Utilization of biomass energy in architectural design

Shabnam Akbari Namdar [1], Farnoosh Minooei [2], Farzad Derakhshan [3], Mohammad Amin Khojasteh Ghamari [4]

1. PhD, Department of Architecture; Tabriz Branch, Islamic Azad University; Tabriz, Iran.
namdar@iaut.ac.ir
2. MA Student, Department of Architecture; Tabriz Branch, Islamic Azad University; Tabriz, Iran.
fm_architect@yahoo.com
3. MA Student, Department of Architecture;Tabriz Branch, Islamic Azad University; Tabriz, Iran.
fd_architect@yahoo.com
4. Department Architecture; Tabriz Branch, Islamic Azad University; Tabriz, Iran. and Payame noor university of Iran, Tabriz - Member of Young Researchers Club of Tabriz, Iran.
arch_khojasteh@yahoo.com

Abstract: Due to increasing environmental concerns especially related with the use of fossil fuels, new solutions to limit the greenhouse gas effect are continuously sought .With the growing concerns of greenhouse emissions, biomass is set to become an important contributor to the world energy need. Today biomass is seen as the most promising energy source to mitigate greenhouse gas emissions .This research is based on library and documental studies that it was done in time that the Crisis in the use of fossil fuels and destructive agents due to it. The purpose of complementary and analytical studies performed on the use of biomass for energy production, is investigating environmental crisis and replacing and modifying sources used for creating energy and equilibrium cycle in nature and continuity of turning production and consumption patterns to solve environmental crises and finding a suitable model in order to use this energy in buildings, and advantages that today's architects and engineers are taking from this matter. Finally, the result is that the design approaches of architects are crucial to the utilization condition and methods of renewable energy. Through profound comprehension of the relationship between biomass energy utilization and design approaches, we can achieve a dual-standard of building environment performance and esthetics.

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1. Introduction:

The vast development of science and technology in the nowadays world seems to results in the welfare of human life. However, this development has caused new problems for humans including environmental pollution, wide changes of weather within earth and etc. Particularly, we know that oil and its derivatives is the valuable national and vital resources of country where sometimes their non-optimal usage leads to irretrievable losses, so authorities and experts seek resources which could be replaced fossil fuels gradually. Fossil fuels impose numerous environmental pollutions, in other words toxic gasses are entered into the environment as a result of burning fossil materials and make the human respiration difficult and pollute the environment and on the other hand, the congestion of these gases in the earth atmosphere prevent heat exhaustion from its surrounding and results in increase in air temperature and vast changes in the earth weather which is called greenhouse effect. The main question of this research is that which patterns could be respond the requirements of present generation in order to produce energy and consumption in this current era, a pattern which consider the interests and resources of future generations. The modern energy systems must be based on structural and fundamental changes in the future where the carbonless energy resources like solar and wind energy, thermal earth and neutral carbon like biomass energy are applied. Garbage and wastes are the problems encountered in most metropolitans, so adoption of appropriate systems to collect and transform these organic wastes has high significance. It is so interesting according to the energy production process from the biomass resources not only due to economical factors, but also due to environmental issues. The appropriate abundance, easy access, environmental economical advantages has resulted in this fact that biomass has found appropriate position among the modern energies within globe. Obviously, renewable energies play an important role in the modern energy systems within globe due to the simplicity of technology over nuclear energy technology from one hand and also due to not making problems like atomic wastes. Therefore, in the international plans and systems like plans of United

Nations organization a particular role has been assigned in the renewable energy resources in order to stable worldwide development.

