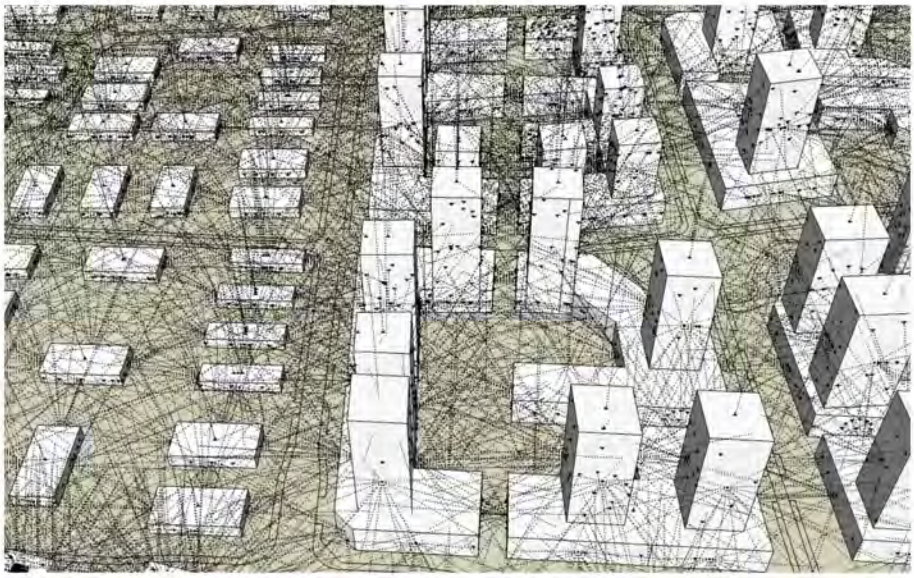


Figure 2.22
Close-up of the model showing the lines being fired and meeting surrounding surfaces. Observe the points on buildings where a façades' rays have intersected obstructions

Finally the list of the files containing all the information required to link the 3D model to HTB2 is created in the same folder where the model has been originally saved (Figure 2.23).

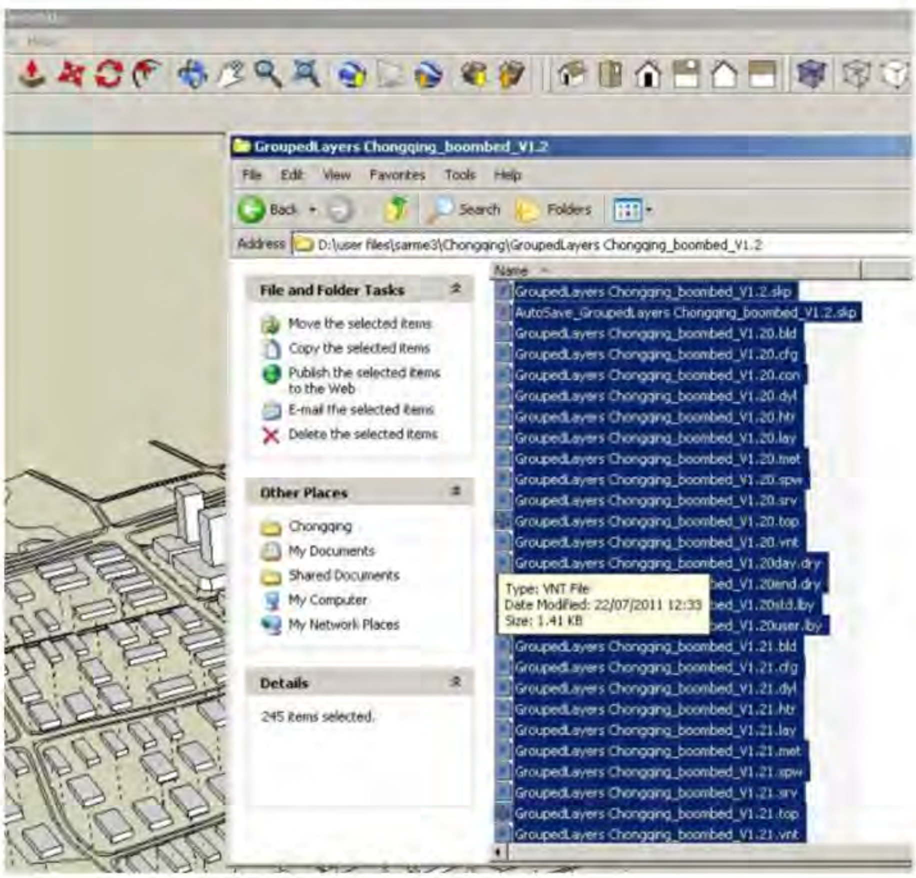


Figure 2.23
Window showing the files originated from the Plugin, where all the data has been extracted from the model. Weather data, construction data, occupancy pattern, etc. is embedded within the software developed

This is the final step where a new menu selection within the Plugin invokes HTB2 from Google Sketch-Up: 'running htb2'.

All the previous steps outlined above have provided our Sketch-Up model with enough information to successfully run HTB2 (Figure2.24).

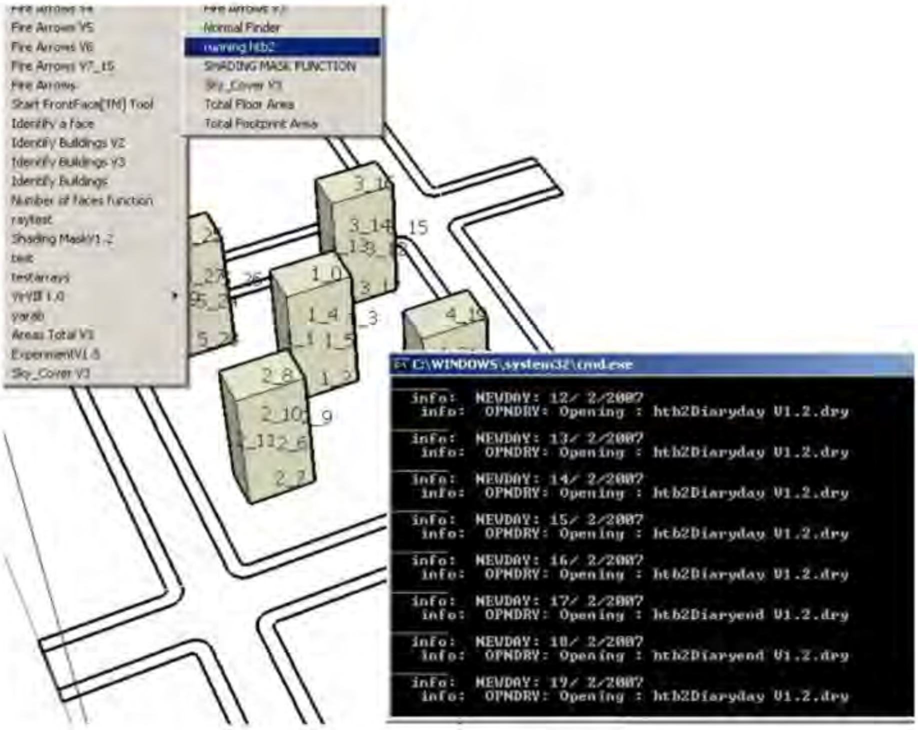


Figure 2.24
The plugin invoking the HTB2 engine for calculations, within the Sketch-Up environment

Conclusion

By developing this Plugin, we are achieving early stage urban modelling, resulting in an extremely valuable tool to estimate - as close as possible - the energy consumption of a whole site, its operational energy and the likelihood to improve the efficiency of the overall design, before any other stage of the construction process.

The HTB2 calculations produce results files (which get saved in the same folder where all the information has been previously created) and can be used to automatically create reports of the different issues of the buildings.

Some of the current values obtained from the thermal calculations are:

- Solar gains
- Heating gains
- Cooling gains
- Incidental gains
- Ventilation gains
- Fabric gains

From these values we can then calculate the amount of solar potential to obtain solar energy from surfaces of buildings (PV potential), as well as the amount of energy that the building would require to be heated and cooled, amongst other significant figures.

Results

Residential

Buildings classified as residential - Comparison of different locations and different heights (high-rise and low rise)

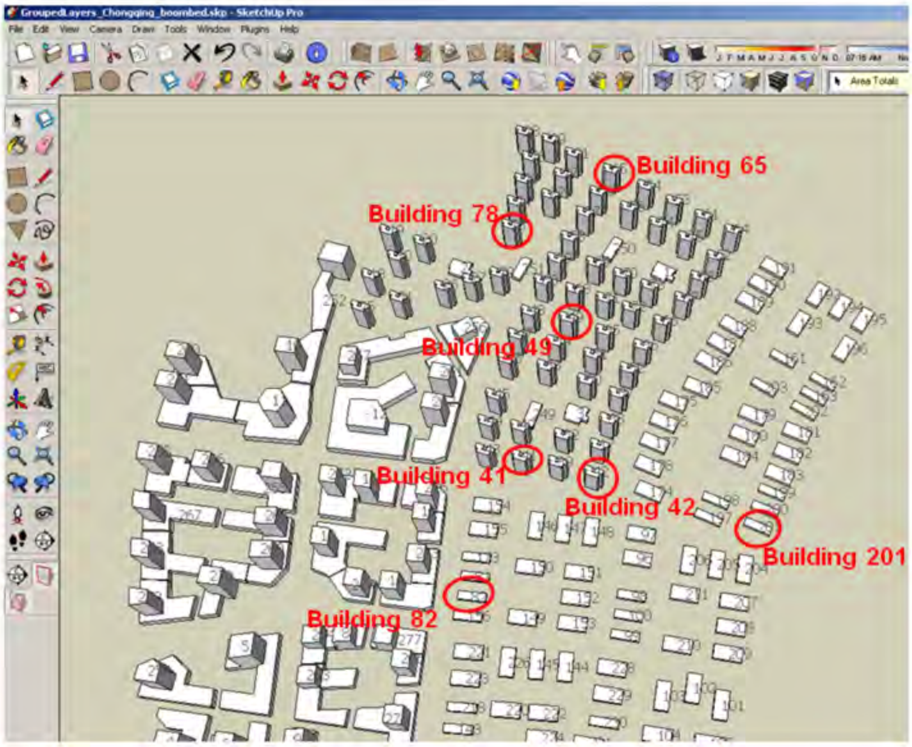
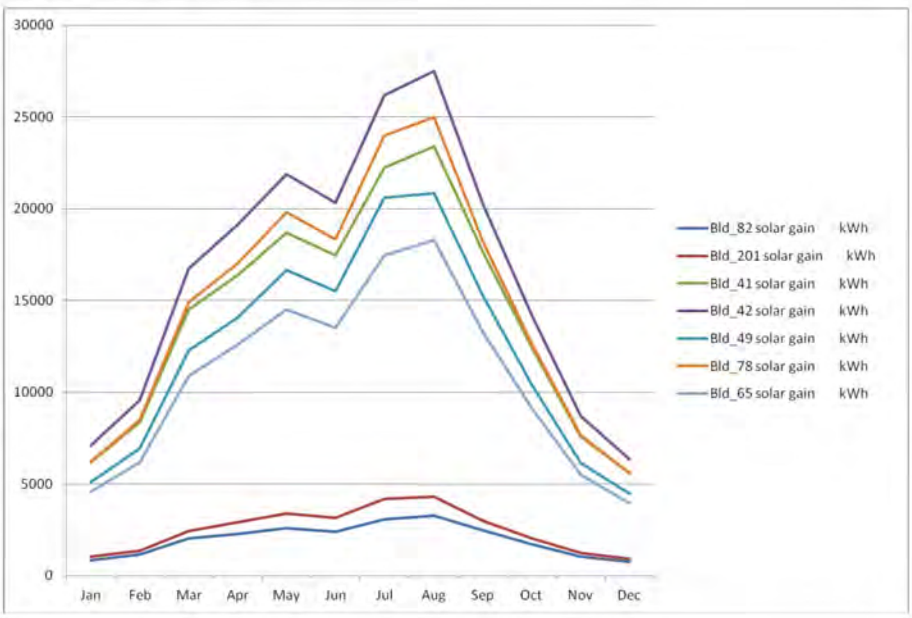


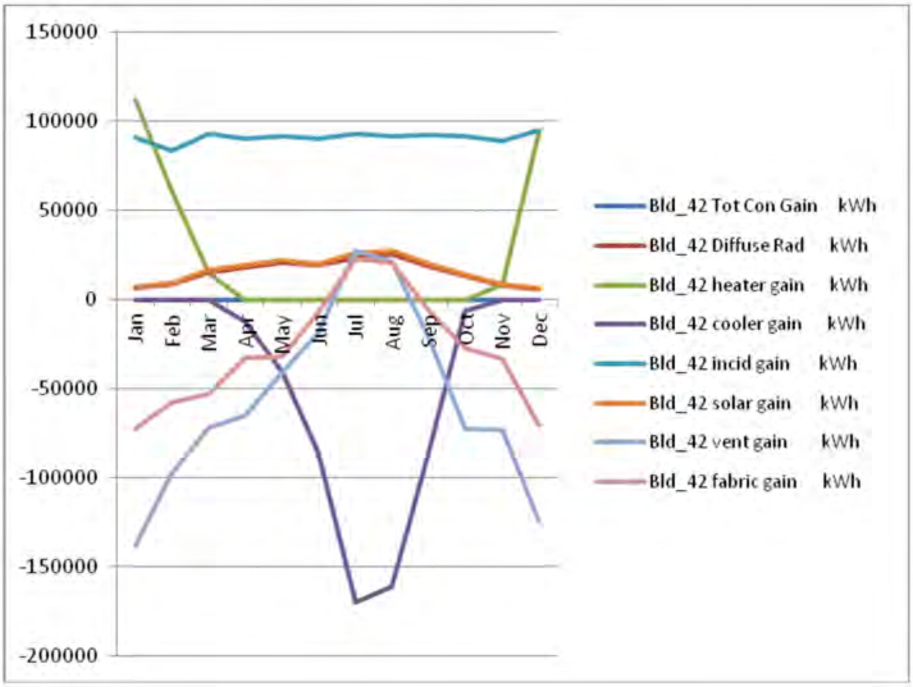
Figure 2.25
Buildings selected to show the comparative results

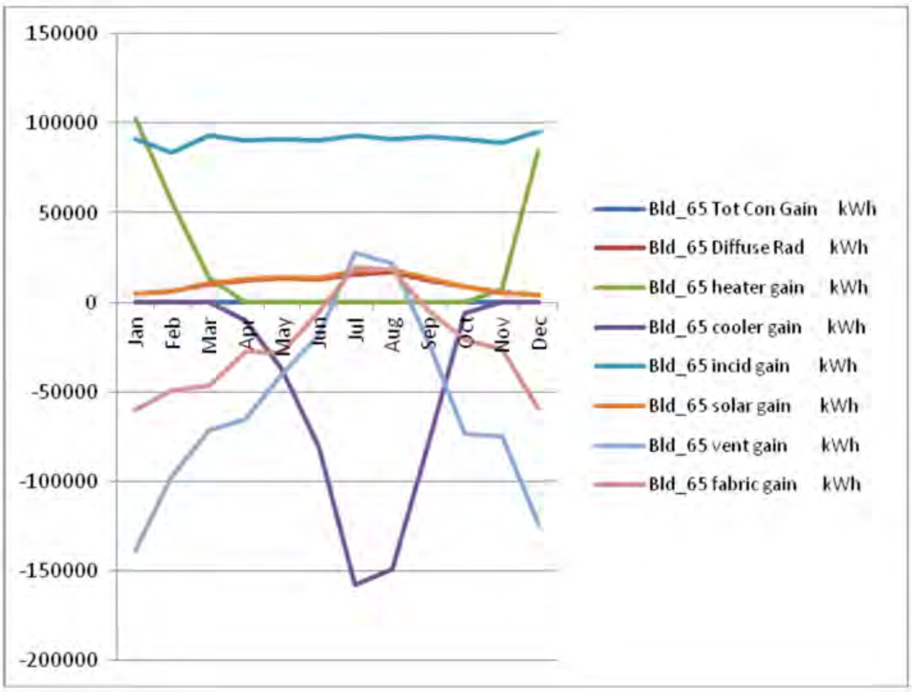
Solar gain comparison



Graph 2.5
Different solar gain for the various buildings selected to investigate (marked in Figure 2.25)
Note: the most dramatic difference in solar gain is due to the size of the buildings. The smaller curves are from the smaller residential buildings located in the industrial sector of the site, and the higher curves represent the solar gains of the high rise buildings, in the residential 2.

Comparison of all the available data provided by the plugin, for two different buildings (number 42 and 65 in Figure 2.25). Both buildings are affected by different shading mask profiles.





Graph 2.6 and 2.7
Values obtained for each buildings: 42 and 65.

They have the same pattern, of course, due to the seasonal variation of the site, but if looked in detail, it is noticeable the different amount of gains generated in the two different positions of the buildings.

Industrial

Initially, we are demonstrating the results of two buildings close to each other, with the purpose of illustrating how this tool can reveal the sensitivity of the location of different buildings with regards to the surrounding environment. By predicting this from an early stage, the different nature of industries can be allocated more sensibly, in order to maximise the use of natural available resources, and assign appropriate activities to the 'correct' buildings, according to their requirements within the built environment.

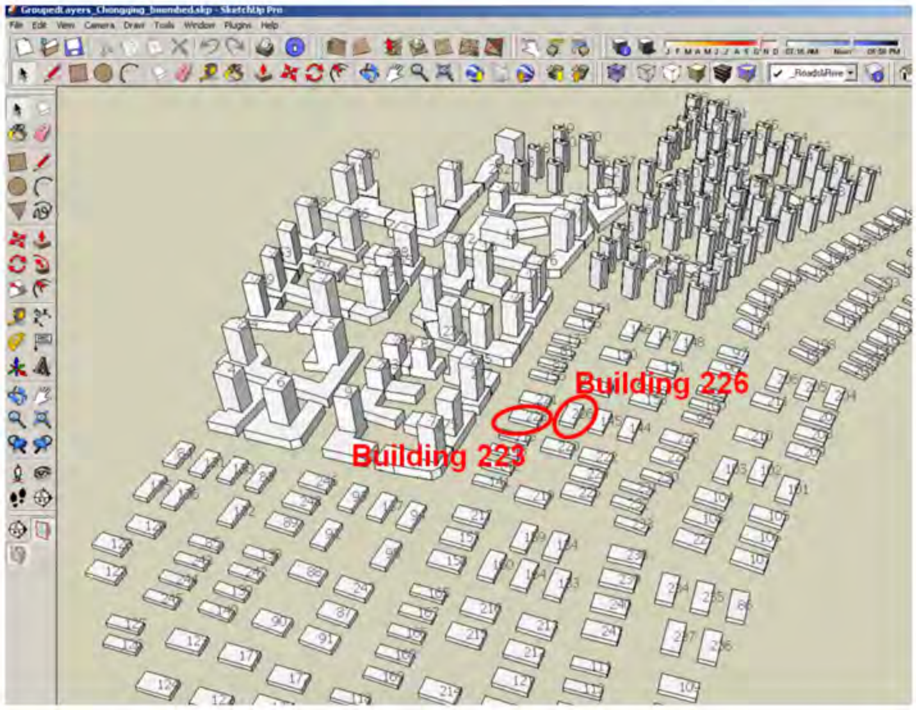
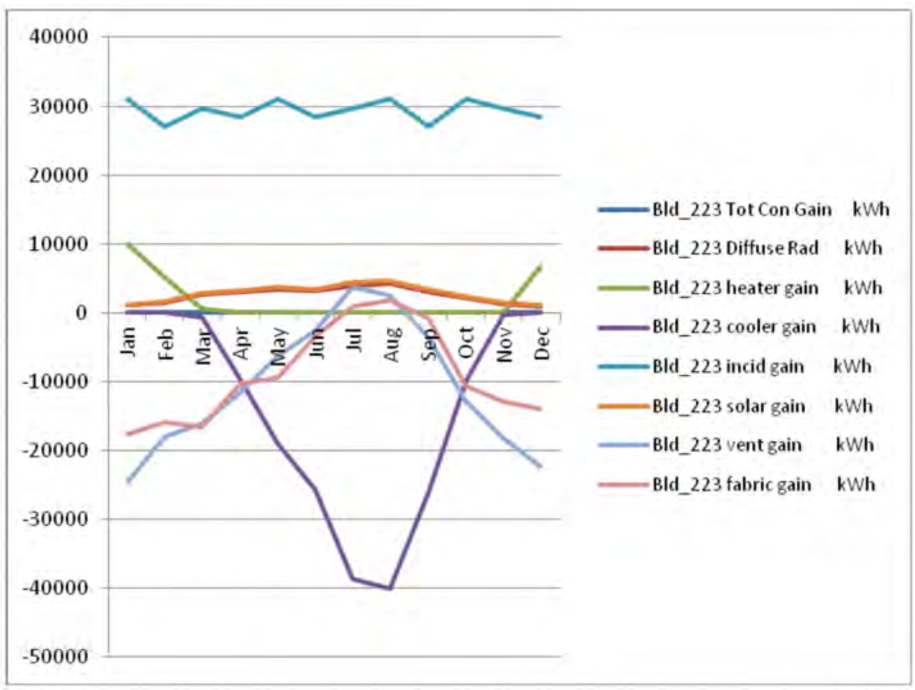
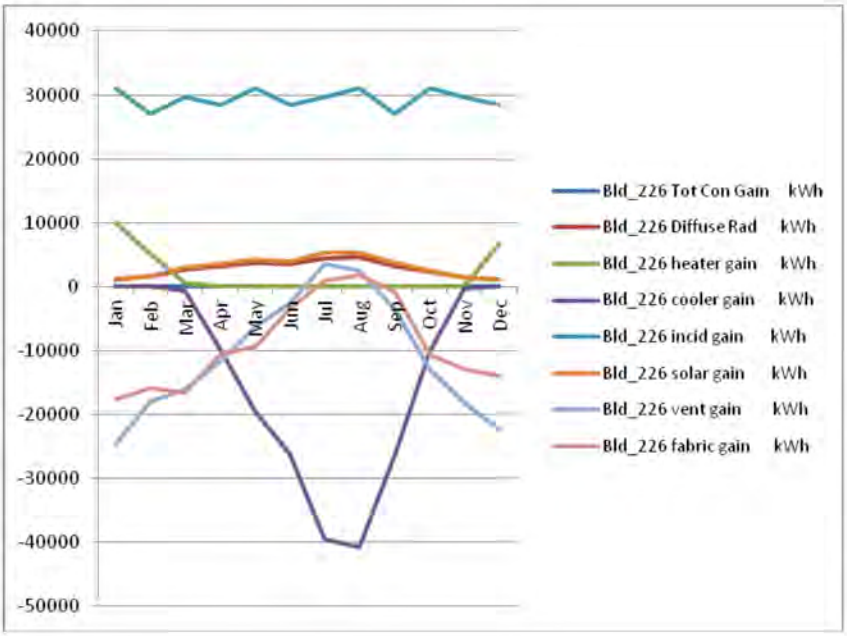


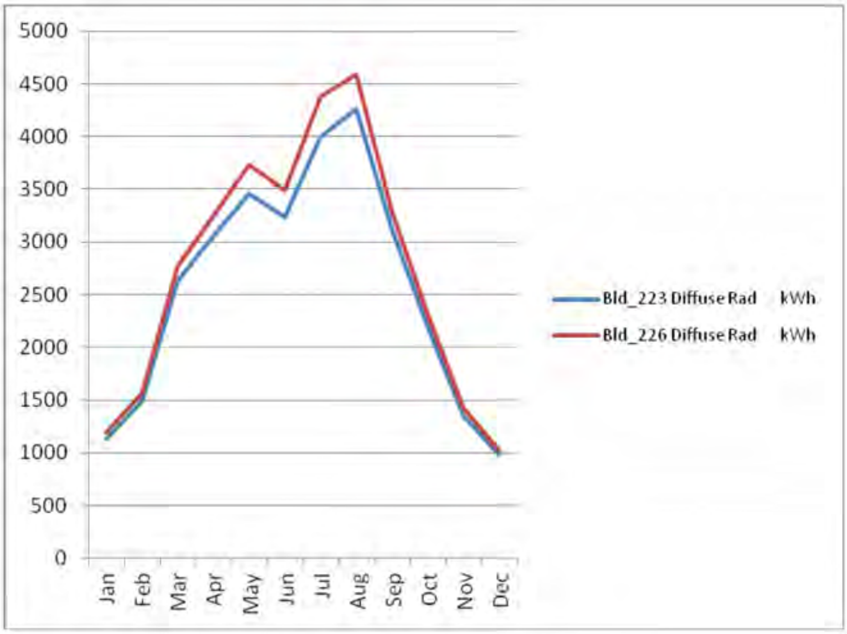
Figure 2.26
Industrial buildings selected to compare their behaviour.