2. What is biomass?

There are various definitions to biomass in the world. As a simple definition we can say that biomass includes whole materials within nature which were close to living in the past, resulted from the organisms or their wastes. As we know that the fossil resources are the source of biomass resources but with this difference that fossil resources have been obtained from biomass resources under particular pressure and temperature conditions. The Europe union following proclamation 2000/177/EC has introduced the definition of biomass as follows in order to develop the usage of biomass in power production in the domestic market of Europe: biomass is the whole renewable biological components of agricultural products, wastes (including herbal and animal materials), forest industries and other related industries, biological and industrial renewable wastes and rubbish. (http://www.suna.org.ir/ationoffice-zisttoodehoffice-zisttoudehenergy-fa.html)

3. Exploitation history of biomass:

From the historical viewpoint, the date of using biomass energy backs to the early eras of history and since the fire has been known, the early human had always used the dry wood and leaf of trees as a fuel. This state has continues until present century. The oldest case of gas exhaustion and its incomplete ignition has been reported via waste disposal in the basements by Bili NiRous. Wen Helmont has introduced the identification and ignition of this gas in 1630. In 1667, Sherli had discovered the marsh gas and the most original practical history of using methane gas, the main compound of biogas resulted from the fermented materials is by Volta started since 1776 and Kain had execute the scheme in 1884 and had provided the lightness of Paris streets by using biomass energy. During 1985 to 1990 the mean annual consumption of biomass energy was 14 quadrillion (BTU) in the globe.

Table 1. Production and consumption of biomass fuels in the 1990-1985 (publication of renewable energy organization of Iran, 1380)

Production and consumption of biomass fuels ***BTU***	Zone
3.63	North America
0.99	Europe
1.2	Africa
4.4	Asia

Using biomass also has old history in Iran. **Muḥammad ibn Ḥusayn al-Āmilī** known as **Shaykh-i Bahāī**, in 935-1031 hijri, was the first one who has used biomass as a fuel in a bath in Esfahan. The first production digester of methane gas in Iran has been built in the NiazAbad village of Lorestan in 1354. This device with capacity of 5 cubic meters uses the cow manure of the village and provides the consuming biogas of adjacent bath. In 1359, it was constructed in an area of three cubic meters in the Bu-Ali Sina University of Hamadan and in 1361, in an area of three cubic meters in the Sharif University of Technology where its fuel was from cow manure. In three cities of Shiraz, Mashhad and Isfahan, the required equipments have been applied to use as a biogas in the areas of waste disposal (publication of renewable energy organization of Iran, 1380).

4. Biomass resources:

A part of solar radiation reaches to the atmosphere of earth is absorbed in plants due to photosynthesis process. This is one of the most appropriate energy resources created as a result of photosynthesis and it is multiple times more than the whole usual energy consumption of the globe. About 90 percent of this energy stored in the trees has been recorded as extractable fossil fuels reserves. Biomass resources which are suitable for energy production include a vast range of materials which are divided into six following groups:

1) Wooden fuels: wood is the main source of biomass energy which human being has used it not only in home usages but also in the vast range of industrial jobs over centuries.
2) Forest, agriculture, gardening and food industry wastes: the leaf of bran stem and subsidiary branches and … are residues and has organic materials.
3) Municipal solid wastes (MSW): the municipal solid wastes include different types of biomass like paper, construction waste and wastes resulted from commercial, office, house and industry operations. By settling these residues within the basement, the biogas could be obtained where by filtration of the obtained gas; we can use this gas in all the industries and especially as a boiler fuel within power stations.
4) Municipal sewage: sewages resulted from human habitats have substantial energy and as animal manure it could be fermented by anaerobic method and produce methane gas.
5) Animal manures: animal manures can be converted into biogas based on anaerobic digestion. As observed, all these materials have organic materials and are able to ignite. Therefore, we can determine a specific thermal value for each one. The thermal value due to the definition is a thermal value which is released from the mass unit of combustible material and this heat value

could be expressed based on the mass unit of either wet or dry material. According to the general following reaction, carbon dioxide and water accompanied with high amount of thermal energy is released from the combination of each organic combustible material with oxygen:

Combustible material + $O2 \rightarrow CO2 + H2O$ + thermal energy + ash + other gases

5. Biofuels:

It is a type of fuels obtained from biomass resources including fluid ethanol, methanol, biodiesel fuels and gas diesel fuels like hydrogen and methane. The researches on biological fuels have three main goals:

1. To produce biofuels
2. To find exploitation methods and use them
3. To determine the sparseness of its constructions

The production resources of these fuels include: sugarcane, plant and vegetable oil (publication of renewable energy organization of Iran, 1380).

6. Biomass energy conversion technology:

Technologies used to convert biomass into energy include from the simple open vapor systems which are developing to be used in cooking to advance Pyrolysis units producing solid, liquid and gas fuels. Biomass conversion technologies could be classified into three main classes: direct ignition processes, thermo chemical processes and biochemical processes.

1) Direct ignition processes: direct ignition is a fundamental process used to convert biomass into useful energy. The produced heat or vapor is consumed to generate electricity or provide the required heat for applications like industrial processes, space heating, cooking or heating of different municipal areas. In large industries, furnace and boilers have been improved to burn different types of biomass like wood, wooden wastes, black liquor resulted from operations of providing paper mache, wastes of food industry and municipal solid wastes. These units are so effective and could compete with efficiency of ovens of fossil fuels.
2) Thermo chemical processes: Pyrolysis is one of the most important processes of thermo chemical methods in converting biomass into valuable and suitable products. The generated products include: a gas compound, an oil like liquid and a thing like net carbon coal, the distribution of these products depends on the amount of store volume, temperature and reaction pressure and also duration of gas presence within ignition position and heat rate.
3) Biochemical processes: this type of processes has an application in biochemistry of raw materials and metabolic action of microbial organisms to produce gas and liquid fuels. There are various types of renewable biomass technologies thorough the globe or these technologies are developing.

7. Biomass heating systems

Biomass heating systems burn plant or other organic matter- such as wood chips, agricultural residues or even municipal waste - to generate heat. This heat can be transported and used wherever it is needed - for the ventilation and space heating requirements of buildings or whole communities, or for industrial processes. Biomass heating systems differ from conventional wood-burning stoves and fireplaces in that they typically control the mix of air and fuel in order to maximize efficiency and minimize emissions, and they include a heat distribution system to transport heat from the site of combustion to the heat load. Many biomass heating systems incorporate a sophisticated automatic fuel handling system. Biomass heating systems consist of a number of elements, including a heating plant, which typically includes an automated biomass combustion system and a peak load and back-up heating system, a heat distribution system, and a biomass fuel supply operation. The system can also include a waste heat recovery system from a process or electricity generation unit. (Ilias J. Gousgouriotis, Yiannis A. Katsigiannis, Pavlos S. Georgilakis, January - April 2007, p 84-88)

Biomass combustion system

In the Biomass Combustion System (BCS), the principal interest in a heating plant, the biomass fuel or feedstock moves through the BCS in a number of stages, many of which are illustrated in *Figure 1* and described here [NRCan, (2002) & (2005)]:

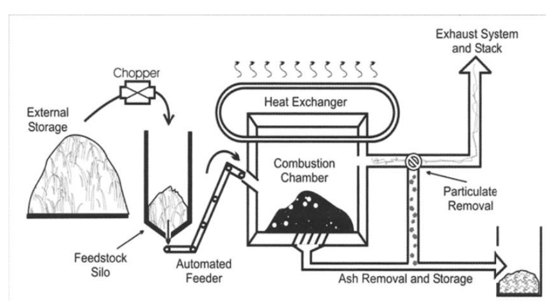

Figure 1: General layout of a biomass combustion system (Ilias J. Gousgouriotis, Yiannis A. Katsigiannis, Pavlos S. Georgilakis, January - April 2007, p 86)