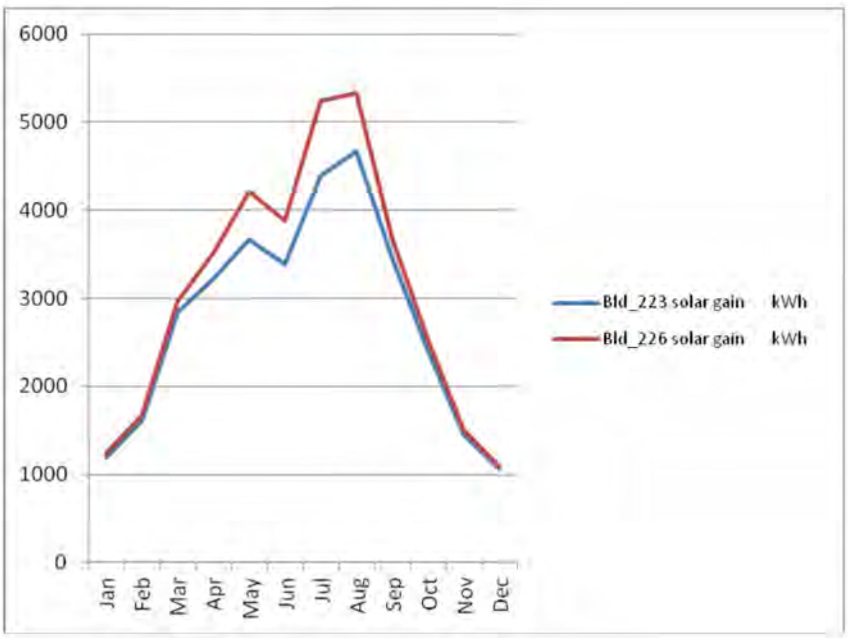




Graph 2.8 and 2.9
Values obtained for each buildings: 223 and 226

Observed that since they are located close to each other, they seem to behave pretty much in the same way, but if we analysed closer, we will notice the significant temperature difference between them - see Graphs 2.10 and 2.11)





Graph 2.10 and 2.11
In these graphs it is highly noticeable that despite their proximity, building226 may over heat during the summer months in comparison to building 223, but it would behave equally during the colder season. This sort of comparison, can be very useful for example when considering industrial symbiosis, since building can be' paired-up' in order to exchange heat when needed during different seasons, in cases where the natural thermal behaviour may be opposite throughout the year.

The site as a whole

The previously outlined computer simulations of the site resulted on a significant amount of numeric results. This section would outline the final figures relevant to the Operational Energy and Embodied Energy.

The following table is the added figure for the total operational energy for the site. The results were obtained from the figures given by this analysis method using the tools developed (in sketchup and HTB2). Note that the specifications used for the simulation, can be found at the end of this report.

Table 2.1 Global Figures for the operational energy of the site:

Table 2.1
Global Figures for the operational energy of the site

	Heating	Cooling
Operational Energy	116,825,891 kWh/a	331,899,401 kWh/a

Tables 2.2 and 2.3 Detailed Operational Energy results:

Global:

Table 2.2
Detailed Operational Energy results - Global

	Heating	Cooling
	kWh/a	kWh/a
Residential	29,150,767	39,313,244
Commercial	67,360,963	277,583,638
Industrial	20,314,161	15,002,519
Total	116,825,891	331,899,401

Per square metres:

Table 2.3
Detailed Operational Energy results - Per square metres

	Heating	Cooling	Total
	kWh/m2/a	kWh/m2/a	kWh/m2/a
Residential	22.44	30.27	52.71
Commercial	10.88	44.83	55.71
Industrial	30.58	22.59	53.17

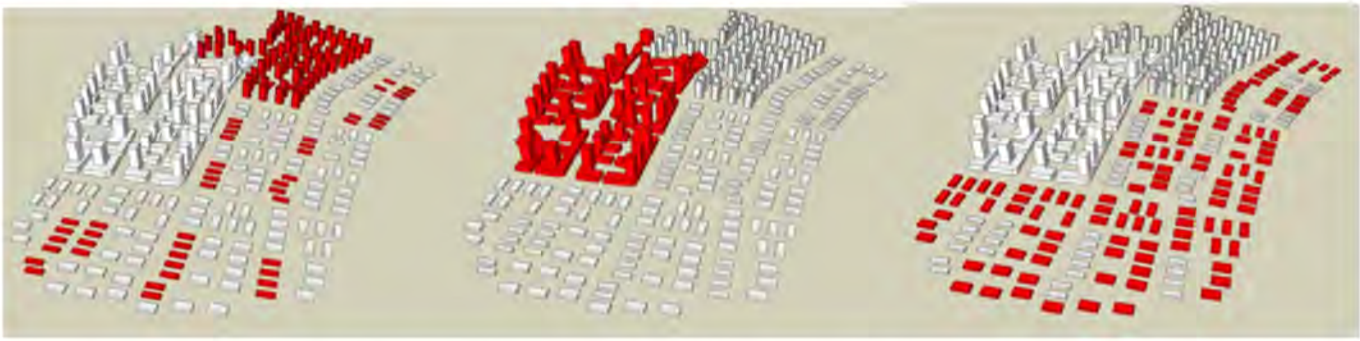


Figure 2.27 These images show the three selections of the distribution of the different types of buildings: Residential (left), Commercial (middle), Industrial(right).

Following the previous analysis and the simulation was repeated various times in order to observe the effect taken on the final results. Issues such as increasing the ventilation rate, or changing the various U-values have an impact on the results.

The following tables show the results of the model, this time the simulation show the impact of improving the fabric performance of the buildings.
It can be noted that in comparison with the previous figures, the overall heating demand increased significantly, and as expected the cooling demand reduced.

Tables 2.4 and 2.5 Detailed Operational Energy results

Global:

	Heating	Cooling
	kWh/a	kWh/a
Residential	16,942,217	38,946,987
Commercial	58,447,776	295,778,847
Industrial	15,384,864	15,848,997
Total	90,774,857	350,574,831

Table 2.4
Detailed operational energy results - Global

Per square metres:

	Heating	Cooling	Total
	kWh/m2/a	kWh/m2/a	kWh/m2/a
Residential	13.04	29.98	43.03
Commercial	9.44	47.77	57.21
Industrial	23.16	23.86	47.02

Table 2.5
Detailed operational energy results - Per square metres

Embodied Energy Results

As shown in the previously outlined software tool, the overall Embodied Energy for the materials used on this case scenario for Chongqing can be found on Table 2.6 below:

Table 2.6
Total Embodied Energy of the materials used for the whole site.

Note: please find the table of embodied energy figures shown in Part 1 of the guidance

	Total Embodied Energy Standard construction	Total Embodied Energy Improved construction
	kWh/m2/a	kWh/m2/a
Residential	323	323
Commercial	271	271
Industrial	394	394

Future research work

In the Welsh School of Architecture, we are constantly developing a significant amount of research in the area of efficient design of buildings, always looking for ways to reduce carbon emission in the building industry, also protecting the high standards of our designs. Urban scale energy consumption is an area directly linked to the problem, and new computer modelling tools can significantly improve the quality of the conceptual design of projects.

For the next stage of the software used for this case study, we are working towards linking the results back into the sketch-up interface, in a more interactive visualisation. Various options are being analysed and discussed. Figure 2.28 is a visualisation of one of the options we are working on, in order to display the figures obtained from the thermal and energy analysis.

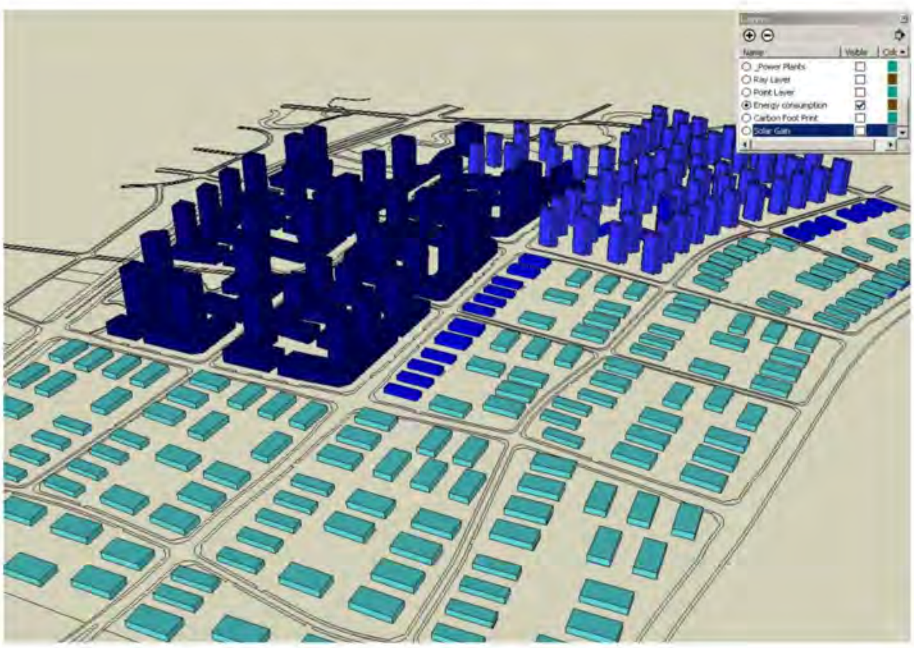


Figure 2.28
A visualisation of simulation result

Supplement

Here are some tips for using the tool to perform simulation; check these issues before running the model.

Rules for building the model:

- Simple the building or complex as far as possible, better no curves
- Delete the layout if it has no influence to the buildings. Make sure there are no line connections between buildings;
- Topography imported from Google Earth, if taken into account its thading influence to all the buildings (all buildings should sit on the topography), should not be ungrouped;
- Delete all unnecessary lines, faces and boxes;
- Make sure all spaces are closed (no missing faces).
- If there is a curve in the model, do not use the 'final flip' command when facing problems with the total area (no colour displays for some façade), but fix the problems manually, such as closing the space by drawing faces or lines, etc.

Appendix A

Details

Since the simulation has been developed at an urban scale, it is recommended to simplify the simulation conditions by setting standard models for different the types of buildings under analysis. In this case, the following classifications have been used: Residential, Commercial and Industrial.

Simulation conditions for our standard models are set according to national and local design standards, and based on basic documents about Ba' nan Low Carbon Industry Park Project, together with related project examples provided by the client. The main references are listed below.

Regulations and standards

- Thermal Design Code for Civil Buildings GB 50176-1993
- Design Standard for Energy Efficiency of Residential buildings in Hot Summer and Cold Winter Zone JGJ 134-2001
- Design Standard for 65% Energy Efficiency of Residential building in Chongqing Area
- Design Standard for 50% Energy Efficiency of Public building in Chongqing Area
- Design Standard for 65% Energy Efficiency of Public building in Chongqing Area (a draft under examination)
- Standard Drawings for buildings in Southwest China (Southwest 04j bound volume)
- Hygienic Standards for Design of Industrial Enterprises GBZ 1-2002
- Plan & Design Guideline for Industry Factory Images in New Developed Area in Liangjiang
- Technical Regulation for Building and Construction Designs for Major project –Steel Industry
- Technical Regulation for Factory Design of Baogang Joint-stock Construction Project
- Technical Regulation for Urban Planning Management, Chongqing.
- Code for Design of Civil buildings GB 50352-2005
- Code of Urban Residential Areas Planning & Design GB 50180-93 (2002 version)
- Code for Design of General Plan of Industrial enterprises GB 50187-93
- Design Code for Office buildings JGJ 67-2006, J 556-2006

Original documents about Ba' nan Low Carbon Industry Park Project

- Feasibility study report about Low Carbon Industry park of Jieshi group in Huaxi Industry area, Ba' nan District, Chongqing, May 2010
- Report about Industrial Area in Jieshi Group-1.7edition
- Location Map of Economic Park in Ba' nan District, Chongqing
- Master map of Low Carbon Industry park of Jieshi group in Huaxi Industry area, Ba' nan District, Chongqing

Others

- Weather data: comes from Joint measurement by China Meteorological Bureau and Tsinghua University, together with reference from actual measurement for GSHP from Research & Development Centre CISDI.
- Residential and commercial building examples, which are practical projects provided by the client.
- Journal paper: Wang Gangjie (1995). Energy Efficiency Technology Problem in Industrial Buildings Design, Industrial Construction, Vol.25, No.11, pp. 10-13.

Appendix B

Simulation conditions for the standard model

Construction and materials

Building type	Construction	U value ($W/m^2.C$)	Material	Thickness (mm)
Residential building	External wall (from external to internal)	0.8	Cement mortar	8
			Foamed concrete 730	188
			Cement mortar	20
	Internal wall	2.0	Cement mortar	20
			Standard sintering shale hollow brick	150
			Cement mortar	20
	Window (from external to internal)	2.8	High-transparent Low-E Glass	6
			Cavity	12
			Glass	6
	Standard floor slab, and Floor slab between ground floor and basement (from up to down)	2.5	Fine aggregate concrete 2300	30
			Inorganic thermal preservation mortar	10
			Reinforced concrete	100
	Roof (external insulation, people can walk on, from up to down)	0.6	Fine aggregate concrete 2300	40
			Cement mortar	20
			XPS plate	32
			high polymer waterproof sheet	3
			Cement mortar	15
			argil fly-ash concrete 1100	100
			Cement mortar	15
			Reinforced concrete	120
			Cement mortar	10
	Ground (from up to down)	0.64	Reinforced concrete	60
			autoclaved aerated concrete block 626-725	140
			SBS modified asphalt rolling material	3
			Fine aggregate concrete 2300	60
			Earth	600

Building type	Construction	U value ($W/m^2.C$)	Material	Thickness (mm)
Industrial building	External wall (from external to internal)	1.0	Color channeled steel plate	1
			Rock Wool panel	5
			Leca hollow block	200
	Internal wall	2.0	Cement mortar	20
			Standard sintering shale hollow brick	150
			Cement mortar	20
	Window (from external to internal)	2.8	High-transparent Low-E Glass	6
			Cavity	12
			Glass	6
	Standard floor slab (from up to down)	3.59	Fine aggregate concrete 2300	30
			Reinforced concrete	100
			Cement mortar	20
	Roof (from up to down)	0.69	High polymer waterproof sheet	3
			Color channeled steel plate	1
			Glass wool panel	46
			Aluminium foil	1
	Ground (from up to down)	0.77	Fine aggregate concrete 2300	30
			Reinforced concrete	100
			Earth	1200
Commercial building	External wall (from external to internal)	1.1	Cement mortar	8
			Foamed concrete 730	126
			Cement mortar	20
	Internal wall	2.0	Cement mortar	20
			Standard sintering shale hollow brick	150
			Cement mortar	20
	Window (from external to	2.8	High-transparent Low-E Glass	6
			Cavity	12

internal)		Glass	6
Standard floor slab, and Floor slab between ground floor and basement (from up to down)	3.59	Fine aggregate concrete 2300	30
		Reinforced concrete	100
		Cement mortar	20
Roof (external insulation, people can walk on. from up to down)	0.69	Fine aggregate concrete 2300	40
		Cement mortar	20
		XPS plate	33
		high polymer waterproof sheet	3
		Cement mortar	15
		Reinforced concrete	120
		Cement mortar	10
Ground (from up to down)	0.77	Fine aggregate concrete 2300	30
		Reinforced concrete	100
		Earth	1200

Design condition indoor

		Residential	Industrial	Commercial
Heating/cooling	**Design temperature & operation schedule**	18-23C, 00:00-24:00, Monday to Sunday	21-23C, 08:00-18:00, Monday to Friday	21-23C, 08:00-18:00, Monday to Friday
Incidental gains (from lighting, small power and occupancy)	**Output power**	$15W/m^2$	$30W/m^2$	$40W/m^2$
	Operation schedule	Monday to Friday: 00:00-08:00 & 18:00-24:00; Saturday to Sunday, 00:00-24:00	08:00-18:00, Monday to Friday	08:00-18:00, Monday to Friday
Ventilation	**Weekday**	0.5,1.0,1.0, 26C	0.5,2.0,2.0, 26C	0.5,2.0,2.0, 26C
		On during 00:00-08:00 & 18:00-24:00	On during 08:00-18:00	On during 08:00-18:00
	Weekend	On during 00:00-24:00	Off all the day.	Off all the day

Notes: Operation schedules for ventilation are simplified to reduce calculation time. However, it will be detailed in the near future, following the development of software.

Building information

For the case study, total areas for building types, roads, green, grey, etc. for floor area and site area (footprint) are as below.

			Total Areas (m^2)
Building Type	**Total Footprint Area**	**Total Floor Area**	**Total Zone Area***
Low Carbon Industry	271,080	664,200	1,333,333
Commercial	308,258	6,191,850.29	450,000
Residential	51,141	1,298,932.19	466,666
Roads	666,268		
Green Area	1,291,665		
External Car Park Area	80,087		
Other:	74,834		
Vocational/Educational	51,333		
River	20,267		
Municipal Utilities	3,234		
Total	2,743,333	8,154,982.48	2,301,332

** Total Zone Area encompasses all the areas within a zone （green, roads, footprints, etc. ）*

建筑信息

对案例研究来说，不同类型的建筑、道路、绿色、灰色等的总体面积及基地面积如下：

	Total Areas (m^2)		
Building Type	Total Footprint Area	Total Floor Area	Total Zone Area*
Low Carbon Industry	271,080	664,200	1,333,333
Commercial	308,258	6,191,850.29	450,000
Residential	51,141	1,298,932.19	466,666
Roads	666,268		
Green Area	1,291,665		
External Car Park Area	80,087		
Other:	74,834		
Vocational/Educational	51,333		
River	20,267		
Municipal Utilities	3,234		
Total	2,743,333	8,154,982.48	2,301,332

*总区域面积,包括一个区域内的所有领域（绿化、道路、基地面积等）

	标准楼板 (从上到下)	3.59	碎石、卵石混凝土 2300	30
			钢筋混凝土	100
			水泥砂浆	20
	屋顶 (外保温，上人屋顶，从上到下)	0.69	碎石、卵石混凝土 2300	40
			水泥砂浆	20
			挤塑聚苯板	33
			合成高分子防水卷材	3
			水泥砂浆	15
			钢筋混凝土	120
			水泥砂浆	10
	地板 (从上到下)	0.77	碎石、卵石混凝土 2300	30
			钢筋混凝土	100
			夯实粘土	1200

室内设计条件

		居住建筑	工业建筑	商业建筑
采暖/制冷	设计温度和工作时间	18-23C, 00:00-24:00,周一到周日	21-23C, 08:00-18:00, 周一到周五	21-23C, 08:00-18:00, 周一到周五
内部得热 (来自照明，家电，人员等)	输出功率	15W/m^2	30W/m^2	40W/m^2
	工作时间	周一到周五: 00:00-08:00 & 18:00-24:00; 周六到周日, 00:00-24:00	08:00-18:00, 周一到周五	08:00-18:00, 周一到周五
通风	工作日	0.5,1.0,1.0, 26C 00:00-08:00 & 18:00-24:00 开启	0.5,2.0,2.0, 26C 08:00-18:00 开启	0.5,2.0,2.0, 26C 08:00-18:00 开启
	周末	全天 24 小时工作	全天关闭	全天关闭

注： 通风操作时间表的简化减少了计算时间。然而，它将在不久的将来与软件的发展一起进行详细介绍。

建筑类型	构造	U 值 (W/m^2.C)	材料	厚度 (mm)
工业建筑	外墙 (从外到内)	1.0	彩色压型钢板	1
			岩棉板	5
			陶粒空心混凝土砌块	200
	内墙	2.0	水泥砂浆	20
			普通烧结页岩空心砖	150
			水泥砂浆	20
	外窗 (从外至内)	2.8	高透射 Low-E 玻璃	6
			空腔	12
			玻璃	6
	标准楼板 (从上到下)	3.59	碎石、卵石混凝土 2300	30
			钢筋混凝土	100
			水泥砂浆	20
	屋顶 (从上到下)	0.69	合成高分子防水卷材	3
			彩色压型钢板	1
			玻璃棉板	46
			铝箔	1
	地板 (从上到下)	0.77	碎石、卵石混凝土 2300	30
			钢筋混凝土	100
			夯实粘土	1200
商业建筑	外墙 (从外到内)	1.1	水泥砂浆	8
			泡沫混凝土 730	126
			水泥砂浆	20
	内墙	2.0	水泥砂浆	20
			普通烧结页岩空心砖	150
			水泥砂浆	20
	外窗 (从外至内)	2.8	高透射 Low-E 玻璃	6
			空腔	12
			玻璃	6

附录 B

标准模型的模拟条件

施工和材料

建筑类型	构造	U 值 ($W/m^2.C$)	材料	厚度 (mm)
居住建筑	外墙 (从外到内)	0.8	水泥砂浆	8
			泡沫混凝土 730	188
			水泥砂浆	20
	内墙	2.0	水泥砂浆	20
			普通烧结页岩空心砖	150
			水泥砂浆	20
	外窗 (从外至内)	2.8	高透射 Low-E 玻璃	6
			空腔	12
			玻璃	6
	标准楼板 (从上到下)	2.5	碎石、卵石混凝土 2300	30
			无机保温砂浆	10
			钢筋混凝土	100
	屋顶 (外保温，上人屋顶，从上到下)	0.6	碎石、卵石混凝土 2300	40
			水泥砂浆	20
			挤塑聚苯板	32
			合成高分子防水卷材	3
			水泥砂浆	15
			粉煤灰陶粒混凝土 1100	100
			水泥砂浆	15
			钢筋混凝土	120
			水泥砂浆	10
	地板 (从上到下)	0.64	钢筋混凝土	60
			蒸压加气混凝土砌块 626-725	140
			SBS 改性沥青防水卷材	3
			碎石、卵石混凝土 2300	60
			夯实粘土	600