8. Biomass heating economic evaluation model:

The methodology presented in this paper can be used to evaluate energy production, life cycle costs and mitigation of greenhouse gasses emission for biomass heating installations and/or a waste heat recovery system. The model has been designed to analyse a broad spectrum of applications, from installations in a large scale such as district heating, to individual applications in residential or industrial sector. The evaluation of the biomass heating project *(alternative heating system* from now on) is carried out in comparison to an existing or a potential heating system using fossil fuel or electricity produced by fossil fuel *(conventional heating system* from now on). To realize the evaluation, a series of technical elements and economic figures is necessary, based on which we shall determine whether the installation of a biomass heating system instead of a conventional fuel system is financially beneficial. In the first stage, we study the technological aspect of the investment where the existing conventional system is analysed and the alternative one is designed so that it fulfills energy supply requirements. Then, after appraising the costs and benefits of each system, a series of economic indexes is calculated, based on which the investment's efficiency is assessed. (Ilias J. Gousgouriotis, Yiannis A. Katsigiannis, Pavlos S. Georgilakis, January - April 2007, p 84-88)

8.1 Models main parameters

The main input data required are listed below:

8.1.1 Site conditions

- Heating design temperature
- Monthly heating degree days below 18~
- Domestic hot water heating base demand
- Heated floor area
- Heating load

This input data is used to estimate the heating energy demand and the peak heating load.

8.1.2 Base Case Heating System characteristics

- Heating fuel type(s)
- Heating system seasonal efficiency
- Unit cost of fuel

This input data is used to estimate the fuel cost of the existing (conventional) heating system.

8.1.3 District heating network

- Design supply/return temperature
- Length of pipe sections
- Use of transfer stations
- Unit costs of pipes and transfer stations

This input data is used to estimate the pipe size of the distribution lines (based on the heating loads) and the cost of the district heating network.

8.1.4 Renewable Energy System characteristics

- System type(s)
- Capacity
- Efficiency
- Moisture content on a wet basis of biomass

This input is used to estimate the percentage of the annual heating energy demand and percentage of the peak heating load that can be supplied by the renewable energy heating system. In general, the heating system may consist by a *Waste Heat Recovery* system (WHR) or a *Biomass* system or *WHR* and *Biomass* systems combined. Furthermore, it may include a *Peak Load* system to meet a small portion of the annual energy demand during peak heating periods. The *Peak Load* system may consume either fossil fuel or biomass. Finally, provisions are made for the use of a back-up system in case of system shutdown or because of an interruption in the biomass fuel supply.

8.1.5 Initial, annual, periodic costs (or credits)

The most significant initial costs of a project concern costs for project development,engineering, purchase and installation of the renewable energy equipment. The annual costs associated with the operation of a biomass and/or WHR heating system include costs for biomass fuel, peak load fuel oil and parasitic electricity consumption. In addition, property taxes, insurance, spare parts, O&M labour and general and administrative expenses could also be incurred. Periodic cost represents recurrent costs that must be incurred at regular intervals to maintain the project in working condition.

8.1.6 Financial parameters

- Energy cost escalation rate
- Inflation
- Discount rate
- Project life
- Debt ratio/Debt interest rate/Debt term
- Income tax analysis

This input data is used to evaluate the financial viability of the biomass project under alternative financing scenarios.(Ilias J. Gousgouriotis, Yiannis A. Katsigiannis, Pavlos S. Georgilakis, January - April 2007, p 84-88)

9. International projects

9.1 Sidwell Friends School, Washington, D.C., USA

Sidwell Friends School features a closed-loop system of water recycling, which processes the school's wastewater in a series of outdoor wetland gardens to be reused within the building. Both the SW 12th Avenue Green Street Project and the Blackstone Stormwater Garden featured in the Fluid chapter incorporate a decentralized bio-based system for integrated stormwater treatment.Designed with a capacity to retain rainfall during storm events, networked planters and bio-swales intercept polluted sediment migration before the sediment reaches nearby water bodies. (Digestive, p 100)

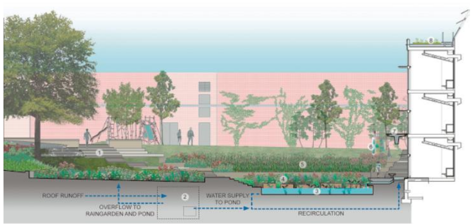

Figure 2:The wetland system treats sewage and grey water from the building.(Andropogon Associates + Kieran Timberlake Associates + Natural Systems International, p112)

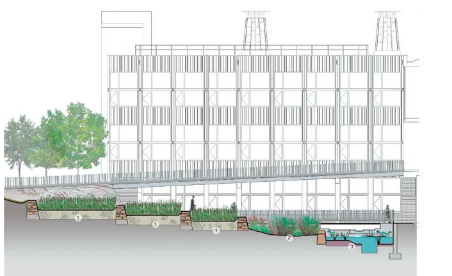

Figure 3: Illustrated section of wetland treatment systems. (Andropogon Associates + Kieran Timberlake Associates + Natural Systems International, p112)

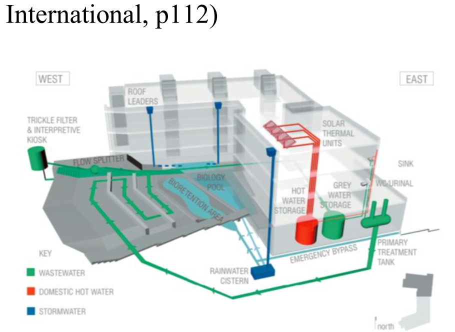

Figure 4: Diagram of the closed-loop water system. (Andropogon Associates + Kieran Timberlake Associates+ Natural Systems International, p113)

Figure 5: Perspective visualization of terraced wetlands and new building.(Andropogon Associates + Kieran Timberlake Associates + Natural Systems International, p113)

9.2 DaimlerChrysler Plaza, Potsdamer Platz, Berlin, Germany

Water-based resources, such as stormwater surface runoff or building wastewater, are typically categorized within a continual time sequence that requires micro- igestion. For example, the Water-Cleansing Biotope at the DaimlerChrysler Potsdamer Platz plaza continually metabolizes excess nutrients in rainwater collected from 13 surrounding buildings through a combination of filter substrate and water plants. Various substrates and materials are currently being studied for their capacity to biodegrade excess nutrients or harmful compounds in wetlands, biotopes, and bioswales. (Digestive, p 100)

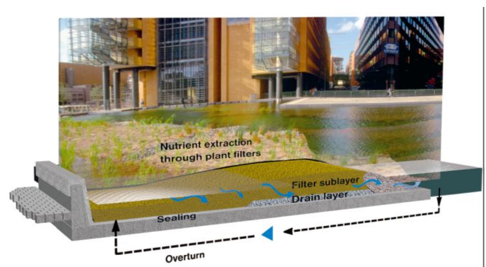

Figure 6: A diagram of sand-mineral substrate and aquatic plants. (Atelier Dreiseitl, p111)

Figure 7: Constructed on top of a traffic tunnel, the biotope is lined with a geomembrane. (Atelier Dreiseitl, p111)

9.3 Former British Petroleum Park, Sydney, Australia

Soil-based resources may combine the two scales of Digestive operations by employing both biological remediation via plants, bacteria, or fungus (mycoremediation), as well as macro strategies of cut and fill or concealment (capping). For example, the former British Petroleum Park combines three different Digestive operations: onsite soil bio-remediation; the introduction of coastal wetlands to continually cleanse polluted runoff; and the reuse of the site's infrastructure in order to redirect runoff to the wetlands. (Digestive, p 101)

Figure 8: Aerial photos of existing conditions after removal of drums and of constructed park. (A telier Dreiseitl,P103)

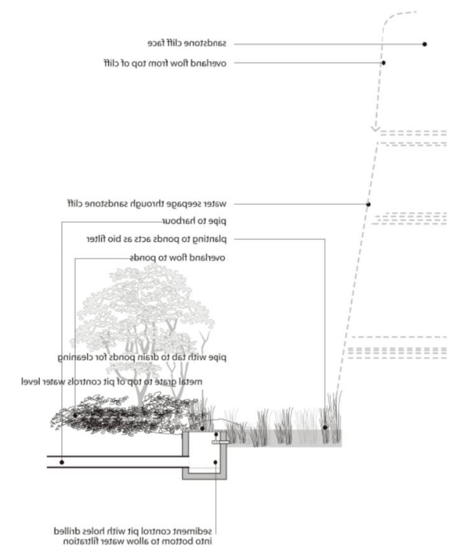

Figure 10: Biofiltration ponds and water control pit. (A telier Dreiseitl,P105)