附录A

详述

由于模拟已经在城市规模的基础上被开发，推荐使用通过设置对不同类型的建筑物进行分析的模型标准以简化模拟条件。在这种情况下已经使用了以下分类：住宅、商业和工业。

我们的标准模型的模拟条件是根据国家和地方的设计标准制定的，并基于巴南低碳产业园项目的基础文件，以及客户提供的相关的项目例子。下面列出主要参考文献。

法规和标准

- 民用建筑热能设计规范GB50176-1993
- 夏热和冬冷地区住宅楼的能源效益设计标准JGJ 134-2001
- 重庆地区65%的住宅建筑节能设计标准
- 重庆地区50%的公共建筑节能设计标准
- 重庆地区的65%的公共建筑的能源效益（待审）
- 中国西南地区的建筑物标准图（西南04j合订本）
- 工业企业设计的卫生标准GBZ1-2002
- 新开发的两江地区的工业工厂映像的规划和设计指南
- 建筑和主要项目一钢铁工业工程设计的技术法规
- 宝钢股份制建设项目的工厂设计技术法规
- 重庆城市规划管理技术法规。
- 代号为GB50352-2005的民用建筑设计
- 城市居住区规划设计守则GB50180-93（2002年版）
- 工业企业的总体规划设计守则GB50187-93
- 办公楼设计规范JGJ67-2006，J556-2006

关于巴南低碳产业园项目的原始资料：

- 2010年5月界石集团在华西工业区关于重庆市巴南区低碳工业园区的可行性研究报告。
- 界石集团1.7版的工业区报
- 重庆巴南区经济园区的位置图
- 重庆巴南区华西工业园区界石集团低碳工业园区平面图

其他

- 天气数据：参考数据来自中国国家气象局和清华大学的联合测量，以及来自中冶赛迪工程技术股份有限公司研究发展中心地源热泵的实际测量 。
- 住宅和商业建筑的例子是由客户提供的实际项目。
- 期刊论文：王刚杰（1995年），工业建筑设计的能源效率技术问题，工业建筑，第25卷第11期，页10-13。

补充

这里有一些使用工具来执行模拟的提示,在运行模型前检查这些问题。

建立模型的规则:

- 尽可能的简化建筑物或复杂性，没有曲线更好;
- 删除对建筑物没有影响的层，确保建筑物之间没有连接线;
- 从Google Earth导入的地形，如果考虑到其阴影对所有建筑物的影响（所有的建筑物都应坐落在地形上），不应该取消组合;
- 删除所有不必要的线、面和体块;
- 确保所有的空间都已关闭（无漏掉的面）。

- 如果模型中有曲线，当面临与总面积相关问题时不使用“最后翻转”命令（一些建筑表面没有显示彩色），但手动可以解决这些问题，如关闭绘图面或线条的空间等。

隐含能耗结果

如先前提到的软件工具中显示的一样，重庆的这一案例中所使用的材料的总体隐含能耗如下表3.2.1所示：

表 2.16整个基地所用材料的隐含能耗总量

	Total Embodied Energy Standard construction	Total Embodied Energy Improved construction
	kWh/m2/a	kWh/m2/a
Residential	323	323
Commercial	271	271
Industrial	394	394

表 2.16
整个基地所用材料的隐含能耗总量（注：请从导则一中找隐含能耗数据表）

未来的研究工作

在卡迪夫威尔士建筑学院，我们不断在建筑物的高效设计领域进行大量研究，一直在寻找在建筑行业内减少碳排放量的方法，这保证了我们设计的高标准。城市规模的能源消耗是与问题直接挂钩的区域，并且新的计算机模拟工具可以显著提高项目概念设计的质量。

在这一案例研究中，在软件使用的下一阶段，我们努力在更加交互式可视化的状态下回到Sketch Up界面下链接这些结果。我们目前正在分析和讨论各种方案，图2.28是其中一个我们正在进行的方案的一个可视化选项，为了展示从热和能耗分析中得到的数据。

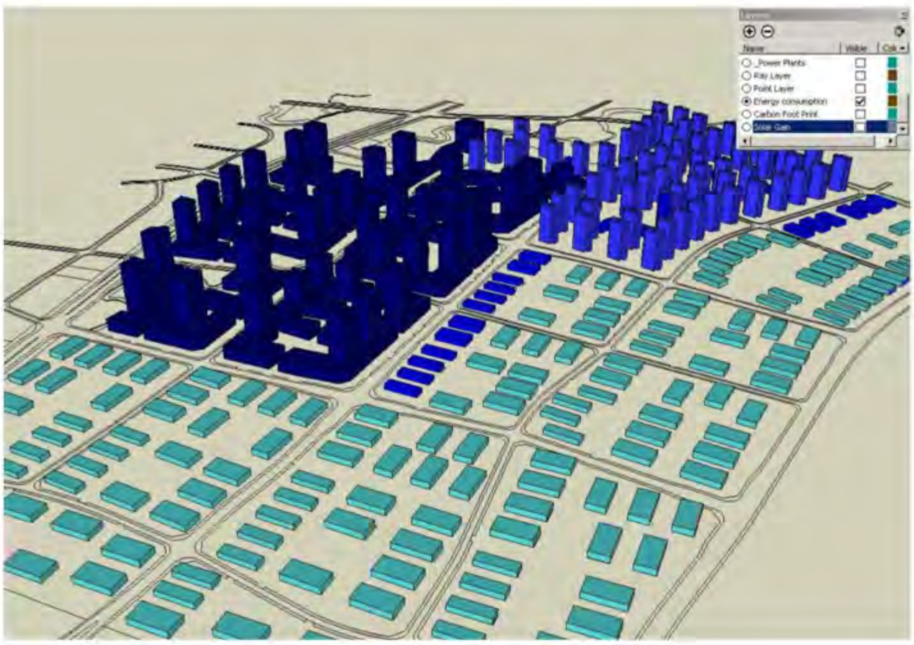


图 2.28
可视化模拟结果图

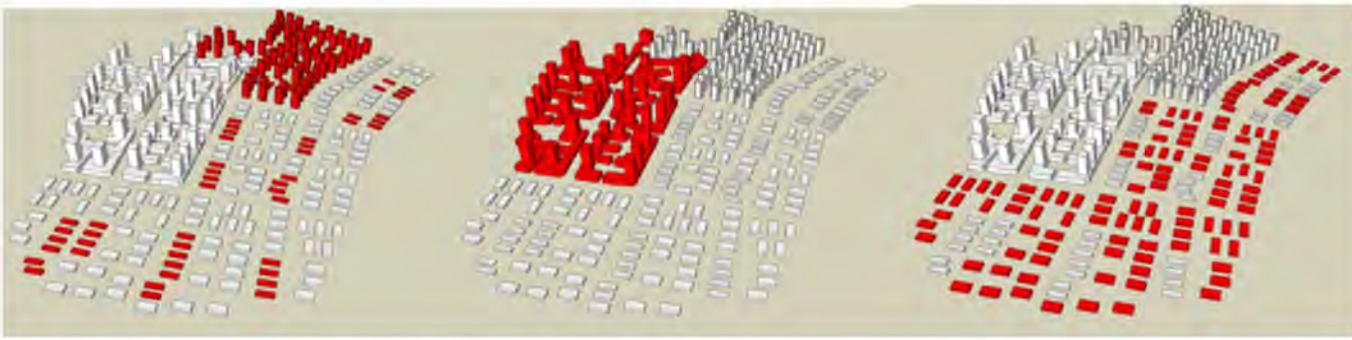


图2.27 这些图像显示不同类型建筑物的分布的三种选择：住宅(左)、商业(中)、工业(右)

继先前的分析和反复多次的模拟来观察对最终结果所产生的影响。如增加通风量或改变各种U值对结果的影响等问题。

下表显示了模型的结果，这次的模拟显示了改善建筑材质性能的影响。可以明确指出的是，与以前的数据相比较，整体供暖需求显著增加，并且如预期的一样制冷需求减少。

表格2.14和2.15详细的运行能耗结果：

全球 -

	Heating	Cooling
	kWh/a	kWh/a
Residential	16,942,217	38,946,987
Commercial	58,447,776	295,778,847
Industrial	15,384,864	15,848,997
Total	90,774,857	350,574,831

表 2.14
详细的运行能耗结果-全球

每平方米 -

	Heating	Cooling	Total
	kWh/m2/a	kWh/m2/a	kWh/m2/a
Residential	13.04	29.98	43.03
Commercial	9.44	47.77	57.21
Industrial	23.16	23.86	47.02

表 2.15
详细的运行能耗结果-每平方米

整体基地

先前概述的基地的计算机模拟造成了显著的数值结果量。本节将概述相关运行能耗和隐含能耗的最终数据。

下表是对基地的总运行能耗的补充数据。结果是通过已开发的工具（在SketchUp和HTB2中）的分析方法所提供的数据获得的。请注意，用于模拟的规范可以在本报告最后部分找到。

表 2.11基地运行能耗的全球数据：

表 2.11
基地运行能耗的全球数据

	Heating		Cooling	
Operational Energy	116,825,891	kWh/a	331,899,401	kWh/a

表 2.12和表格2.13 详细的运行能耗结果：
全球 –

表 2.12
详细的运行能耗结果-全球

	Heating	Cooling
	kWh/a	kWh/a
Residential	29,150,767	39,313,244
Commercial	67,360,963	277,583,638
Industrial	20,314,161	15,002,519
Total	116,825,891	331,899,401

每平方米 –

表 2.13
详细的运行能耗结果-每平方米

	Heating	Cooling	Total
	kWh/m2/a	kWh/m2/a	kWh/m2/a
Residential	22.44	30.27	52.71
Commercial	10.88	44.83	55.71
Industrial	30.58	22.59	53.17

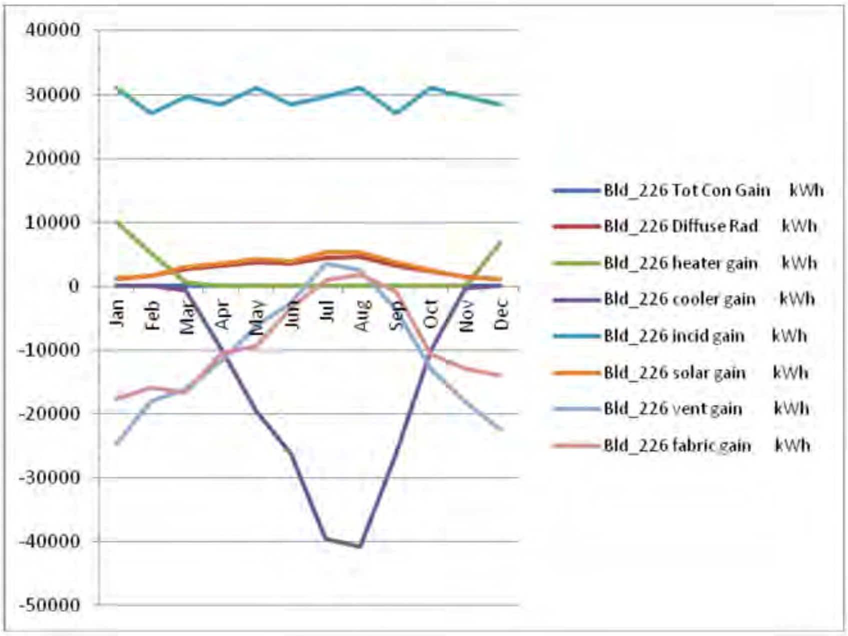
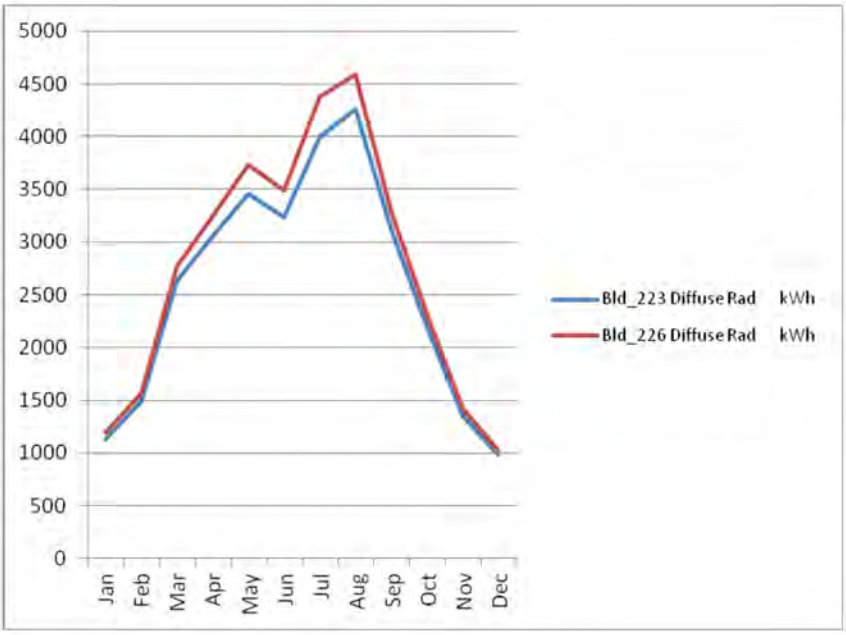


表2.8 和 2.9
每栋建筑所获得的值 223 和 226

通过观察发现，由于它们彼此接近，它们似乎表现出相同的方式，但是如果进行进一步的分析，我们会发现它们之间显著的温度差异 - 见表2.10和2.11



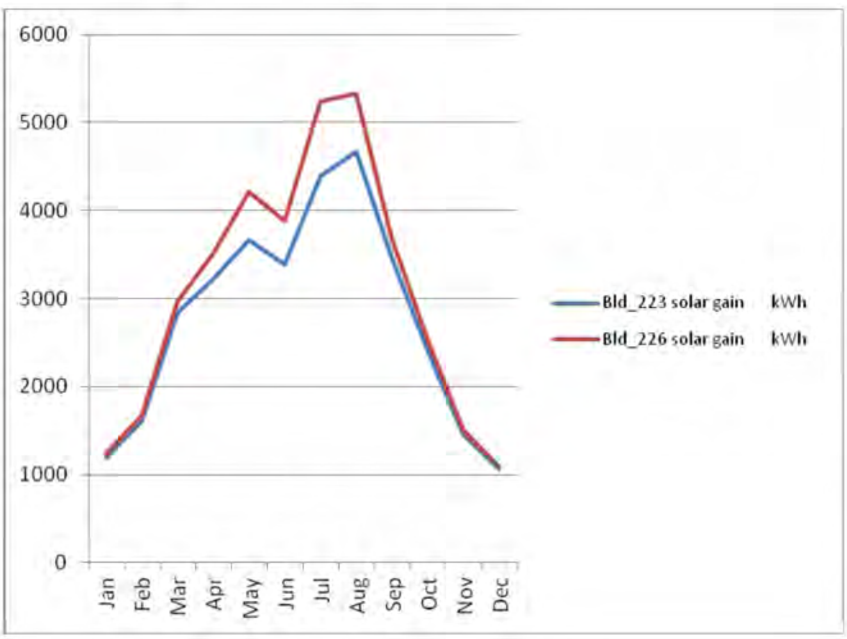


表2.10 和2.11
在这些表中可以很容易发现尽管它们很接近，226号建筑域223号建筑相比在夏天的几个月会有点过热，但是在寒冷的季节它们表现相当

这种比较是相当有用的，比如考虑到产业共生时，由于建筑在不同季节内需要换热时可以“配对”，这些案例中全年里的自然热属性可能是相反的

工业

最初，我们展示了两个彼此相邻的建筑物的结果，目的在于说明这个工具是怎样揭示不同建筑及其周围环境的位置的敏感性。通过从早期阶段开始的预测，不同性质的工业可以被更理智地分配，以最大限度地使用自然资源，并且根据它们在建筑环境中的需求将适当的活动分配到“合适的”建筑。

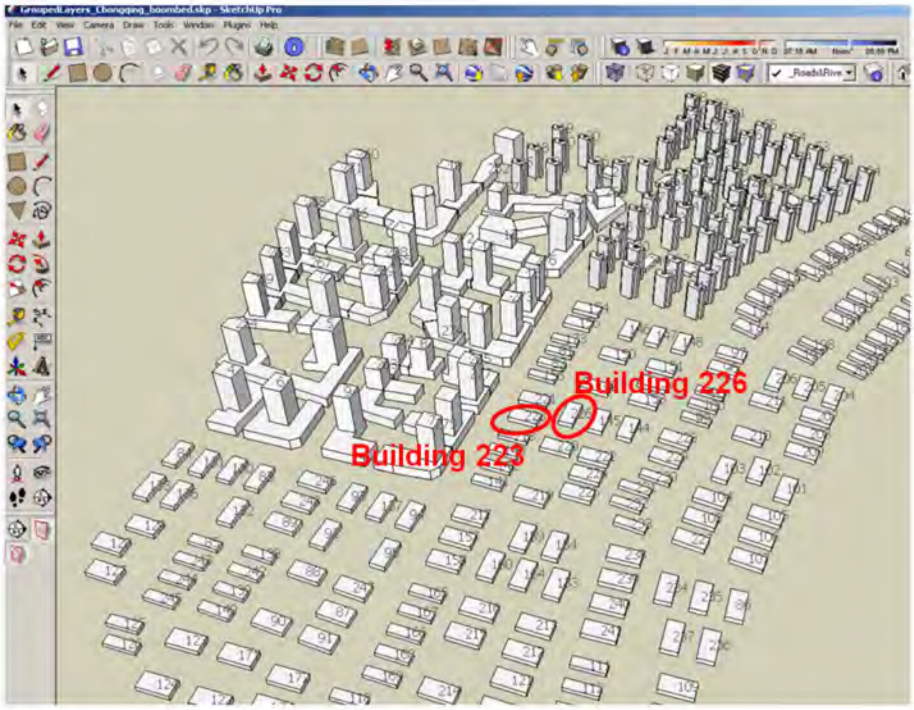
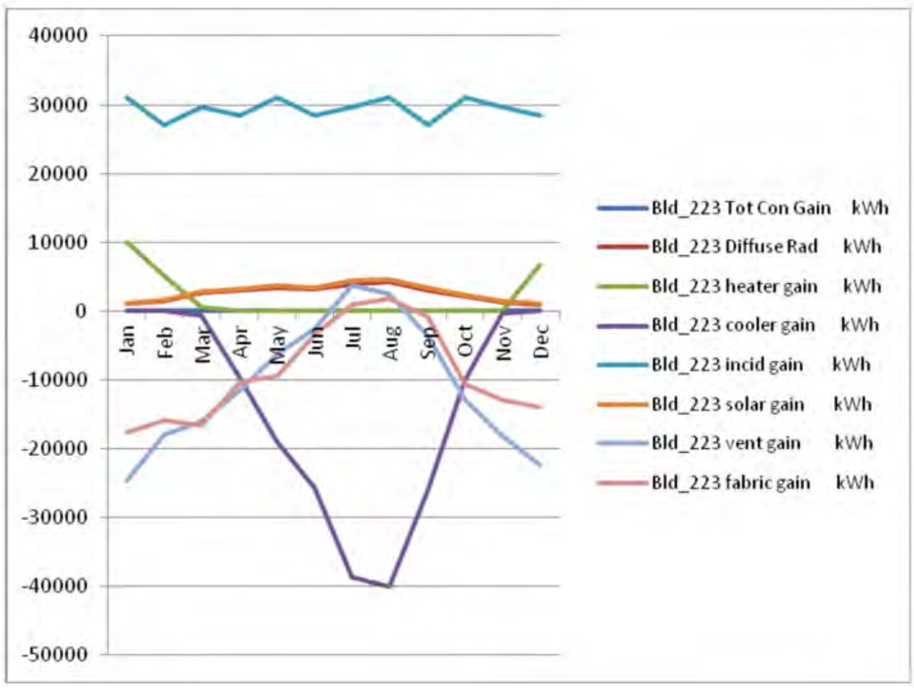
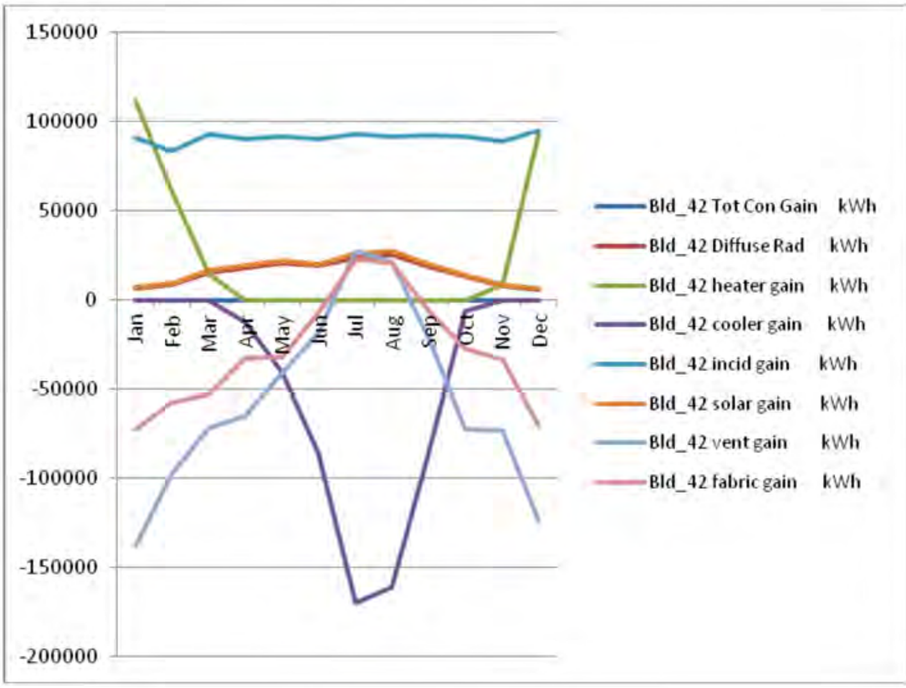


图2.26
选择工业建筑来比较它们的性能



比较两个不同的建筑物（图2.25中的42和65 ）由插件提供的所有可用的数据。这两个建筑物都受到不同的遮阳罩型材的影响。



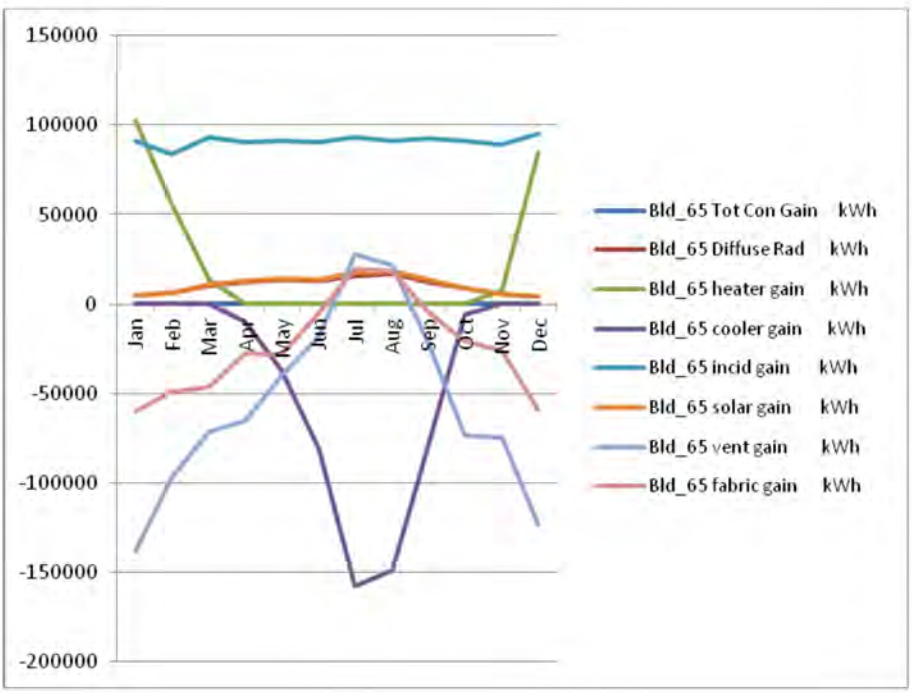


表 2.6 和 2.7
每栋建筑所获得的值 42 和 65. 它们有相同的模式，当然，由于基地季节的变化，如果详细看，会发现建筑物不同的位置得到的增益量是明显不同的。