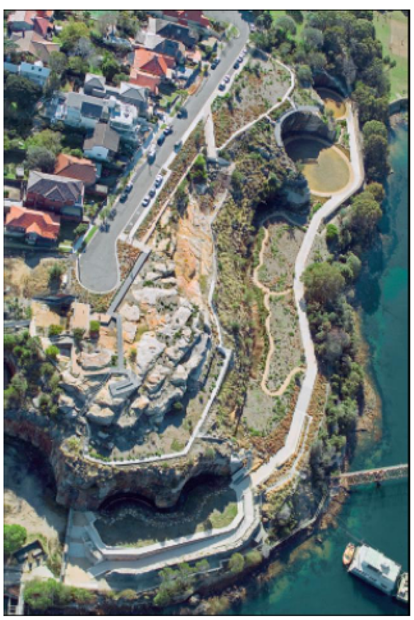

Figure 9: Plan showing the concrete platforms, where the drums once stood, as they relate to the stormwater detention wetlands.(A telier Dreiseitl,P103)

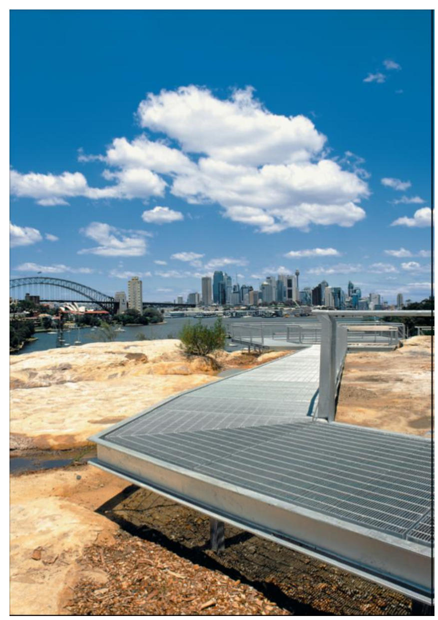

Figure 11: The emergent landscape and Sydney's skyline. (A telier Dreiseitl, P105)

9.4 The University of Hong Kong green-roof research site, Hong Kong

This field-based study in humid, tropical Hong Kong evaluated green roofs of three vegetation types with different growth forms and biomass structure in comparison with a control plot. The passive cooling effect of green roofs was investigated with respect to diurnal temperature variations across the vertical profile. As the first green-roof research in the city, the study could provide practical experience on extensive green-roof establishment and maintenance using different vegetation types. The findings could also provide a scientific basis to support the greenroof movement in tropical cities in this region and beyond. (C. Y. Jim, 2011)

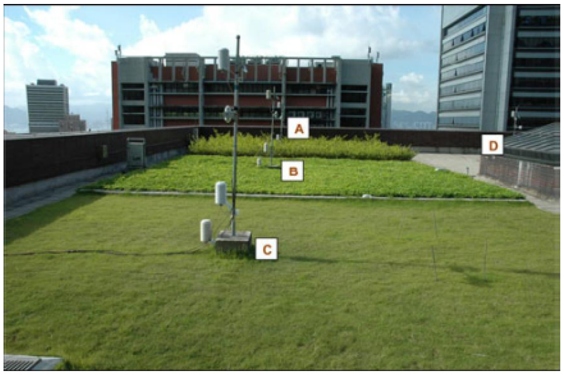

Figure 12: Three experimental plots (A, B, C) and the control plot (D) at the University of Hong Kong green-roof research site, with the environmental sensor stations located at the center of each plot (C. Y. Jim, 2011)

10. Projects of exploiting biomass energy in Iran:

1) Performed projects: project of potentiometry of biomass resources in Mashhas and Shiraz
2) Executing projects: construction of biomass pilot in Saveh – prodivding biomass atlas in the country – feasibility studies and construction of power station of 10 megawatt biomass. (http://www.suna.org.ir/projectdetail/fa-27.html)

11. Conclusion:

The date of initial emergence and growth of energy production patterns backs to few last centuries. But in the present century, due to emergence of problems caused by overuse of fossil fuels and introducing the problems of environmental pollutions and its resulted phenomena, the significance of studying fuel and energy production has been increased, so that in the developing countries, many activities are formed and processed in order to produce energy from clean fuel and innovation in this field and the motivation of all these activities is to solve the crisis caused by fossil fuels either in the form of limitation or in the form of pollution of environment and we as planners of a set called city or society must consider this important fact in order to create a desirable set and proceed in the path directing activities and researches so that it could improve this replacement in order to minimize the crisis caused by energy production and consumption. In order to achieve the goal of increasing the renewable energy proportion in energy consumption, architects should evaluate the site at the concept design phase. For site planning, how the buildings' and plants' arrangement will affect the utilization of renewable energy must be considered. In the construction design phase, constructing nodes, material selection and some other details must be carefully dealt with. On the aspect of management and equipment selection and others, architects should cooperate with the HVAC engineers and communicate with each other thoroughly, so that they can optimize the efficiency of the utilization of renewable energy (Fig. 13). By means of this integrated design, the utilization of renewable energy would not only stay in a stage where several PV boards are placed on the roof, but together with he building itself, they will become an integral and comprehensive system.

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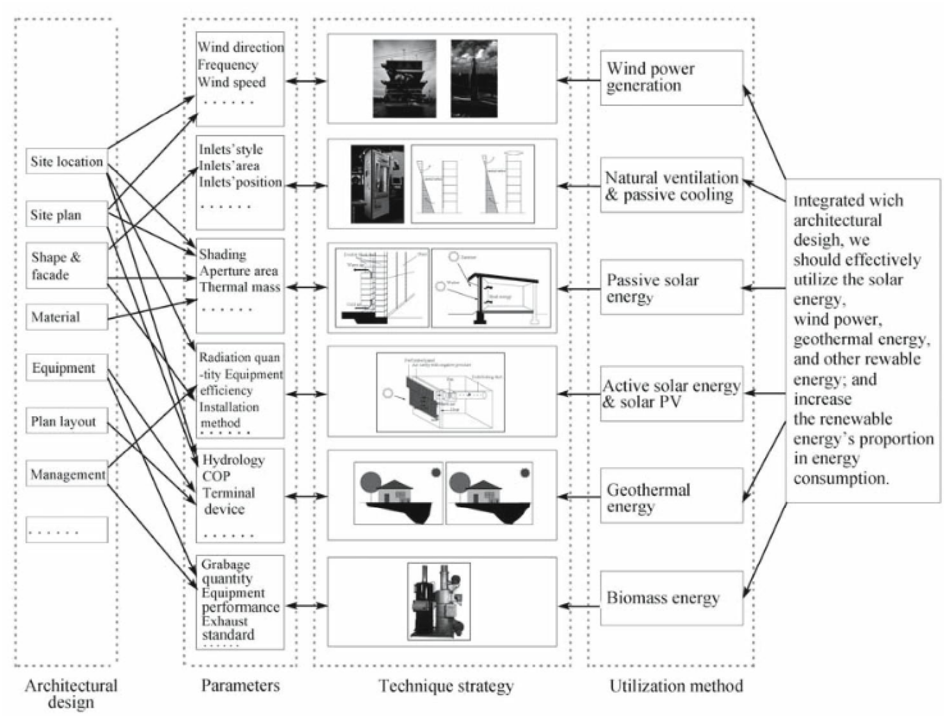

Figure 13: Diagram for integrated design method (TIAN Lei, QIN Youguo, 2007, p 114- 122)

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