结果

住宅

住宅建筑物分类 - 不同地点和不同高度的对比（高层和低层）

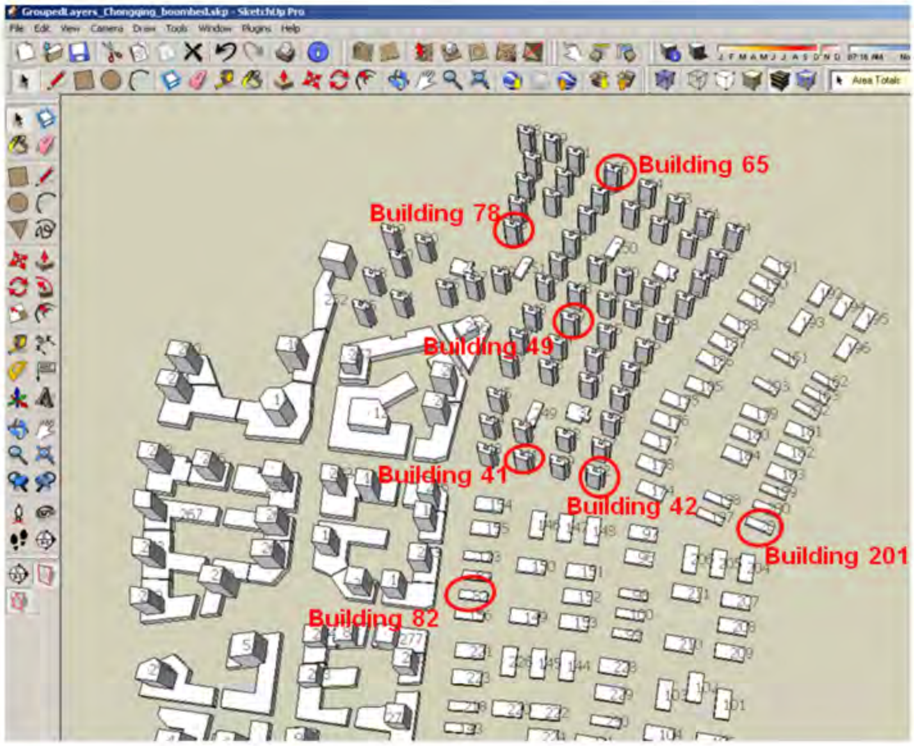


图 2.25
选定的建筑显示出了比较的结果

太阳能增益比较：

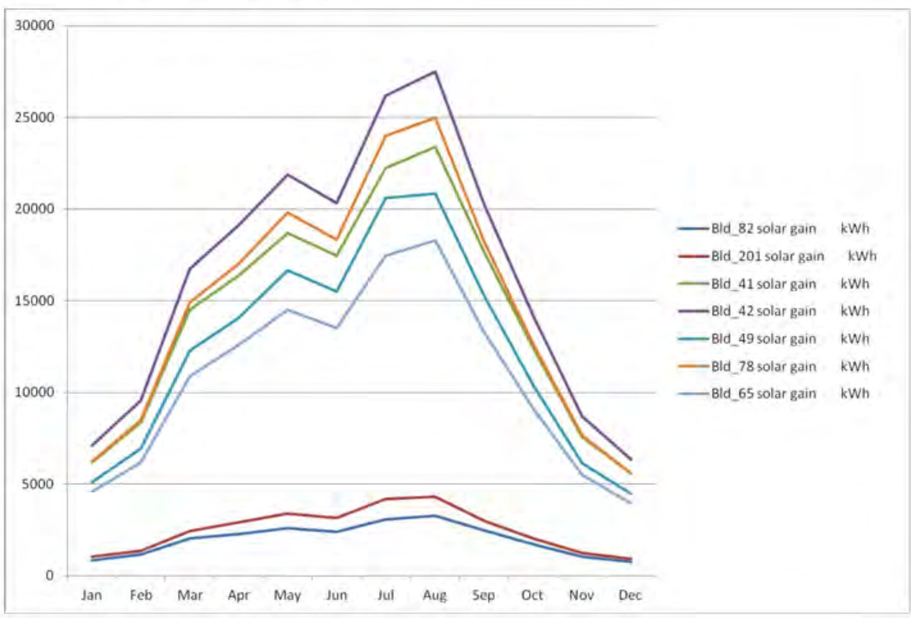


表 2.5
选择研究各种建筑的不同太阳能增益（标记在图2.25中）.
注：太阳能增益最大的差距是由建筑体积来决定的。较低的曲线是 位于基地工业部门的规模较小的住宅建筑，较高的曲线代表住宅区高层建筑的热增益

这是最后一步，在插件中的一个新的菜单选项里从Google Sketch-Up中调用HTB2：“运行HTB2”。

上述所有前面的步骤，为我们提供了关于Sketch-Up建模软件及成功地运行HTB2的足够的信息（图2.24）。

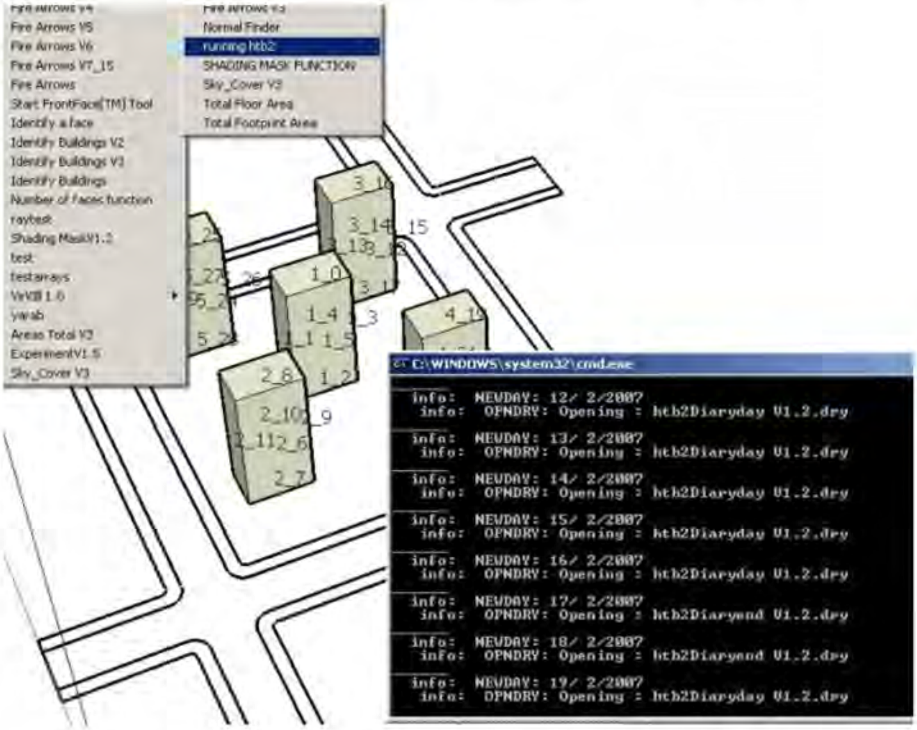


图 2.24
在Sketch-Up 环境下，该插件调用HTB2引擎进行计算。

结论

通过开发这个插件，我们正在实现初期的城市建模，以致有了极其宝贵的工具，这一工具用来在施工过程中的任何其他阶段前估计－尽可能地接近－整个基地的能耗及其运行能耗和促进总体设计效率的可能性。

HTB2计算生成了结果文件（与先前已经创建的所有信息保存在同一文件夹）和用来自动生成建筑物存在的不同问题的报告。

目前热计算所得到的值有：

- 太阳能增益
- 供暖增益
- 冷却增益
- 附带增益
- 通风增益
- 材质增益

我们可以从这些值中计算出的太阳能的潜能量来从建筑物表面获得太阳能（光伏发电潜力），以及建筑用来供暖和制冷的能耗量，以及其他重要的数据。

请注意，为了更快的得到结果，插件里的在模型里显示所有射线的功能已经升级了。我们现在使用的版本不直接显示这些射线以节约计算时间。但依然有可能通过调用插件菜单中的“天空视野”计算来显示射线。

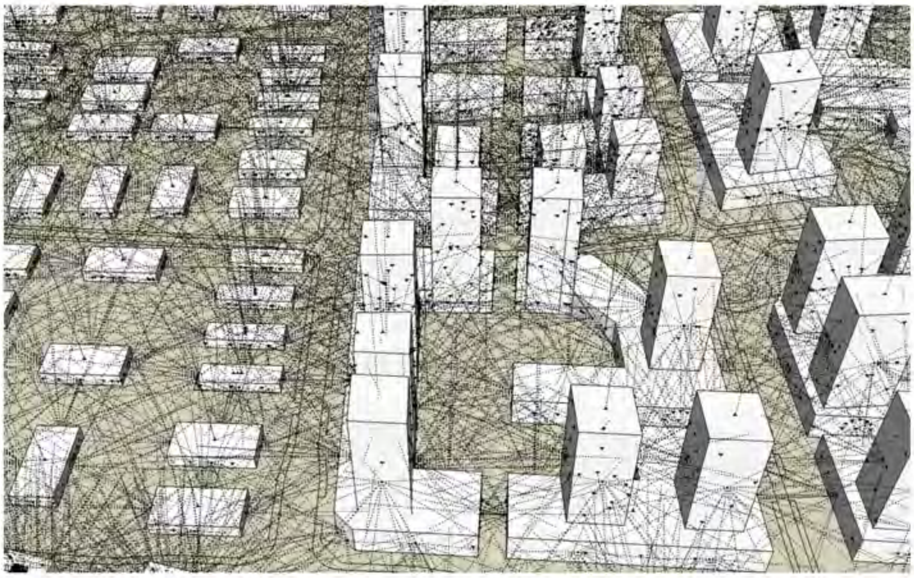


图 2.22
模型的特写显示出被分解的线并可以观察周围的面，观察建筑上的点，那里外墙上的射线相交形成了障碍物。

最后，所有包含要求链接3D模型与HTB2的信息的文件清单都创建在同一个文件夹里，与此同时，模型也保存在这里（图2.23）。

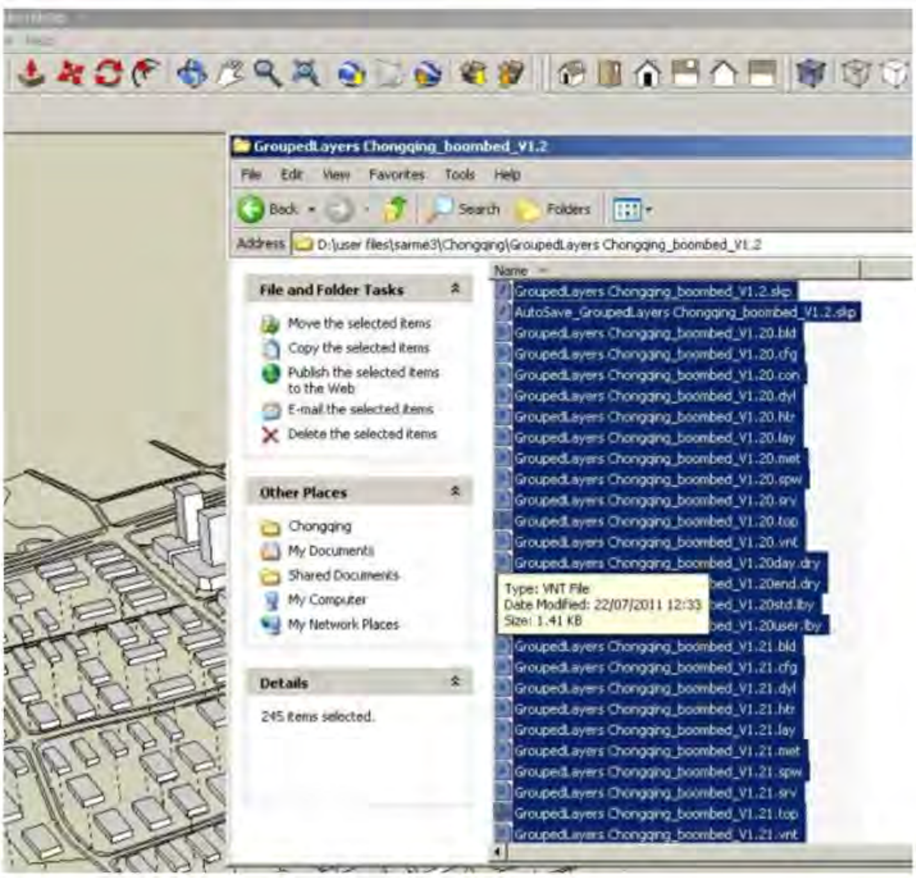


图 2.23
窗口显示了源于插件的文件，所有的数据已从模型中提取出来。气象数据、工程数据、占用模式等嵌入所开发的软件中。

创建HTB2文件

这一步是为导入HTB2的模型数据做准备，同时也为每个立面做了的遮阳罩。VirVil插件自动创建的文件需要与HTB2进行链接。这些文件是通过遮光罩分析和其他整体模型的属性而获得的信息来创建的。

插件用来为每个立面加遮阳罩的技术是为了从每栋建筑物的每个立面拍摄线，找出是哪一个障碍物阻挡了可以看到天空穹顶的视线。这个过程可以更准确地根据从每个面上被拍摄的每条线的分离角度来做。

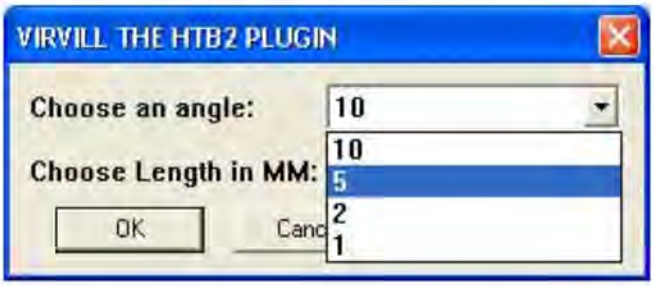


图 2.20
遮光罩选择的准确性

遮阳罩计算的准确性是由间隔度来决定的，间隔被设定为10°、5°、2°、1°（较低度数的分离意味着更多的从每个面上被拍摄的线，这意味着更高的精确度与更长的计算时间（图2.20）。这种准确程度的敏感性的研究为对于这一案例计划说明书来说建议箭头的5度分离已足够精确的结论提供了足够的信心。

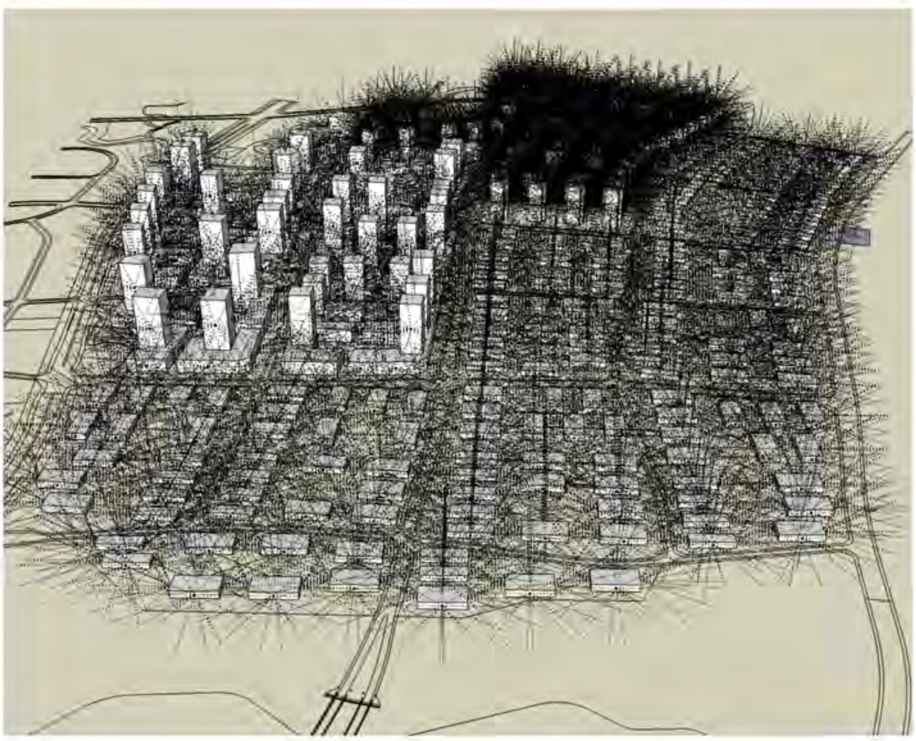


图 2.21
用插件开发出的城市外立面的阴影

右击菜单中选择建筑属性的选项，打开对话框（图2.18），显示出建筑的各个方面或选定的元素。这种建筑类型的分类将在入住模式的热建模过程中使用，以影响制冷和供暖计算，它默认的实例是住宅。

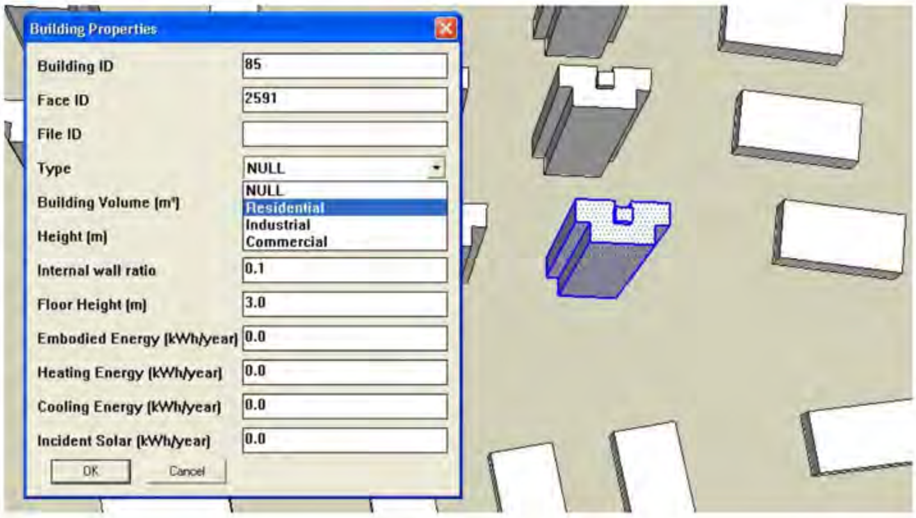


图 2.18
查看建筑物的属性，在这里它们是可以改变的。注意：如果没有指定的建筑类型，则默认为住宅

隐含能耗

在Sketch-Up中使用的VirVil插件可以计算出每栋建筑的隐含能耗。

目前，该插件提供了整个建筑的或任何选定面（外墙、屋顶或地面）的MJS隐含能耗数据。数据出现在建筑和面属性列表中（图2.19）

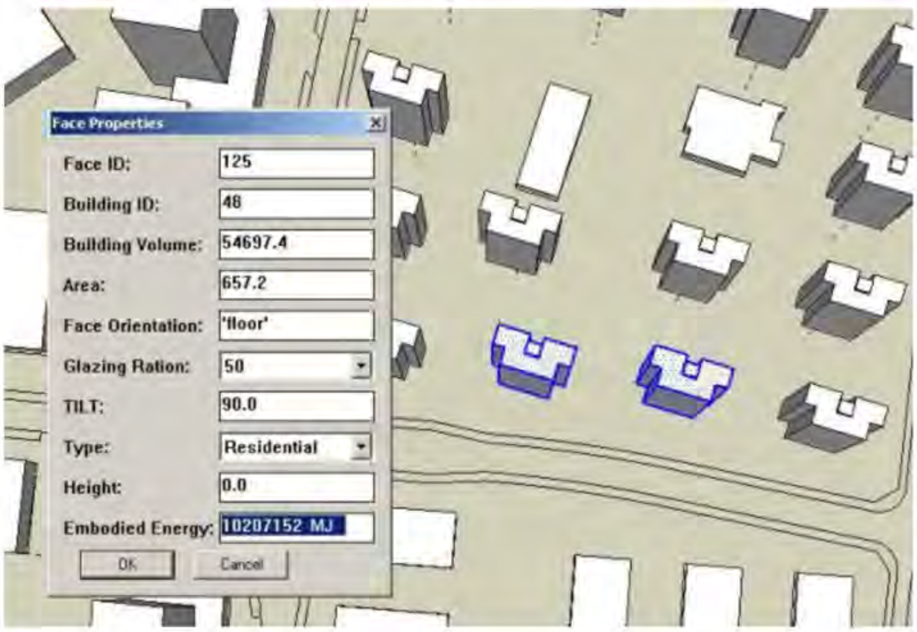


图 2.19
隐含能耗值（对于被选建筑的）在建筑属性菜单中显示

该工具通过使用嵌入式数据来计算整个模型的隐含能耗值。此数据是在对城市规模的隐含能耗经过广泛的研究和调查后搜集的。这个插件使用的计算原理可以在导则的第一部分“隐含能耗”部分找到。

归类建筑物

使用Sketch-Up中VirVil插件归类建筑物是关键的一步。模型的物理位置和时区会分配到每栋建筑， 为每栋建筑分配一个类型（例如住宅、工业、商业），并在每个建筑和表层做一个独特的标记以方便未来的分析和计算。

运行后，下面的消息在Ruby窗口上显示（在Sketch-Up环境中打开）， 用于热计算建模的数据有（图2.16）：时区、纬度、经度和建筑物的总量。

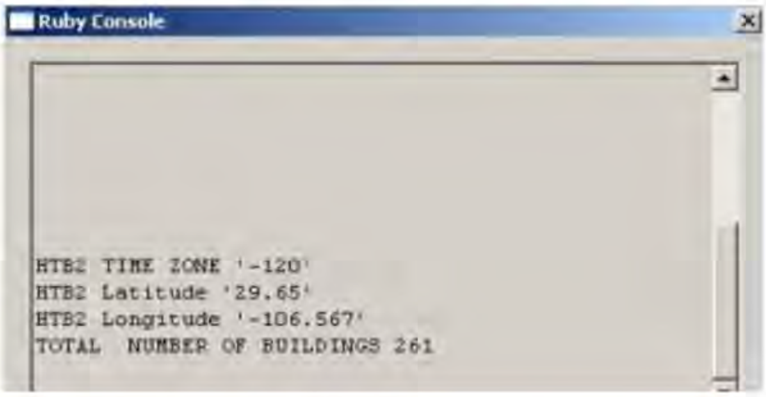


图 2.16
初始属性的模式，将用于使用HTB2进行的热计算

新的属性可以分配给模型的不同部分。通过在Sketch-Up中使用建筑属性菜单，建筑物属性列表可以被查看或修改。单个或多个建筑物的属性都可以改变（图片2.17）。

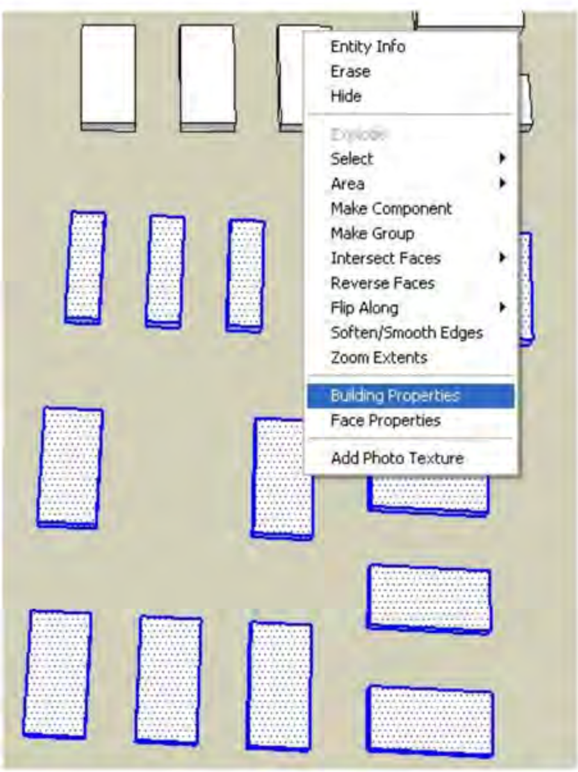


图 2.17
选择建筑指定不同的属性

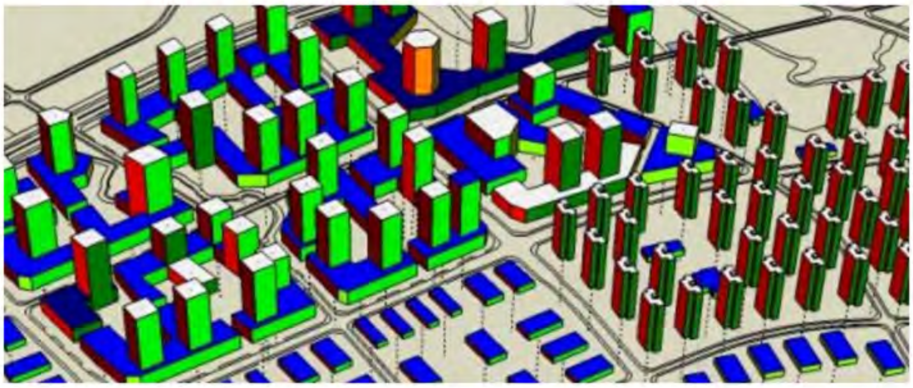


图 2.13
最后反转后的模型，一些表面还没有颜色

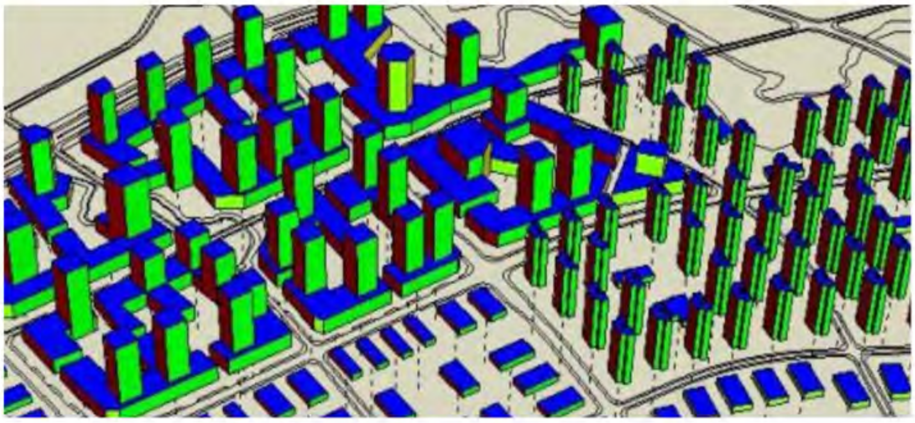


图 2.14
最后反转完成后所有的表面都着了色

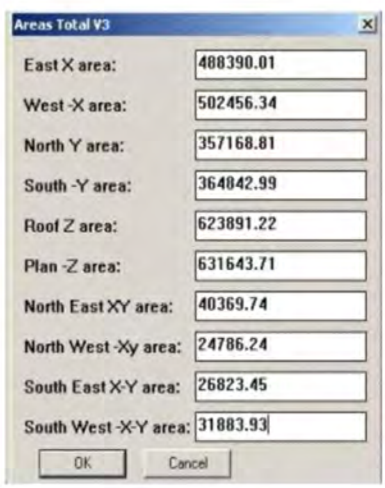


图 2.15
最后的总面积

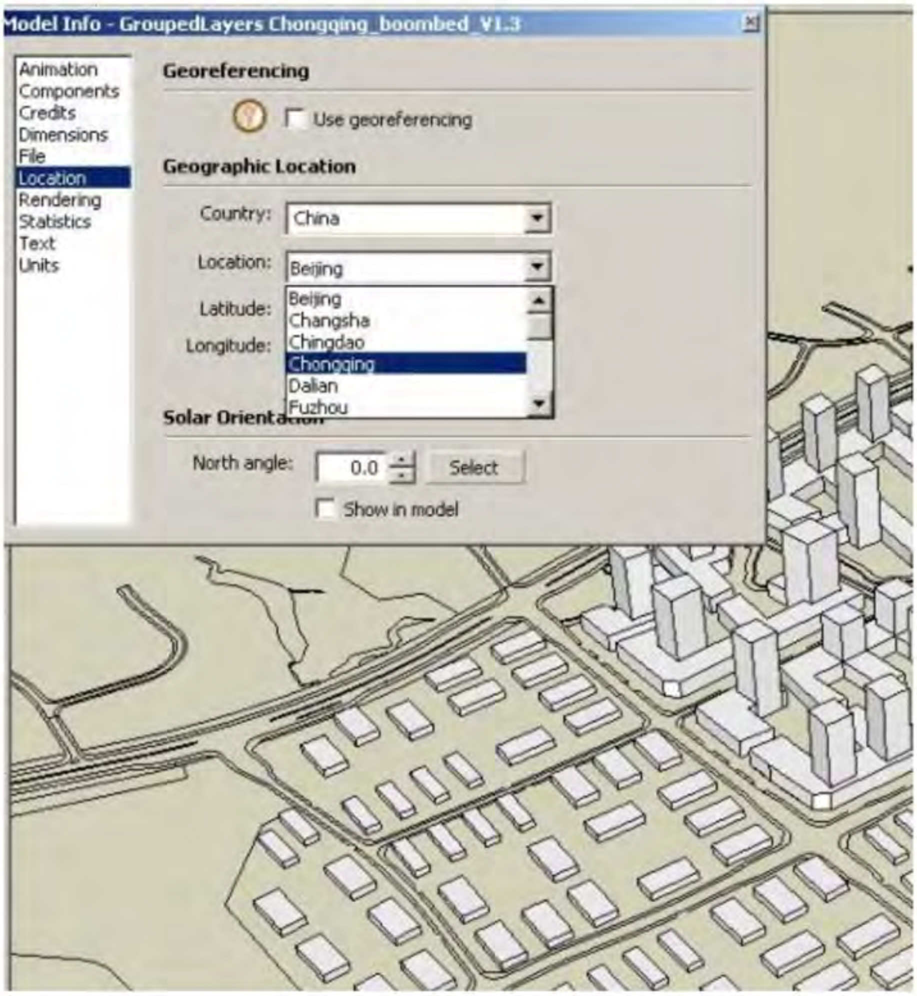


图 2.11
归于地理位置的基地

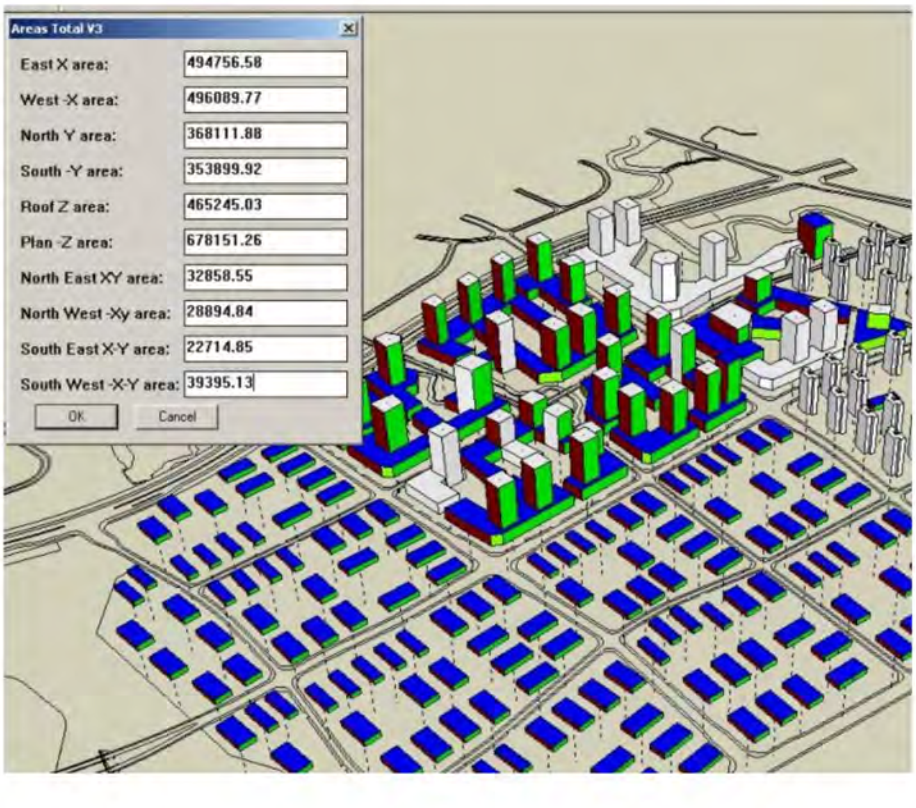


图 2.12
表面积插件的计算结果

图2.10
解散群组后的可视化基地

基地定位

确保模型是最简化的形式后，应给基地定一个地理位置。Google Sketch-Up中包含了与几乎可以搜索地球上任何位置的Google Earth进行的链接（图2.11）。

面积测算和常规的表面核查

该插件进行表面积和朝向的测算。一旦基地位置被指定并且所有用HTB2建立的热建模结构已经“取消组合”（未创建组），用户就可以在插件中调用“总面积”计算，它会计算给定方向下所有建筑的表面积。所有相同方向的建筑表面会根据不同的朝向自动着色。

这种测算方法可证实所有表面的法线“面向外”，这是在下一步进程中创造遮阳罩的基本的质量保证。如果在运行总面积计算后建筑表面是无色的，就可以使用插件中被称为最后反转的工具，并且再最后运行一次总面积计算以确保所有的外墙被着色并且表面法线朝外（如图2.12－2.15所示）。

我们标准模型的模拟条件是根据国家和地方的设计标准设定的，并基于巴南低碳产业园项目的文件以及客户提供的相关项目案例。主要的参考资料已在附录A中列出。

附录B详细介绍了标准模型的模拟条件，其中显示了施工和材料的详细情况及室内设计条件和该基地的总面积。

软件工具和流程概述

以下是Sketch-Up 中VirVil插件的功能概述：

导入建筑物

为了使用该工具，用户首先要对Sketch－up 有一个基本的了解。通常情况下，项目建筑师或基地设计师应该能够提供一个基地的Sketch-up模型。

一旦模型在Sketch－up中开放，模型中任何没有进行热建模的部分必须保持为组件或块的一部分，这是非常重要的。取消块（或“取消组合”）的几何形状可以在HTB2中建模。

图2.9-10所示是调用插件前几何结构和组件的去除 。

图2.9
解散群组前的可视化基地

案例建构过程

建立研究案例

假设该基地的布局和建筑物遵循了本项目第一部分（巴南导则）的标准和参数。

如前所述，新开发的软件工具侧重于城市设计的早期阶段。用于计算所选的接口和引擎（Google Sketch-Up和HTB2）是在对这一地区进行深入研究后被选中的。人们发现，Google Sketch-Up主要作为一个前期的“草图”工具被建筑师和设计师普遍使用。然而这个软件有着进一步的设计能力而不仅仅是对建筑物粗糙的初期设计。从已知的背景研究中发现该软件已经在设计过程中发挥了相当大的作用，超过50%的建筑师在项目的一些点上会使用到它，[参考：阿提亚，S.，2009，“建筑师之友：关于十个不同建筑性能模拟工具的比较”，第十一届国际IBPSA会议]。因此，由于这个平台的使用，建议的计算方法可以很容易地应用于任何项目。

此外，HTB2已被广泛应用于世界各地，以获得可靠的建筑的热行为的具体数据。将这些软件工具放在一起使用是一次先锋的尝试，大量的研究和改进使的这一切成为可能，并比较最终的计算结果与以前研究的基准以确定结果的可靠性。

Google Sketch-Up包括一个嵌入式应用程序编程语言Ruby，这使得我们能够在Sketch-Up内创建并使用自定义插件。我们最近开发的插件允许计算任何的Sketch-Up模型，其中包括：

- 运行能耗
- 隐含能耗总量
- 潜在的可再生能源
- 遮光罩
- 表面积
- 结构容量

详细分析

当建筑模拟运行时，分析个别建筑物或整个城市基地时应该用不同的分析方法。在这种情况下，通过设置不同类型建筑的模型标准，城市规模范围使得分析对模拟条件进行简化（已被推荐）。在这种情况下，以下的分类已被使用：住宅区、商业区和工业区。

基地的地形背景

图 2.6　　重庆低碳工业园

基地风分析和案例研究布局

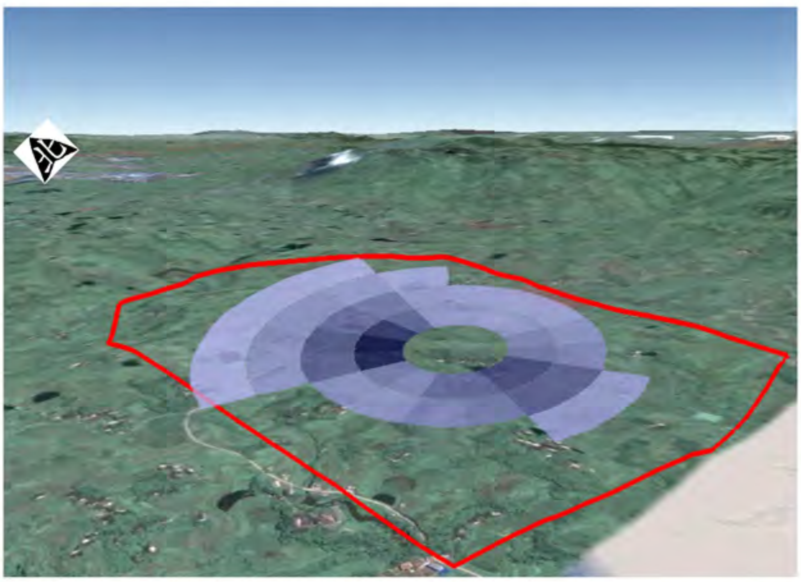


图 2.7　　基地在重庆场所内的边界

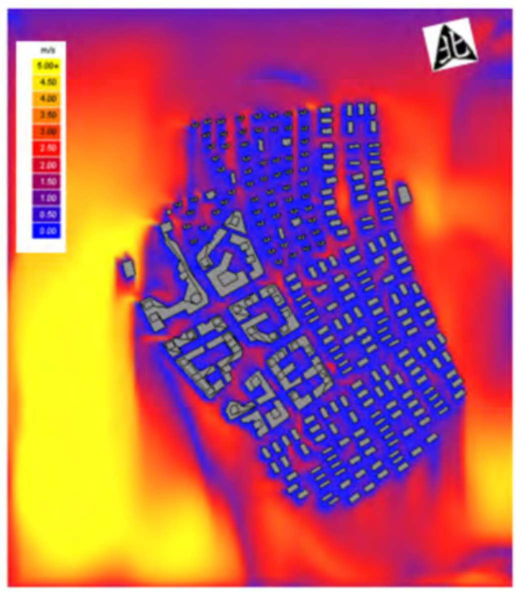


图 2.8　　建议项目的CFD分析.

基地和分区的规范

这个项目的客户提出了使建筑物可以相对混合的使用的要求，尽管如此，该项目的最终设计并没有完成（建筑物和其使用的具体数量），因此为了达到这一示范项目的目的，我们选择了一个具有混合功能的建筑物，以考虑处理不同性质的建筑物时各种可能出现的各种问题 。

这一研究案例的分区使用是基于以下常见的一般区域（图2.5）：

- 工业区
- 住宅区
- 商业区

2

该基地的总面积约2.8平方公里。这一综合体一直位于客户给的地理参考中（图2.6），使我们能在基地上展示一部分天气分析（图2.7和2.8）。

图 2.5
基地布局和分区的案例研究

关键：工业区
住宅区
商业区

重庆的气候条件

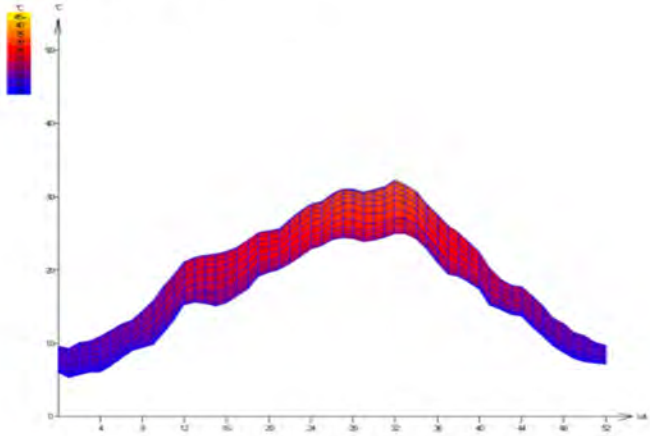


表 2.1　温度 (℃)

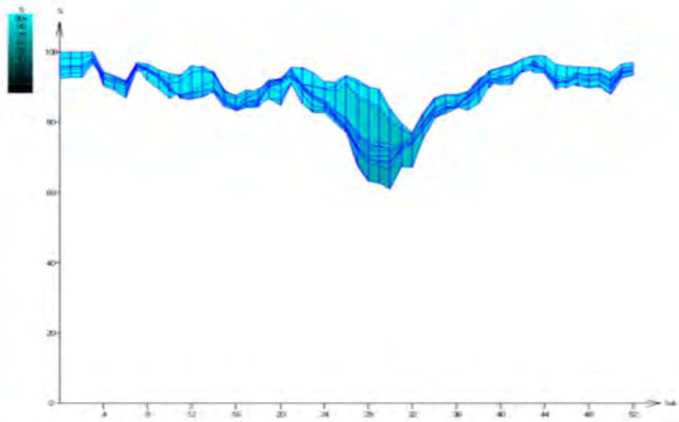


表 2.2　云层

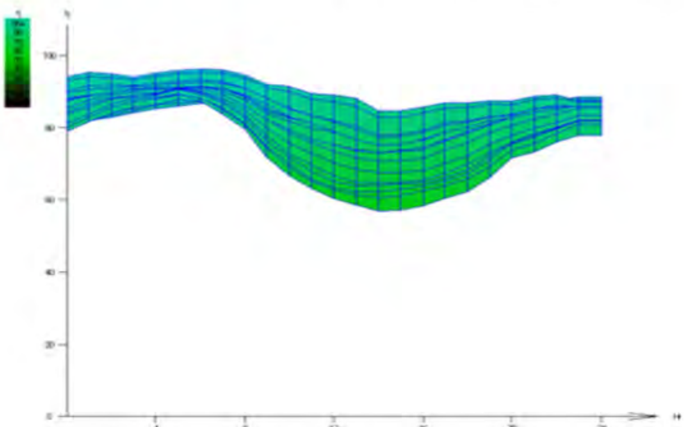


表2.3　相对湿度(%)

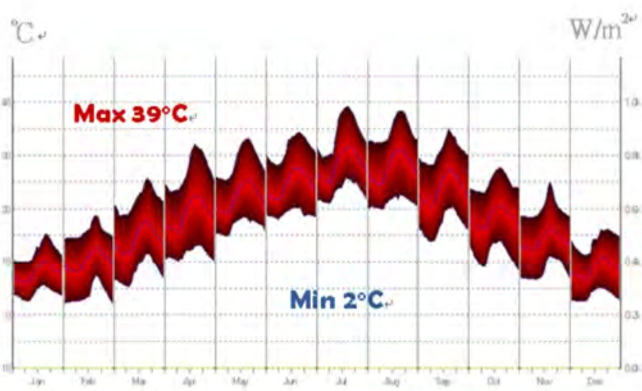


表 2.4
重庆详细的温度数据

基地特点：气候、位置和布局

为了整体的设计一个基地，在设计进程的第一阶段应考虑基地的地理位置、地形和气候特点，以建立要求的与给定条件下的整体建设相协调所需的的设计特征。

在重庆低碳工业园建设的第一阶段（概念阶段），该地区的信息已经收集（图2.4，表2.1-2.4）。现在的案例研究在建模时就考虑到了这种气候变化。

影响这个基地（位于巴南区）的主要特点是极端的温度、高云盖和相对湿度。这些问题的复杂影响可以通过分析提出的灵敏度设计来缓解，所以简单的建筑立面或玻璃比例的变化的重新定位有利于设计，因此早期计算机建模的重要性是作为一个重要工具去减少二氧化碳排放量 。

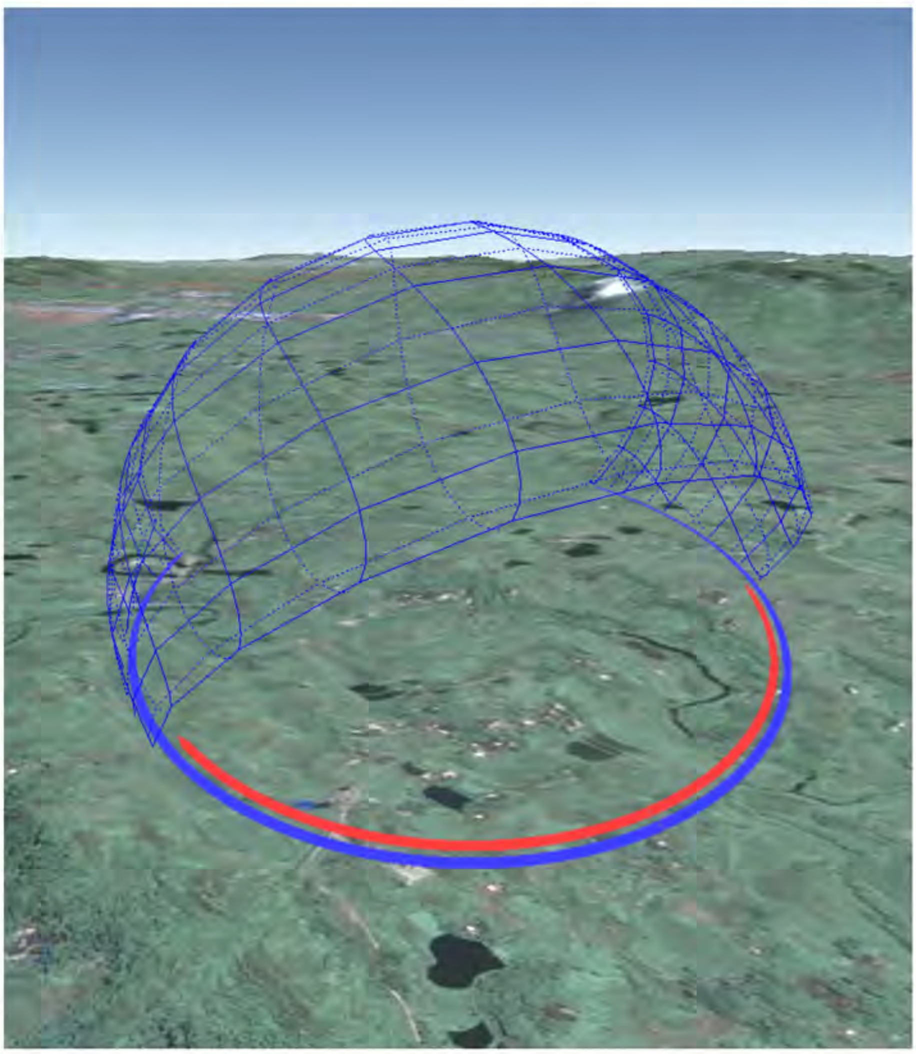


图 2.4
重庆的日照路径图

到入住时间表以帮助计算内部的增益。这些数字与结构材质的施工库相结合，可以使 HTB2 很容易计算出供暖、制冷和小功率的需求率。

这样的分析通过各种不同的HTB2文件（建筑类型、入住时间、通风率）运行多次，能计算出城市区域的最终能源需求。在这一点上，能源供应可以在之后讨论。热力和电力基础设施的可达性可以用“Google Earth”来进行定位。比较不同系统的性能，并最终在需求的基础上计算出能源供应率。

隐含能耗

隐含能耗是低碳总体规划可轻松地用工具计算的另一个方面。通过附加建筑材料和他们在有Ruby脚本的模型里接受隐含能耗的指数,一个城市规模的隐含能耗可以通过元素、幕墙、建筑、街区、或整个模型很容易计算出来。通过改变模型内的建设文件，隐含能耗值可以与相同体积的模型进行比较。从2D模型所得到的人行道和机动车道路的区域，可以用来计算城市区域和整个基础设施的隐含能耗率。

可再生能源

最后，城市规模的可再生能源供应可以用工具进行分析。可以直接分析地形使地源热泵/热交换器适当使用。指定位置或在为了社区合作供热厂或加热和发电厂的模型内进行讨论。最重要的是，使用 Ruby开发的太阳能分析插件所产生的数据，太阳能的获得和潜在的太阳能热水（SHW）和光伏（PV）面板的输出可以为每个幕墙和建筑服务，可以为了城市规模的能源供应而计算可再生太阳能解决方案的贡献。

未来的研究

基础设施和运输方面的低碳总体规划是未来研究的目标，这些主旨下的输出是可以被未来的工具预计的。现存的基准可暂用于城市规模的计算方法。

灵活性

Sketch-Up有自己的编程语言 - Ruby,它允许用户创建自定义插件以实现特殊的效果。几乎任何任务分析都可以使用这一程序，并且它可以与HTB2进行无缝链接。

Sketch-Up及它的脚本语言Ruby与HTB2的结合，在城市规模的基础上创建了一个功能强大的能源分析工具。一旦勾勒出城市区域的模型，HTB2就可以导入Sketch-Up中，创造HTB2热分析所需的所有文件。反之，这些文件可以被使用并创造相对较快的比较输出（玻璃比率，墙体结构，入住类型等），此外，这个工具是直接适用于导则里的低碳总体规划建议的，解释如下：

图2.3 显示了在先前发行的巴南导则中建立的巴南低碳总体规划过程。以下是一个关于这个案例研究是怎样根据导则中的准则进行的简介。

图 2.3
巴南导则的低碳总体规划意见

基地分析

Google Sketch-Up可以与Google Earth配合工作。两者之间的沟通允许用户进行详细的现场分析，以评估基地的位置、地形、面积，并了解那些通过目测可能对小气候发挥作用的因素。物理特性可以在Google Earth上立即看到，并且客户或能源分析师可以直接考虑这一特性。社会特性通常可以用Google Maps来突出或使用Google的搜索引擎进行查询。此外，该基地的地形可直接导入到Sketch-Up里对结构布局、位置及太阳能分析等方面进行辅助。气象数据可从美国能源部的网站上直接获得，并且创建了转换工具把这些文件输入到HTB2中进行热研究。

运行能耗

运行能耗，从供应和需求之间划分出来，在该工具内进行分开处理。 城市区域范围内的运行能源需求可以直接使用低碳基准进行计算。一旦在Sketch-Up里建模了，Ruby脚本使它们全都快速归到工业类、商业类、住宅类、教育类等。这些类别的基准（通常按每平方米计算得出）有：用水量、照明需求、通风率、小功耗等。大概的人口数量（通过基准或者直接从客户那里得到）也可以归入

软件和低碳总体规划简介

这一案例中所使用的分析方法是一种新的软件模拟/建模方法，这种方法目前还在开发改进。适用于这个项目的参数基于已经提供的“巴南指导意见”，其中给出的基准可以为城市模型性能提供指标。

现有的建模软件在单一的结构下工作良好，以往的经验表明，快速高效地将基准应用到一个城市区域是很困难的。一般来说，建模受电子表格和地理信息系统软件的限制，或局限于将一个单一的建筑模型（在Transys，HTB2，ECOTECT里，或Energy Plus里，仅举几例）多次复制来模拟城市区域。我们一直使用的方法是将Google Sketch-Up和HTB2进行链接：前者是一个简单的，功能强大的初期分析工具，后者是一个功能强大但是相对复杂的针对结构和体积的能源建模工具。

使用Google Sketch-Up，具有以下三样工具优势：

简便性

Sketch-Up是一个体积建模工具，通过挤压，允许用户在一个2-D的平面上快速便捷的创建一个简单的、预备建筑外墙热建模的模型。Sketch-Up可以自动排除冗繁多余的能源模型，当与HTB2进行匹配时，要求模拟一个简单的体积的全部外壳，这可以通过使用Sketch-Up从平面上的推拉工具来办到。 Ecotect、Design Builder、IES，和其他能源模拟程序既需要许可证和也需要在每个程序中建模的工作知识，并需要（在一定程度上）复杂的模型而不仅仅是一个外壳来获得更合适的结果 。Sketch-Up是直观的、简单的，并且可以免费使用。

图 2.2　城市设计方法意见

可达性

Sketch-Up目前被一半以上的建筑事务所使用。它是一个免费的程序，全球范围内可供下载，并被专业人员广泛应用于项目的早期阶段以查看完成后的结构看起来是什么样的。

重庆低碳工业园

案例研究架构

- 软件和低碳总体规划简介
- 路线图和基本分区 – 基地、定位、设计
- 案例研究的施工、分析和工具的详细描述
- 结果
- 附件

图 2.1　重庆低碳工业园

第二部分
低碳工业园项目
重庆巴南地区

1. Survey The development zone should be surveyed at the start of the planning/design process	• Topographical survey. • Identify all private and public stakeholders involved. • Identification and recording of existing functions and communities • Identification and recording of existing buildings, green/blue structures and heritage cultural value • Identification and recording of existing road and other transport systems • Climate analysis of site, including annual variation of temperatures, wind velocity, relative humidity, solar radiation and rainfall – now and in future. • Identification of existing infra-structures for energy supply, water/sewage and waste. • Develop brief for mix of buildings and infra-structures. • Meeting to consider issues and prepare for concept planning/design stage.
2. Concept Planning/Design The concept planning/design stage should identify sustainability objectives and how they can be evaluated	• Zoning for use, including density and number of units against each use type. • Seek views of stakeholders. • Retention of existing communities and built environments. • Assess opportunities for communities, jobs, etc. • Location of public transport systems and links with existing systems, and locating major transport hubs. • Car use and roads. • New infra-structures for energy supply, water/sewage and waste. • Set targets for energy use, material use, water use, recycling of material waste, etc. • Set targets for the type and use of renewable and 'low carbon' energy systems. • Set targets for transport use and modal mix between public, private, cycle and pedestrian flows. • Meeting to consider concept design and prepare for detailed planning/design stage.
3. Detailed Planning/Design The detailed planning/design stage should include:	• Building layouts, density, and orientation and view, to take account of solar gains in winter, solar overheating in summer, access to daylight and use of renewable energy systems, noise and pollution from traffic flow. • Integration of new build with existing structures. • Location and concepts for green/blue structures, public spaces and water side developments. • Road and rail transport layouts and pedestrian and cycle routes. • Infra-structure location and layout, including any district/heating/cooling, water sewage treatment, waste treatment. • Evaluate (life-cycle approach where possible) against targets for energy use, renewable/low carbon systems, material use and waste management, water/sewage systems, transport systems. • Provide three-dimensional design options for major areas of site. • Meeting to review detailed stage.

表1.23　步骤

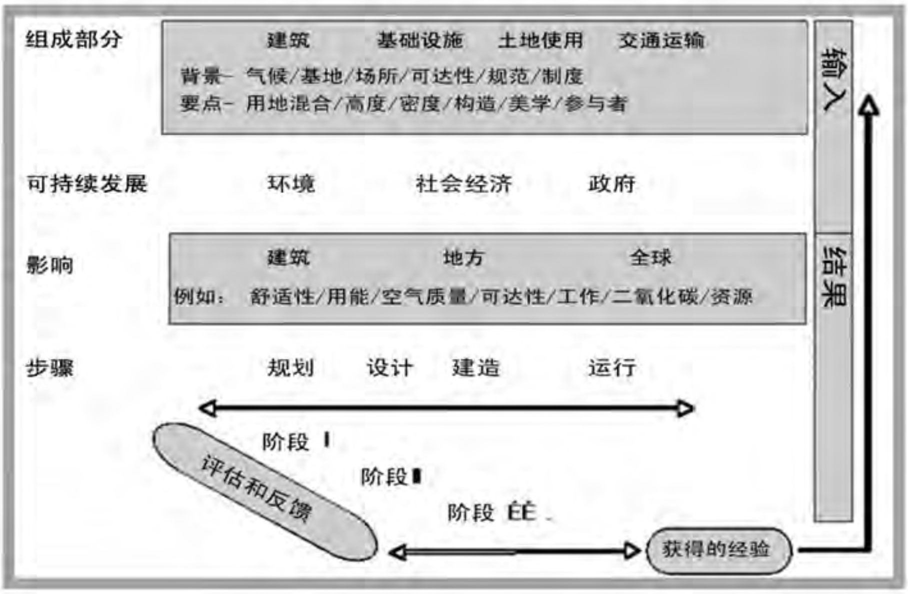


图. 1.17
可持续总体规划的评估框架

城市规模的检查清单法一般是由建筑尺度的评估工具发展而来的，如BREEAM社区版[9]和LEED邻里版[10]。他们为可持续总体规划提供了一个很有价值的方法。然而，他们往往只处理输入，而非产出。建立在网络基础上的方法如PETUS [11]，提供了参考资料来源，一份基于可持续环境影响评估的检查清单，以及确定适合的评估工具。

我们所需要的评估框架，不仅仅可以确定总体规划的各个部分，而且清楚的将这些输入和与影响相关的结果分隔开来。下面的流程图建议了如何根据特定目标建立实施步骤，确定基准条件，制定目标以及实施导则，确保其与评估相符，同时学以致用，适当根据时间协调进度和目标。

开始阶段需要提供两类信息。第一类是背景信息，包括气候、基地、场所、可达性、规范和制度的详细信息。这些是关于场地的物理特性和其它方面。第二类是项目概况，包括建筑类型混合，他们的密度，高度，当地构造标准，参与者，等等。它也包括基础设施部分，如供能、供水、排水、废物、景观和地貌，以及道路和交通。总体规划的最初阶段应收集尽可能多的这些信息。

步骤&评估

步骤

所有的步骤都很重要！根据需要进行改变，做什么和怎样做，这很难一蹴而就，必须通过一系列可控制的变化，从每一个阶段获得经验，同时反馈到过程中去。对于大范围的可持续总体规划而言，在第一阶段可能不是很费力，轻松的制定切实可行的目标，同时更多的专注于怎样将可持续发展整合到过程中来。这将确保，建成环境将不仅是物质上更加可持续的，而且也将获得社会认同，同时经济上也是可接受的。总之，最终目标应该是通过最高效和有效的利用资源，提供一个更健康，更干净，更多产的建成环境。

所以，第一阶段应该是在规划和设计过程中开发可持续和文化的背景。花费、技术和培训需要、参与者扮演的角色，所有这些都应该被更好的理解。有些项目将会持续很长时间，通常 5到20年，这样的话，将来可获得的技术现在并未存在。因此，前期不宜描述太多的细节。图1.17与表1.23阐述了过程中的一些导则。

评估

评估必须识别出那些在规划、设计和建造的不同阶段可以被检测的结果。我们的大部分低碳设计和规划都是关注那些被称为输入的东西。我们可能常常会有一张“购物清单”，上面列出了设计中应该考虑的条款（见图1.17中第一部分简介）。 这些往往是定性的，而且很具体。然而，我也要关注基于性能考虑的项目结果（见图1.17中第三部分部分影响）。输入和产出都是低碳可持续设计的必要组成部分。评估和反馈活动不仅在从规划到设计等的过程中必不可少，而且可以协助从项目的实施阶段中获得阶段经验。这些经验应该在工业中传播，从而推动对可持续规划和设计的更好理解。

可持续总体规划评估过程的形成应关注规划、设计、建造和运行的所有的阶段性结果。我应该制定明确的目标，包括针对特定项目我们想要达到什么样的结果，我们将如何评估这些结果，衡量成功与否的标准是什么。不同的项目将会有不同的目标，但是必须要建立一个用来制定明确目标和评估方法的一般步骤。

一个低碳城市往往被贴着生态的标签，但是却没有明确的目标。可能也会有一张“购物单”，列出所有的概念，如低碳，健康，减少私家车，绿色，等等。但到了“做”的步骤，如果这些概念不能落实到我们现有的方法和工具上，在更详细的规划和设计阶段他们将不再出现。

污物

人们处理污物及污水通常是避免其威胁人体健康，而非利用其进行厌氧分解发电的潜力。

处理和使用污物副产品获得能源的方式多种多样。许多案例开始展开研究，如下水道的污泥可以在焚化厂回收能源，亦或简单的作为某些工艺流程的替代燃料，如水泥的生产。对于一个开发项目而言，这些应该仔细研究。

废物

城市人均垃圾生产指标

对于所有的可持续开发区，一个共同的城市指标是“城市人均垃圾生产指标”。城市垃圾，根据其起源和终结（摇篮到坟墓），可分为不同的种类。处理危险和有毒物质时，需要特别小心。共同的基准如表1.22所示，但其只考虑了无危害及无毒的废弃物。

	Waste generation rates (kg/per capita/day)		
	Low-income country	Mid-income country	High-income country
Mixed urban waste Large city (>500000)	0.50 - 0.75	0.55 - 1.1	0.75 - 2.2
Mixed urban waste small to medium city (<500000)	0.35 - 0.65	0.45 - 0.75	0.65 - 1.5
Residential waste only	0.25 - 0.45	0.35 - 0.65	0.55 - 1.0

表1.22　每人每天垃圾制造量

参考来源:《爱尔兰的废物产生率》

城市固体废弃物的处置最基本的方法是垃圾掩埋法，这种方法最不被环境提倡，并且其对空间的利用有限。其他常用方法包括回收、堆肥和焚烧，后者环保意识要高。

工业园内，建议建立一个工业共生计划，这将促成各个工业内那些能够被重复利用，否则导致浪费的副产品之间的交换。“工业共生（ISS）和生态工业园（电子信息产品）是工业生态学（IE）的关键概念。工业共生和生态工业园的目的是通过利用副产品和能量流动最大程度地减少使用低效材料和能源。”

水资源

一般来说，城市发展需要提供：

- 供应洁净水
- 污水和雨水的安全运输
- 有卫生和环保意识的废水处理

若要获得可持续发展的凭证，建筑场地建设应考虑：

- 有效的配水方法（供水和排水）
- 水的用途分类
- 地方上管理水污染和雨水径流所作出的努力
- 规划方法应包括在整个基地内最可持续的利用水资源的方法
    - 雨水收集
    - 洁净水、中水和污水的分离
    - 尽可能鼓励水资源再利用
    - 在设计中体现低水耗特点

重庆的水资源

不同类建筑每人每天最高用水量如表1.20和1.21所示。

表1.20
居住建筑人均最大日用水量

Residential building style		Setting standard for sanitary ware	Water quota (Litter/p.day)
Normal residential	I	Stool, sink	85-150
	II	Stool, wash basins, wash basin, washing machines, water heaters and shower	130-300
	III	Stool, wash basins, wash basin, washing machine, central hot water supply (domestic hot-water heaters) and shower	180-320
Villa		Stool, wash basins, wash basin, washing machines, sprinkler bolt, and domestic hot water shower unit	200-350

资料来源：《建筑给水和排水设计代码》GB50015-2003

表1.21
宿舍、酒店和其他公共建筑的人均最大日用水量

No.	Building type	Water quota (L/p. day)
1	Dormitory * I · II III · IV	 150～200 100～150
2	Apartment	200～300
3	Hotel Rooms guests employees	 250～400 80～100
4	Public bathroom shower shower · bathtub	 100 120～150
5	Canteen	20～25
6	Commercial building Employees and visitors	 5～8
7	Office building	30～50
8	Fitness centre	30～50
9	Meeting rooms	6～8
10	Parking ground cleaning water	2～3

* Classification for dormitory – Type I for PhD candidates, teachers, scientific and technological personnel, one person per room, with bathroom; Type II for master students in universities, two persons per room, with bathroom; Type III - for University undergraduates and College students, 3-4 persons per room, with relative centralized bathrooms; Type IV - for students in secondary school and factory workers, 6-8 persons per room, with centralized bathroom

资料来源：
1.《建筑给水和排水设计代码》GB50015-2003.
2.其它类型的建筑的日用水配额值应根据《建筑给水和排水设计代码》GB50015-2003.中的表 3.1.10

大规模存储

根据使用的类型和容量，电力储存的方法各异。其存储容量及输送速度，即其额定功率。

地热能存储

该储热系统通过储存季节性余热和余冷满足以后的季节需要。它常常和地源热泵系统结合，以地球为热源。

地质储能技术

压缩空气储能法（CAES）在用其驱动涡轮机之前，把空气储存在高压下，往往在一个大型的地下空间。 这是一个大功率系统，能够提供可观的储备服务。

抽水存储水电

利用水库，建设两个高差很大的水库， 在低峰期间（便宜），水是从下水库用泵抽到上水库的。在需求的高峰期，水从高水位水库流回低水位水库，流经大型发电机组时可以发电。大约75-80%的用电可以收回。

大型水或地面储热

这些可以从夏天到冬天提供跨季节蓄热。该系统采用与上面介绍的地热能储存系统一样的原理，但是在大范围开发项目中，他们可以使用大体积的水或者土壤来存储相当多的热能。

基础设施

提供可持续的基础设施是低碳规划和设计的一个主要部分。图1.16总结了主要的基础设施系统。系统间交叉合作的可能性在项目开发的最初阶段就应考虑，如废弃物能源的使用。

图 1.16
主要基础设施总结

应运而生使得能源分配系统的效率得到显著提高。下文将介绍其中的一些方法。

热电联产（CHP）

热电联产（CHP）可以现场供电得益于废热回收，从而优化了从初级能源到终端使用的转换效率。“主要化石燃料，如煤炭和天然气，向电能的转换是低效的。即使是最先进的联合循环电厂也只能达到50-60%。大部分能量被浪费在转换过程中，以废热的形式释放到环境中。英国发电站通常会避免废热比整个家用能耗高。

热电联产电厂的效率通常在80%以上，热电联产电厂可使用多种燃料，包括天然气，垃圾和下水道气体，燃料油和汽油，煤炭，生物质能和沼气，固体废物，废气以及废热。

区域采暖和制冷

区域采暖和制冷系统是以整个基地内传送冷水、热水或蒸汽的地下干管管网为基础供冷和供热。这是由一个发电厂供给，该电厂完美的使用热电联产（废热回收）供给分配泵所需能耗。

其效率主要是基于两个因素：

- 设备（即制冷机）类型和所用技术，及其高效运作和维护。
- 利用环境无害热源（热电联产，河水和海水作为冷源和热泵源等）

参考来源：《Building and Environment》文章

其成功实施很大程度上取决于系统的容量，以获得较高的供回水温差。以热水为主的区域系统，其标准温差：$\Delta T's \geqslant 40°C$

带储热和冰式制冷机的冰系统最低供水温度是1℃。“制冷系统相应的回水温度最好在运行高峰期达到12 ℃。因此，在运行的高峰期，系统的最大温差，对于冰系统只有11℃，而对于常规制冷机系统则为8℃。”该区域采暖和制冷系统的管道大小应根据以下几个方面来确定：

- 系统温差（标准值是8-11℃）
- 允许的最大流速（避免速度高于2.5-3.0米/秒，除非系统设计允许。该速度应取决 于压降限制，以及瞬变现象所造成的重要系统紊乱（如，水锤效应引起的干扰）
- 设计荷载下的配电网压强。
- 偏远地区的供给应尽量减少压差不同。

参考来源：“国际能源机构》国际能源署区的加热和冷却

可再生能源

	建筑一体化	社区	电网
太阳能光伏发电	☆☆☆	☆☆	☆☆
集热式太阳能	☆☆☆	☆	☆
风能	☆	☆☆	☆☆☆
生物质能	☆☆	☆☆☆	☆☆☆
水能	☆	☆☆	☆☆☆

图 1.15 可再生能源适用性概览
☆ 低
☆☆ 中
☆☆☆ 高

可再生能源系统可以与建筑设计整合，并以社区或开发区为基础或通过外来输配网络供给。常规系统总结如下：

太阳能光伏发电

太阳能光伏板适用于建筑一体化设计，可以提供10%至15%的能源。面板的隐含能耗高达58gCO2eq/kWh，但这可以通过使用薄膜技术而减少 。

集热式太阳能

在需要采暖的地方，太阳能可以加热空气，这个太阳能采暖系统可以集成到墙体和屋面系统中。通常，它们可以提供一个建筑物热水需求的40%。不同类型的面板，效率有所不同，变化范围从平板类的22%到真空管类的29%。

风能

理论上，风力发电机组最高效率可达60%左右。他们被认为是隐含能耗最低的可再生能源（除了核电和水电）之一，约为4.64gCO2eq/kWh。把它们安装在社区或电网中最适当不过的，因为它们很难在城市环境中安装。

生物质能

木质生物燃料一般来源于木片或木球，其能源的生产量取决于所用木材的含湿量，一般木屑为3.5兆瓦/吨而木球为4.8兆瓦/吨（17 GJ /吨）。要满足一个标准住宅的生物质燃料需求，所需的土地大约是0.3到2公顷，如果是利用木材制品，主要看木材的种类。

能源供应

在尽量使用可再生能源满足能源需求后，当务之急还要考虑还有多少可通过化石燃料获得，这将有助于战略性的选择最环保燃料。为减少化石燃料的使用，各种“低碳”技术

Transport mode	Person-Miles Per Gallon (PMPG)	Passenger capacity
Scooter	75	1
Motorbike	60	1
Small car	30 to 40	1
SUV (Sport Utility Vehicle)	15 to 21	1
Bus	78	25
Tram	92	30
LRT (Light Rail Transit)	887	65
Express coach	180	20
Train	115	30

表 1.19 关于能源使用和交通系统运输能力的概述

市场和价格的导向因为更多关注车辆流动而扭曲，从而牺牲了更多的可持续选择。区域开发的花费应该考虑土地开发补贴，以平衡步行和骑自行车，公共交通和私人机动车这些不同的交通模式。相对于其它运输模式来说，机动车往往得到不公平的补贴，而且在规划阶段也是被优先考虑的。机动车污染和交通堵塞造成的社会经济损失往往被忽视。机动车级别可以通过经济处罚来限制，如道路收费，这将缓解交通拥堵，使自行车和公共交通工具可以更加自由行驶。

应该考虑设置无车区，缓解交通，减少流量，同时应该保持完整的街道概念，即街道应该有多重用途，而不仅仅是“交通下水道”。

好的连接空间，即通过一个吸引人的环境人们可以很容易从一个地方到达另一个地方，对于一个成功的可持续交通系统来说非常重要的。对于行人和自行车来说，应该从出发点开始考虑直接路线，因为此后它们将很难再被添加。临近交通的质量、趣味性、连通性和速度会提高步行和自行车空间的吸引力。“主要街道之间联系越直接，土地混合使用的潜力越大”（Llewellyn - Davies, 2000年）。

区域开发应关注那些公共交通机制已建立，基础设施已经建成的地区。人口应主要集中在交通枢纽周边以保证其使用最大化，如火车站。专用公交路线其交通节点清晰可见可以吸引更多的使用者。规划初期就应该开始整合交通规划，以减少对私家车的依赖。

总之，可持续发展的交通系统应该(资料来源：DGENV(2005)的 EC (2001))

- 提供基本的可达性和发展需要
- 确保安全，以及人类和生态系统的健康
- 促进各代内部以及各代之间的公平
- 是可负担的、公平的、有效的
- 提供多种的交通选择
- 支持有竞争力的经济和区域平衡发展
- 限制碳排放和废物生产，使其在地球吸收的范围内
- 控制资源消耗速度以允许其可再生，或可替代。
- 尽量减少影响土地使用，和制造噪声。

步行

通向基础服务设施，如商店、娱乐场所、社会服务和公共交通节点。按照4到6公里／小时的平均步行速度，其服务半径都应该在0.4公里以内（最多0.8公里）。因此，所需时间应该是6到10分钟。到达这些服务设施的一般距离和时间如表1.18所示。

Facility	Recommended distance
Postbox	250m (2-3 mins)
Newsagents	400m (5 mins)
Local shops, bus stop, health centre and primary school	800m (10 mins)
Local park	250 – 400m (3-5 mins)
Regional park and open space	3.2km – 8km
Metropolitan park	3.2km
District park	1.2km (15 mins)

表1.18到达各设施的一般步行距离和时间
Llewelyn Davies, 2000. Urban Design Compendium

街道应相互联系、可通达，并应采用一种清晰的模式通过直接路径联通各主要目的地。在没有或者限制私家机动车的地方应该确保通达安全、有保证。

自行车

合理的自行车服务范围是2到5公里，正常速度是12到25公里／小时，所以2公里距离需要不到十分钟。主要目的地之间应该可以互通，没有交通障碍，保证单车可以持续通行。此外，道路应维护良好。

公共交通

其它道路使用者对公共交通的性能影响很大。因此应考虑进行公交分离，或为其提供“道路行驶”的优先权。

鼓励市民使用公共交通工具，需要一个便捷、舒适、安全和经济实惠的系统。提倡市民步行和骑自行车必须考虑安全性及与私人机动车分离，尽管在许多城市，步行、自行车和公共交通系统，如电车及地下铁路（地铁）共享路线。

众所周知，私人机动车将继续在地方交通，尤其是多点旅程中发挥重要的作用。超低排量机动车市场的发展将在很长时期内解决这个问题。欧盟已经制定到2020年达到交通系统消耗燃料10%来自可再生能源的目标。然而，降低私人机动车重要性这一规划应包括在行程起始点减少停车位数量这一内容。

各个交通系统的能源使用概况如下表1.19。

PV Modules	Embodied Energy kWh/m²
Monocrystalline	1320 (720 - 2400)
Polycrystalline	1130 (540 – 1570)
Thin Film	360 (215 – 500)

表 1.17b
可再生能源系统的隐含能耗（MJ/m2）

Turbine Size	Embodied Energy (EE) (GWh)	Annual Produced Energy (GWh)	Lifespan of Turbine (years)	Time to offset EE (years)
850 kW [d]	8.16	8.571	20	0.95
1.8 MW [c]	1.89	3.27	20	0.58
2.0 MW [c]	3.1	5.98	20	0.52
3.0 MW [d]	25.6	29.743	20	0.86

表 1.17c
风力发电的隐含能耗(GWh)

低碳的交通规划

交通运输

流动性 (减少和变化模式)	可达性 (提高)
步行/自行车	工作
公共交通	购物
私人机动车	休闲/娱乐
	公共交通

图 1.14
关于交通运输系统的考虑

可持续的交通运输系统应为个人和社区提供流动性，同时尽量减少能源使用、环境破坏的影响，以及社会经济中存在的问题和危害。该系统应该关注于通过改善每日目的地如办公、商店、娱乐和其它提供必要服务的地方的可达性来减少出行需要。此外，该系统也应鼓励步行和自行车以促进人们的身体健康，减少空气污染和交通隐患。该系统应该经济实惠，并可以减少由于交通拥堵引发的社会经济问题。

一个可持续的交通运输体系应该是多模态的，即它提供了一个包括步行、自行车、公共交通、私人机动车（PMV）的混合模式，且其内部组合联系方便，可实现不同模式间的转换。

不同模式的要点如下

Building type Normalising the data to the total floor area (gross internal floor area) of the building	Embodied CO2 kgCO2e/m²
Supermarket	
CFA concrete piles (1,144 Nr 13m x 380mm nominal diameter)	376
CFA concrete piles (1,144 Nr 13m x 380mm nominal diameter)	384
Steel H-piles (641 Nr of various sizes)	395
Mixed use (office, residential, hotel, car park)	
Slimdek1	480
Concrete fl at slab: 260mm thick slab in office floors 250mm thick slab in hotel floors	467
Cellular steel beams supporting lightweight concrete slab on profiled steel decking[2]	395
Office	
Cellular steel beams supporting lightweight concrete slab on profiled steel decking	452
350mm thick post-tensioned concrete fl at slab	506
School	
390 precast concrete piles	309
450 precast concrete piles	344
248 steel H-piles	301
Warehouse	
Steel portal frame	234
Glulam beams and purlins supported on concrete columns	266
Steel portal frame with north lights	251

图 1.13
不同类建筑的隐含能耗
Target Zero

开发区

隐含能耗贯穿于包括建筑、道路及其他基础设施在内的整个开发过程。目前还没有太多这方面的信息。下面为收集到的部分信息，关于道路如表格1.17a 所示，关于可再生能源系统的如表格1.17b所示。

	Embodied Energy
Roads	kWh/m²
Asphalt road – Hot construction method – 40 yrs	700
Construction	300
Maintenance – 40 yrs	130
Operation – 40 yrs	270
Asphalt road – Cold construction method – 40 yrs	840
Construction	230
Maintenance – 40 yrs	430
Operation – 40 yrs	270
Concrete Road – 40 yrs	580
	250
	65
	270

表 1.17a　道路的隐含能耗（MJ/m2）

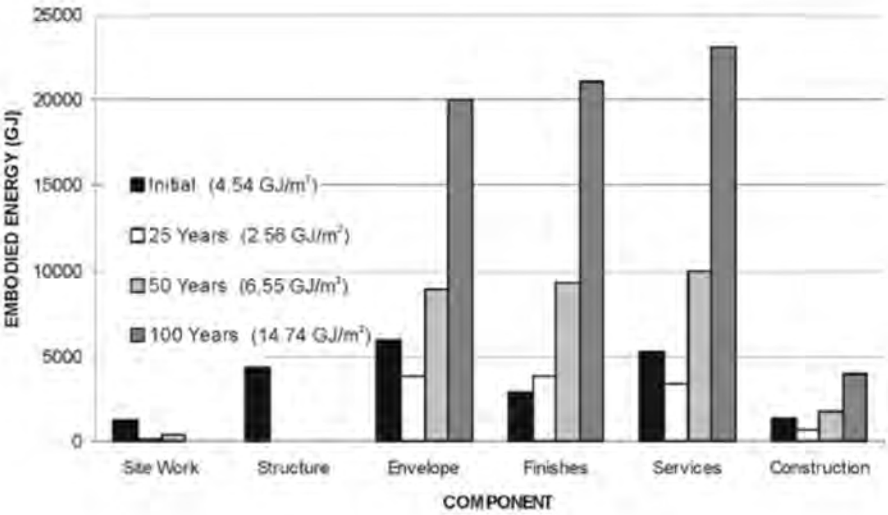


图1.12
建筑不同部分隐含能耗的比较

建筑

不同类型和用途的建筑，会产生不同的隐含能耗。如前所述，随着建筑结构效率的提高，和运行能耗的降低，关注的重点将转向供给该结构的能源需求。对于一个低碳或零碳建筑,结构建造中的耗能的不能忽略不计，这是有证可循的。隐含能耗也将考虑其生命周期内由于维护、修理和更换可能产生的能量输入。

隐含能耗随着建筑类型（工业、商业或住宅），建造类型和建造方法，以及所用材料（钢和混凝土框架结构）的变化而变化。与商业和公共建筑相比较，住宅建筑由于设计不同，每平方米一般需要更多的材料， 因此，每平方米的隐含能耗也就更多。此外，所有材料单位体积的能量强度也不一样。对项目隐含能耗影响最大的是钢、混凝土、砖和铝。所有的案例中，这些材料的再利用和回收，可显著减少隐含能耗。

不同类建筑一般的隐含能耗如图1.13所示

常用建筑材料的隐含能耗的比较如图1.9所示.

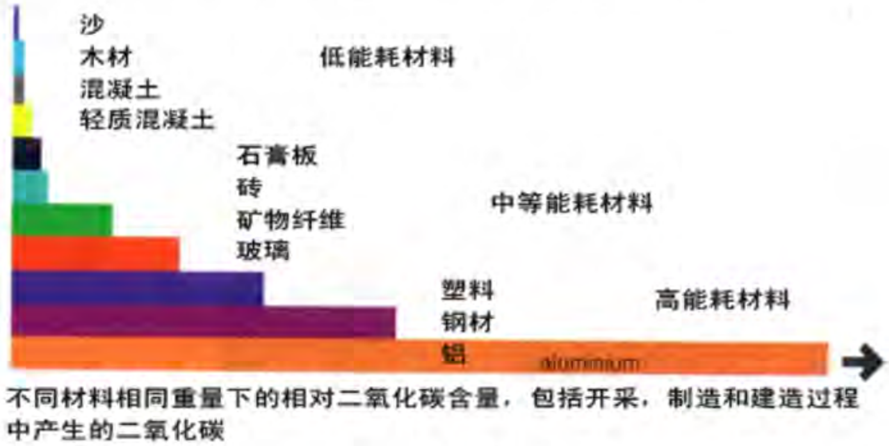


图 1.9
常用建筑材料的隐含能耗的比较

建筑各组成部分

对于项目隐含能耗的计算而言，不仅建筑材料从原产地运输到基地的距离很重要，不同建筑材料隐含能耗的不同也要考虑。

如上图所示，尽管混凝土的二氧化碳排放量相对较小，但因其在建筑中的广泛应用，其二氧化碳排放量占全球人类生产二氧化碳总量的5%左右。如图1.10所示，很多降低二氧化碳排放的方法是通过使用不同类混凝土。图1.11和1.12所示则为建筑各组成部分隐含能耗的比较。结构特别是地基的隐含能耗往往很大。

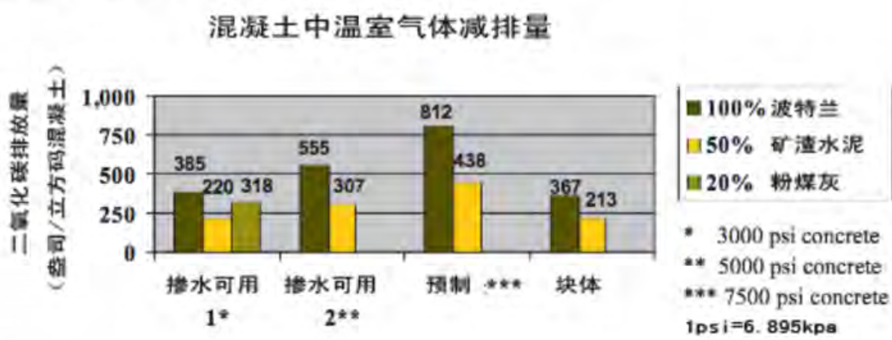


图 1.10
不同种类混凝土的二氧化碳排放量示意图

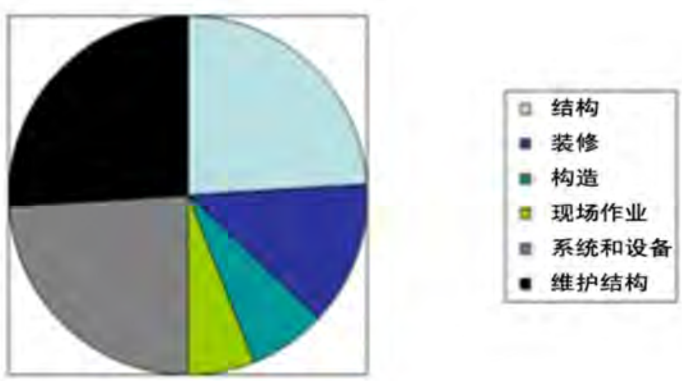


图1.11
建筑不同部分隐含能耗占生命周期隐含能耗的比例
Raymond J. Cole, Paul C. Kernan
Life-cycle energy use in office buildings Building and Environment, Volume 31, Issue 4, July 1996, Pages 307-317]

Concrete		
General 91:2:4 as used in construction of buildings under three storeys	0.95	0.035
Precast concrete, cement: sand: aggregate		
1:1:2	1.39	0.057
1:1.5:3	1.11	0.043
1:2.5:5	0.84	0.030
1:3:6	0.77	0.026
1:4:8	0.69	0.022
Autoclaved aerated blocks (AACs)	3.5	0.076—0.102
Fibre-reinforced	7.75	0.123
Road and pavement	1.24	0.035
Road example	2.85MJ/m2	51KgC/m2
Wood-wool reinforced	2.08	–
Glass		
General	15	0.232
Fiberglass (Glasswool)	18	0.417
Toughened	23.5	0.346
Steel		
General, 'typical' (42.3% recycled content)	24.4	0.482
General, primary	35.3	0.749
General, secondary	9.5	0.117
Bar & rod, 'typical' (42.3% recycled content)	24.6	0.466
Bar & rod, primary	36.4	0.730
Bar & rod, secondary	8.8	0.114
Engineering steel, secondary	13.1	0.185
Galvanised sheet, primary	39	0.768
Pipe, primary	34.4	0.736
Plate, primary	48.4	0.869
Section, 'typical' (42.3% recycled content)	25.4	0.485
Section, primary	36.8	0.757
Section, secondary	10	0.120
Sheet, primary	31.5	0.684
Wire	36	0.771
stainless	56.7	1.676
Timber		
General	8.5	0.125
Clue laminated timber	12	–
Hardboard	16	0.234
MDF	11	0.161
Particle board	9.5	0.139
Plywood	15	0.221
Sawn hardwood	7.8	0.128
Sawn softwood	7.4	0.123
Veneer particleboard (furniture)	23	0.338

Source: Authors: Hammond, G. P. and Jones, C. I. Embodied energy and carbon in construction materials. In Proceedings of the ICE - Energy, 161/ 2, p. 87 –98, ISSN: 1751-4223, E-ISSN: 1751-4231

表 1.16　常规材料的隐含能耗值

隐含能耗是建筑和装修（图1.8）过程中因材料加工和产品使用产生的能耗，包括获取自然资源、生产材料以及部件过程中的能耗，以及在它们生产和运输过程中所产生的交通能耗。通过更高效的节能设计，系统和设备的能耗得到了降低，这就使隐含能耗变得越来越重要。在某些低碳建筑中，隐含能耗等于系统和设备能耗。隐含能耗贯穿于整个生命周期，而且与原料加工、材料制造、运行消耗，以及达到使用寿命后的分解处理等环境成本紧密的联系在一起的。对于一种建筑材料或建筑构件而言，其隐含能耗是决定其可持续能力的主要因素。隐含能耗可以从以下几个方面减少：

- 最好使用当地材料以降低运输能耗
- 少用高度加工的材料，一般来说其隐含能耗很高。
- 使用可再生材料，或具有高回收内容的材料如金属，尽管回收过程会增加它的隐含能耗。
- 可持续设计应该鼓励建造系统使用更少的材料。某些建造方法本身就比其它的要浪费。
- 标准化，应该鼓励减少包装，使用更多当地的场外预制的建造方法。
- 材料运输也在隐含能耗的计算中起着显著的作用，特别是远程定位建筑物时。

材料

特殊材料的隐含能耗值如表1.16所示

Materials	Embodied energy (MJ/Kg)	Embodied carbon (KgC/Kg)
Bricks		
General	3	0.060
Limestone	0.85	--
Cement		
General	4.6+/-2	0.226
Portland cement, wet kiln	5.9	0.248
Portland cement, semi-wet kiln	4.6	0.226
Portland cement, dry kiln	3.3	0.196
Portland cement, semi-dry kiln	3.5	0.202
Fibre cement	10.9	0.575
Mortar (1:3 cement : sand mix)	1.4	0.058
Mortar (1:4)	1.21	0.048
Mortar (1:0.5:4.5 cement : lime : sand mix)	1.37	0.053
Mortar (1:1:6 cement : lime : sand mix)	1.18	0.044
Mortar (1:2:9 cement : lime : sand mix)	1.09	0.039
Soil-cement	0.85	0.038

如上所述为建筑节能标准设置了一系列典型目标（见表1.14）。这些目标都是建立在下文所述策略的基础上。

等级	标准	CO2 减排量
一级	基础层面改进	25%
二级	低碳	50%
三级	零碳	75%

Office building	Current standard (kWh/m²/year)	basic level (kWh/m²/year)	low carbon performance (kWh/m²/year)	zero carbon performance (kWh/m²/year)
EU	130	98	65	33
China	135	101	68	34

表 1.14　低碳设计目标

办公室照明和其它电器设备用电负荷如表1.15所示

Use	Electrical power (W/m²)
Lights	12
Small power	10

表1.15办公室照明和电器设备

目前，英国的住宅年能耗平均约4700kWh，并有潜力减少到约2400kWh每年。中国的住宅年能耗平均只有约160kWh，而中国现代住宅的耗能很可能像西方住宅一样还有降低的潜力，所以这些目标是适用的。

隐含能耗

图 1.8
隐含能耗概述

Power Grid	Provinces and Cities Covered
North China Power Grid	Beijing, Tianjin, Hebei, Shanxi Province, Shandong Province, Neimenggu Autonomous Region
Northeast China RPG	Liaoning Province, Jilin Province, Heilongjiang Province
East China Power Grid	Shanghai, Jiangsu Province, Zhejiang Province, Anhui Province, Fujian Province
Central China RPG	Henan Province, Hubei Province, Hunan Province, Jiangxi Province, Sichuan Province, Chongqing
Northwest China RPG	Shanxi Province, Gansu Province, Qinghai Province, Ningxia Autonomous Region · Xinjiang Autonomous Region
Southern China RPG	Guangdong Province, Guangxi Zhuang Autonomous Region,Yunnan Province, Guizhou Province
Hainan Power Grid	Hainan Province

表 1.12　区域电网

Power Grid	EFgrid,OM,y (tCO_2/MWh)	EFgrid,BM,y (tCO_2/MWh)	EF (tCO_2/MWh)
North China Power Grid	1.0069	0.7802	0.89355
Northeast China RPG	1.1293	0.7242	0.92675
East China Power Grid	0.8825	0.6826	0.78255
Central China RPG	1.1255	0.5802	0.85285
Northwest China RPG	1.0246	0.6433	0.83395
Southern China RPG	0.9987	0.5772	0.78795

表1.13　2009年中国地区标准电网碳排放系数

Zhao Guan-wei, Chen Jian-fei, Cui Hai-shan, Chen Ying-biao (2010), Carbon Emission in Energy Consumption in Guangzhou During 1997 to 2007, Resources & Industries,12, Issue 6, 179-184.

建立运行能耗标准

在中国，新建住宅建筑要求比20世纪90年代建造的同类建筑节能65%。其中50%是通过优化构造来实现，剩下的15%则靠提高暖通空调系统的效率。

通过与现有标准相比较，本导则新建建筑“低碳”标准的设定以下面三个层级为基础进行考虑：

1. 对规范指标的总体优化，具有代表性的是欧洲的能源或二氧化碳指标每5年就被改进25%。
2. 环境评估方法　如 LEED和BREEAM，需要在国家标准基础上节能50%左右才能获得最高的评分。
3. Passivhaus(德国)类标准要求在国家标准基础上节能75%。

Standard	Domestic	Non-Domestic		
		Retail	Industrial	Office Buildings
	kWh/m2/a	kWh/m2/a	kWh/m2/a	kWh/m2/a
Chongqing University Research		260		135

表1.9: 重庆某案例的能源供给值

1) Office building data: TAN Xiaoyan. Survey and Research on Energy Consumption of Office Building in Chongqing. Chongqing University, 2008;
谭晓艳, 重庆市办公建筑能耗调研及节能对策研究. 重庆大学硕士学位论文, 2008年
2) Research on Energy Consumption Status and Energy Consumption Simulation of Emporium in Chongqing. Chongqing University, 2008;
王树健. 重庆大型商场建筑能耗调研与能耗分析. 重庆大学硕士学位论文, 2008年

初级能源和二氧化碳排放

初级能源涉及到所用材料的含能量，如化石燃料，既可直接在建筑中使用，也可在发电站转化为电能。系统和设备能源向初级能源转换的转换系数如表1.10. 所示 。

能源使用产生的二氧化碳排放和所用燃料的类型也有关系。表1.11总结出了与中国相关的部分。

Fuel	United Kingdom	China
Electricity	2.5	3.3
Natural Gas	1.1	1.24

表1.10系统和设备能源向初级能源转换的转换系数

Fuel	Kg CO_2 / kWh
Raw coal	0.354
Coke	0.385
Crude oil	0.264
Gasoline	0.249
Diesel oil	0.267
Fuel oil	0.279
Liquified petroleum gas	0.227
Natural gas	0.202
Coal oil	0.259
Fuel gas	0.227
Electricity	0.694

表1.11 引自中国的二氧化碳排放系数

城市能源的分配必须考虑地方供应和外来电网供应的不同，因为方式不同，效率也就不同，产生的碳排放量也不同。举例来说，在中国，不同的电网系统有不同的碳排放指标，如表格1.12和 1.13所示。

Types	Residential building		Commercial building	
	National standard	Local standard (Chongqing)	National standard	Local standard (Chongqing)
COP (Coefficient of Performance)	2.3	2.8	Depends on system types, 4.0 for average	Depends on system types, 4.1 for average
EER (Energy Efficiency Ratio)	1.9	2.8	Depends on system types, 3.0 for average	Depends on system types, 3.2 for average

表 1.6　引自中国的热泵系统效率

能源供给基准

表1.7和1.8为英国常规的能源供给值。表1.9给出重庆的目标值。

Standard	Domestic		Non-Domestic					
			Retail		Industrial		Office Buildings	
	kWh/m2/a		kWh/m2/a		kWh/m2/a		kWh/m2/a	
CIBSE- Guide F	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice
	291	496	209	259	96	103		
office types								
naturally ventilated cellular							112	205
naturally ventilated open plan							133	236
air conditioned standard							225	404
air conditioned prestige							348	568

表 1.7　CIBSE 的能源供给值

Figures for CIBSE (F): 'Energy consumption benchmarks for existing buildings'. These benchmarks are from the lates publication (2004).

Standard	Domestic		Non-Domestic					
			Retail		Industrial		Office Buildings	
	kWh/m2/a		kWh/m2/a		kWh/m2/a		kWh/m2/a	
Carbon Trust	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice	Good practice	Typical practice
office types								
naturally ventilated cellular							89	150
naturally ventilated open plan							88	148
air conditioned standard							115	210
air conditioned prestige							130	245

表 1.8　Carbon Trust的能源供给值

Figures for Carbon Trust: 'Energy consumption guide' these benchmarks are from the 2000-2003 publication

Standard	Domestic	Non-Domestic		
		Retail	Industrial	Office Buildings
	kWh/m2/a	kWh/m2/a	kWh/m2/a	kWh/m2/a
Passivhaus				
Heating only	15	15	15	15
Cooling only		15 (*)	15 (*)	15

表1.3: Passivhaus标准　　(*)如果需要

Minergie是瑞士的标准，它包括采暖，热水供应，及机械通气（如需要）所需的能量。
[http://www.minergie.ch/minergie_fr.html]

Minergie- P标准主要涉及可再生能源系统

Standard	Domestic		Non-Domestic					
			Retail		Industrial		Office Buildings	
	kWh/m2/a		kWh/m2/a		kWh/m2/a		kWh/m2/a	
	Post 2000 Buildings	Pre 2000 Buildings	Post 2000 Buildings	Pre 2000 Buildings	Post 2000 Buildings	Pre 2000 Buildings	Post 2000 Buildings	Pre 2000 Buildings
Minergie	38	60	40	55	20	40	40	55
Minergie - P	30	30	25	25	15	35	25	25

表 1.4　Minergie 和 Minergie-P值

系统表现

建筑围绕供暖、制冷、通风或湿度控制有一系列的环境控制系统。与供暖系统相关有能效系数，制冷系统有性能系数(COP)，热泵有性能系数(COP)或能效比（EER）。此外，系统还会有管道和管道间的内部损耗（通常为5%至10%）。表1.5给出英国典型系统的性能系数(COP)，表1.6给出中国常规系统的性能系数(COP)。

System	%
Direct acting electric boiler	100
Ground-to-water heat pump (electric)	320
Ground-to-water heat pump with auxiliary heater (electric)	300
Water-to-water heat pump (electric)	300
Air-to-water heat pump (electric)	250
Gas-fired, ground / water source	120
Gas-fired, air source	110
Community boilers	80
Community CHP	75
Community waste heat from power station	100
Community heat pump	300
Community geothermal heat source	100

表1.5　引自英国的系统性能系数

Table 1.2c Internal heat gains for a typical office (Switzerland)

Factor		Heat gains (W/m^2)		
Density (m^2/ person)		14	17	11
Sensible heat gain	People	5.0	4.0	6.5
	Equipment	7.0	3.0	15.0
	Lighting	15.9	11.6	15.9
Latent heat gain		5.5	4.5	7.5

Source: Standard-Nutzungsbedingungen für die Energie- und Gebäudetechnik 2006

基准的制定

低碳设计是一个国际性概念，它可以通过许多不同的途径实现。其中，一些方法采用以该国家或地区的具体标准为基准改善建筑能耗，从而进行环境影响评估。其他设计师则在全球范围内比较相似项目的节能性以优化基准数据。通过对众多基准及其数据进行比较分析发现，很少有完全相同的两个项目，每个项目都是有其独特处。然而，基于城市尺度设计考虑的社会需要，人们试图使建筑物满足类似的“测量模具”。

以下是各国基准的概述。尽管如此，我们还是应该知道，建筑规范中对建筑设计不同方面的数据，应该根据地区不同而有所改变，尤其是将英国（或欧洲）的基准与重庆进行比较，很显然，重庆的气候是显著不同于英国（或欧洲）的。

这部分提供了各公认标准给出的基准数据。这些数字代表建筑物的能量需求或供应量（如下示），这里包括了所有的能量需求（除非特别指出，如Passivhaus standard)

能源需求基准

建筑物的能源需求可分为热（采暖，制冷，热水）和电（小功率，灯光和机械通风）。例如，欧洲标准的国内建设热能需求可能会在100kWh/m2左右。低能耗建筑则是它的一半左右约50kWh/m2，而低到零碳建筑则约为15kWh/m2。

下表是特定标准下建筑认证的能源需求数据，以德国（Passivhaus）和瑞士（Minergie）建筑为例。Passivhaus规定的家庭用电量一般可能是40到50kWh/m2。

Passivhaus起源于德国，提供达到低碳和零碳的能源需求标准，着重于减少热损失，且通常采用机械通风系统进行热回收。其能源需求的基准数据如表1.3所示：

环境要求

表 1.1 根据典型情况总结的主要设计条件

Parameter	Range
Air temperature	Winter 21°C Summer 26°C
Radiant temperature	Within 2°C of air temperature Internal internal surface temperatures, eg. glazing, <5°C above air temperature
Air speed	< 0.15m/s
Relative Humidity	40 to 60%
Fresh air ventilation	10l/s/person
Lighting	2% daylight factor/ 300-500 lux/ 9-15 W/m² lighting load

表1.1　　内部设计条件概要

从内部人员和设备处获得的热能

表 1.2 办公类建筑的内部得热和人员密度

Table 1.2a　Internal heat gains for a typical office (UK)

Factor		Heat gains (W/m²)				
Density (m²/ person)		4	8	12	16	20
Sensible heat gain	People	20	10	6.7	5	4
	Equipment	25	20	15	12	10
	Lighting	12	12	12	12	12
Latent heat gain		15	7.5	5	4	3

Source: CIBSE Guide A: Environmental Design, 2006.

Table 1.2b　Typical internal heat gains for office spaces (US)

Room type	Occupancy Density (m²/per)	Equivalent People Sensible W/m²	Lighting (W/m²)	Plug load (W/m²)
Office: light computer usage	18.58	3.85	11.84	5.38
Office: light computer usage	18.58	3.85	11.84	10.76
Office: light computer usage	18.58	3.85	11.84	21.53
Conference room	1.86	38.61	13.99	5.38
Lobby	9.29	7.72	13.99	2.69
Corridor	NA	NA	5.38	2.69
Kitchen/ break room	1.86	38.61	12.92	5.38

Source: ASHRAE: Advanced Energy Design Guide for Small to Medium Office Buildings

能源基准的定义

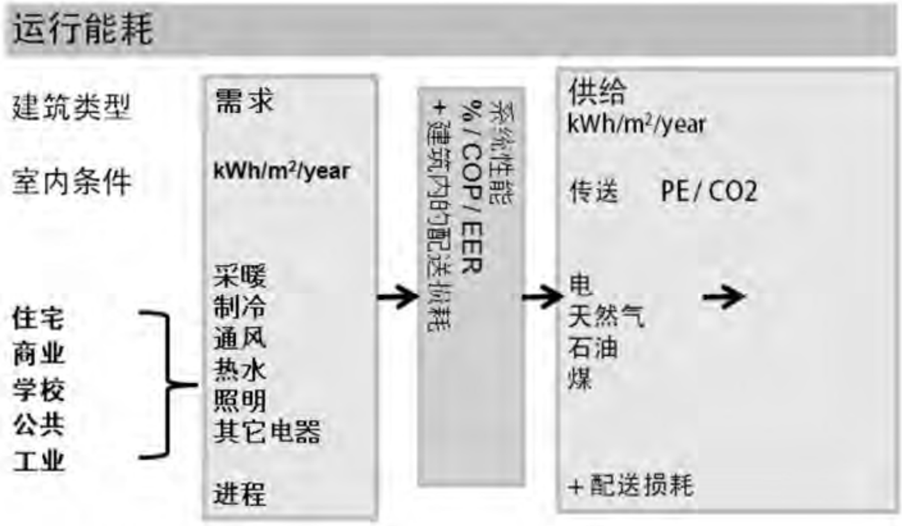


图 1.7
能源专有名词摘要

建筑运行能耗有一系列基准，主要是根据所包含的内容，如采暖，制冷，通风，热水，照明，其它电器等。其中，有些基准数据包括全部能耗，另一些则把他们分为热能和电能。任何的工艺流程耗能，如工业建筑，一般并未被包括在基准内。图1.7总结了主要的术语。

能源需求涉及热损耗，采暖，通风，制冷及电耗。能源供给涉及到的系统与设备能耗也就是供给建筑的部分，例如建筑的计量能耗。能源需求和建筑系统与设备能耗之间的区别，涉及到系统的性能系数，如能效和性能系数（COP），是与采暖，通风和制冷设备相关的。能源供给在初级能源（PE）关于使用燃料供给能源的条款中有描述，如，天然气、石油、煤炭，以及发电站发电所使用的燃料。二氧化碳排放量与初级能源的使用有关。

下面是与上述定义相关的基准数据

室内条件

室内条件包括：

- 温度的环境要求、相对湿度（RH）和气流速度
- 来自于内部人员和设备的热量

社会特性

- 社区模式可能已存在，而且可能会被纳入新开发项目中，以提供服务和劳动力。
- 应从所有相关团体中选择参与者，包括地方的诸多社区，他们应该适当参与规划新的开发区。
- 需要被保护的历史建筑，其形式中可能存在的遗产特征。

整合和互动

在项目发展的早期应该确定跨部门的机遇，包括：

- 美化市容
- 交通联系
- 废弃物能源开发
- 基地瀑布和水资源管理
- 中央与地方基础设施
- 基础设施的社区管理

建筑运行能耗

这部分将列出建筑运行能耗的基准数据。它因建筑类型和位置的不同而不同，所以中国的建筑与世界其他地区的建筑会有很大的不同，并且跨越中国不同气候带也会有变化。但是，认识到基准数据的区域限制这一点非常重要，因为它可以帮助我们完善重庆的标准。

低碳能源规划

低碳能源规划的关键点是减少需求量，然后尽可能通过使用可再生能源满足需求。 因此，总体规划应提供能源需求和供给（图1.6）之间的平衡。本节中的“能源”一词主要是指建筑耗能。

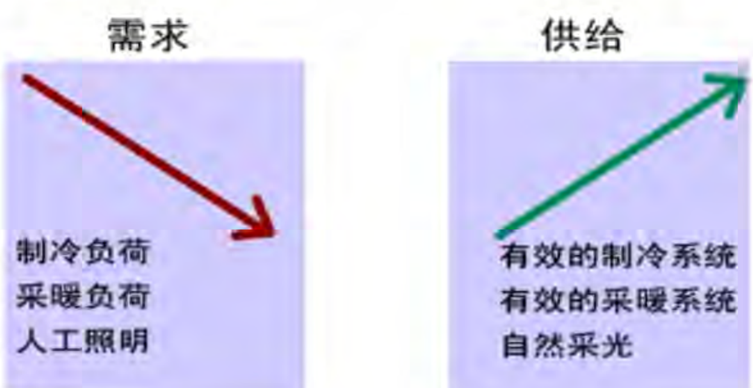


图1.6
减少需求，同时提供高效和有效的能源供给

基地分析为低碳设计提供了背景。它侧重于与基地相关的特定情况，主要分为三个方面：自然的、物理的和社会的。这三方面信息在项目开始时就应该考虑。不同的项目有不同的优先权，侧重的区域也不一样。图1.5总结了主要需要考虑的因素。除上表所示数据外，在基地内由推动可持续发展和达到低碳所引发的交叉研究也应该列入考虑范围内。

自然特性

- 气候分析包括季节温度、太阳辐射、风速和风向、相对湿度和降水。
- 地质景观包括该地区的地质，地貌和水文研究。
  生物多样性应结合已有动植物和新系统的开发考虑。
- 生态：研究应包括观察植被和生物的昼夜循环，原住物种的避难所和栖息地，自然能源的来源，以及当地废弃物的沉积池。
- 栖息地景观：应考虑植物的分布和产地以及景观生态的基础。
- 视觉及感觉：应考虑通过感官感知确定景观特质，如地貌和土地覆被的特殊物理属性，其分布的视觉形式和感知特性，及其在特定区域相互间的关系。
- 历史景观：关注于考古、历史遗址之间，及与其周边景观间如何相互联系。
  人文景观：评估人与空间之间存在的关系，人类赋予
- 空间的意义，景观如何影响人类行为，及人类行为如何改造景观。

物理特性

- 现有的基础设施可能包括： 运输系统的架空电力线路和地下设施。它们可能对区域开发产生制约， 也可能提供机遇。
- 对先前使用中被污染的区域进行补救，修复基地的环境。
- 绿，蓝的结构（关于绿化和水资源利用的生态结构）可能存在于之前的开发中，或者可以根据场地内自然特征适当考虑。
- 防洪措施可能很有必要，它可以利用基地内的自然特征，同时与上面新的蓝-绿结构系统相结合。

各部分基准

图1.4给出了与低碳总体规划相关的各主要方面，包括：基准条件，设定目标并给出实现这些目标的指导方针，确保通过评价来遵守基准，从实践中吸取经验教训并且指导以后的发展，随着时间的推移，在适当情况下调整程序和目标。

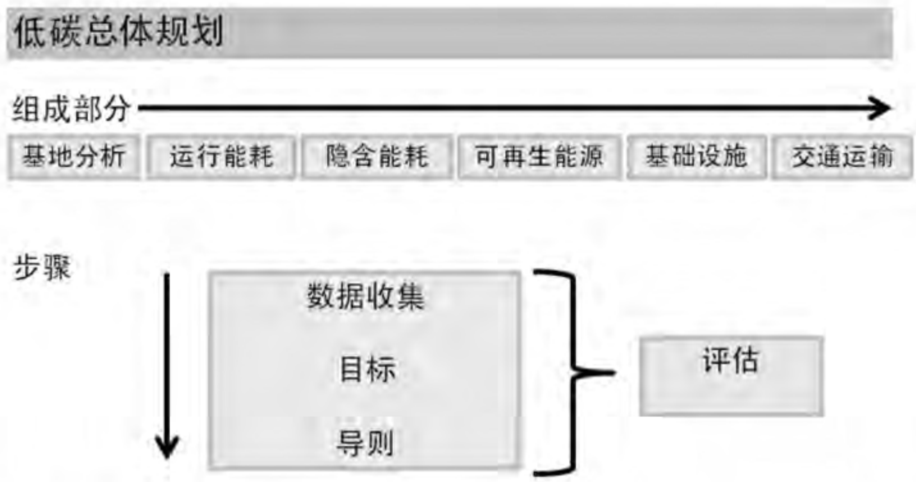


图 1.4
低碳总体规划框架

低碳总体规划应该是一种整体的方法，提出基准和目标制定的基本方针。这一需要评估的过程会在第一部分中详细介绍。导则的第二部分以巴南项目为例提出了预测二氧化碳排放量的评估工具。

基地分析

图 1.5
基地分析、数据收集汇总

高密度与低密度开发

适当密度的开发应基于建筑和景观的适当平衡，用以减少能耗（建设和运输）。规划设计建筑与绿地区域的结合应该以减少热岛效应、热点污染，并保证开发建设足够的通风廊。

社区

已建成建筑应该考虑被重复使用，保留原有社区模式，并辅以适当的开发。在可能的情况下，应尽可能的开发和使用当地劳动力和供应链。

成本计算

应根据二氧化碳排放量来使用全生命周期成本计算方法。对于交通运输和其他基础设施中牺牲更多的可持续设计选项的非可持续设计途径应该避免补贴鼓励。

很多指标和标准都致力于推动可持续发展。标准的选择取决于项目背景和发展方向，无论何时，它们都应该被理解为帮助相关者群体实现进一步的可持续发展的行为指导方针。可持续发展的基本原则包括：注重预防原则、保持多样性、一体化的解决方案、制造创新机会、公平和团结的居住模式、加强求知欲望、确保生活质量和健康、合理的支持、加强地方认同感。

项目应该能诠释支持它们发展的社会经济基础，而不是一个简单的没有明确的社会经济战略的物业炒卖活动。可持续发展的方针应该是建立在一个全面的系统的方法上。

影　响

发展的影响应该综合考虑全球范围、地方范围和建筑范围内的诸多因素。这些要素包括：

- 建筑范围内，包括舒适、健康、生产力等因素;
- 地方范围内，包括室外空气质量，方便服务，就业机会，等;
- 全球范围内，包括二氧化碳的排放、资源消耗等。

这些影响关乎于可衡量的成果，并由评估体系来决定。

图 1.3
根据可持续发展三重底线，建成环境可以在全球、地方和建筑范围内产生影响

与低碳总体规划相关的可持续发展问题

影响可持续发展和低碳性能的总体规划，其最初阶段会做出许多基础决策，。这些在下文中有介绍。

供给与需求

首先要考虑的事应该是降低需求，接着是提供高效率和有效的供给。

地方与中央

基础设施应该与建筑适当搭配，无论是地方还是中央，任何基础电网的储能问题都应该被考虑，尽可能的使用低碳设计。

可达性与流动性

在最大化流动性以确定一个低碳的、减少交通拥堵的解决方案之前，设施可达性应该被考虑。步行、骑自行车和使用公共交通工具的流动性都要大于私家车。

运行能耗与隐含能耗

碳议程需要被整体考虑，其中包括运行能耗与隐含能耗及相关的二氧化碳排放量，以及最大限度地使用零碳能源供应。

目的

导则的第一部分首先介绍了低碳的概念和什么是可持续发展的总体规划，然后介绍了它在不同行业中的基准信息，以及这些信息如何用于评估框架。评估框架需要与规划和设计紧密结合，并清楚地确定需要进行评估的部分，以及相对应的评估标准。第1部分主要分成两小节来介绍：

- 低碳方法
- 各因素和基准
- 步骤和评估

低碳方法

什么是低碳?

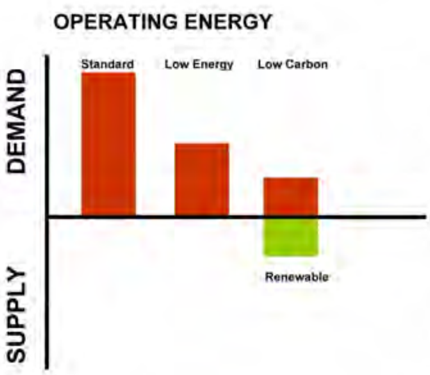


图 1.1
低能耗建筑耗能是常规建筑的50%，并可以通过可再生能源和其他低碳能源供应达到进一步降低能耗。

有时候低碳建筑或低碳建筑环境的概念并不能完全被理解。人们往往将低碳与低能耗相混淆。“低能耗”建筑会要求减少运行能耗，例如，通过更节能的建筑构造或采用更有效的采暖、照明和通风系统，运用“被动”和“低能耗”的建筑设计方法。低碳建筑要求进一步降低能源需求，同时将使用可再生能源供应以满足这一需求。

这种可再生的能源供应既可以被集成到建筑设计中，也可以作为社区系统的一部分被置放在“附近”。一般来说，可再生能源系统应该是项目整体的一部分，而非来自现有的绿色能源。

能源是用于制冷、采暖、通风和照明的。这些能源的使用越来越多地由政府监管。使用小功率也有能源消耗，包括电脑、电视用电。目前来说，这些能源的使用通常是不受监管的。二氧化碳的排放与使用石油作为供应能源是分不开的，当然也包括建筑中的使用能源，例如，石油，天然气等，或者用发电站进行发电。

图 1.2
可持续发展的“三重底线”包括环境、社会和经济三方面

可持续发展

与低碳总体规划相关的规划和设计必须与所谓的三重底线可持续发展相协调，包括环境/社会/经济，及相关问题处理等。许多声明、概念或咨询文件中都有关于可持续发展的定义，所有解释都是“从长远来看，经济增长，社会凝聚力和环保必须携手. . . . . . . “（斯德哥尔摩欧洲理事会的声明）。此外，它的目的是更好地链接所涉及到的利益相关者，其中包括规划和决策过程中所有重要的执行者。

第一部分

低碳方法和基准

简　　介

导则框架

本“低碳总体规划”导则旨在帮助新开发项目显著减少二氧化碳排放量提供指导和示范，它主要由两部分组成：

图 1
巴南项目的sketch模型

第一部分 低碳方法和基准

这部分将介绍低碳总体规划中的一些概念，并阐述与能源消耗和二氧化碳排放相关的主要部分，其中包括建筑运行消耗，隐含消耗，可再生能源的供应，交通运输系统和基础设施的建设。

第二部分 低碳模式和在巴南项目中的应用

这部分描述了卡迪夫大学建筑学院开发的基于城市尺度的低碳总体规划模型，并通过巴南项目说明这一模型是怎样使用的。它可以用来预测建筑的运行能耗、隐含能耗，及其使用可再生能源的潜力。

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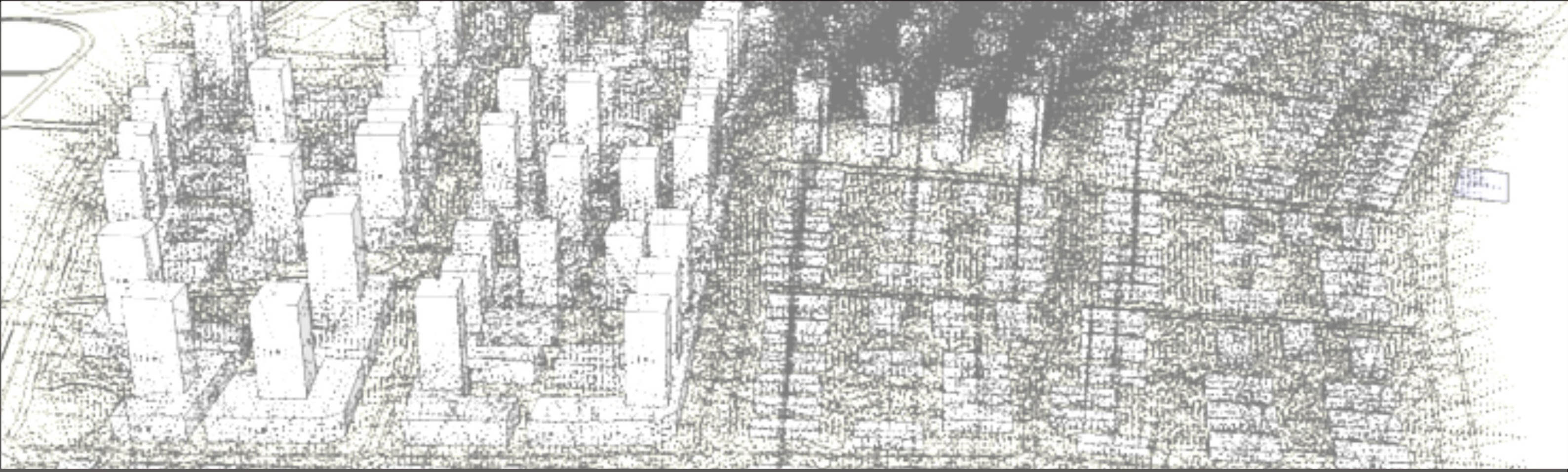

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