International Urban Planning Conference 2005

2005 年国际城市规划年会

Xi'an, China

中国西安

24th – 27th September 2005

2005 年 9 月 24 日至 9 月 27 日

Keynote Address:

Towards a Low Energy, Sustainable Future for our Communities: A Low Carbon Vision for China-UK Collaboration

为我们的社区创造一个低能耗、可持续发展的未来：中英合作的低碳未来

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Towards a Low Energy, Sustainable Future for our Communities:
A Low Carbon Vision for China-UK Collaboration

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Abstract

It is widely recognised that significant steps must be taken soon to combat the ever-increasing emission of carbon dioxide into the earth's atmosphere and the consequential warming of the planet. Many prominent scientists believe that the developed world must aim to cut emissions by 60% by 2050 if the worst effects are to be avoided. This is a challenge facing us all as we strive to alleviate poverty and yet protect the planet and its resources for future generations. Tackling the problem requires innovation, creative solutions but above all a multi-pronged approach. It is insufficient to consider only technical solutions: the correct legislation and management structures must also be in place as well as a desire to continually assess and improve on past performance. Above all there must be a raising in awareness of the issues among the business and the general public. It requires a dialogue that is visionary and free of technical jargon.

In 2003 the **CRed** (Community Carbon Reduction Programme) was established in the University of East Anglia to provide an integrated approach to the problem of climate change. This paper reviews the approach taken by this programme and in particular the methods by which it is both engaging the community while at the same time trying to address the barriers which affect the development of a low carbon sustainable community. It is critical in this approach to recognise that there is much already which is effectively trying to promote a low carbon future, but often these are done in isolation and integration of complementary ideas is important. The **CRed** Programme recognises that while communities of the future will have to address the issue though innovative new design, planning and management, there remain substantial social barriers in tackling many areas. Issues such as old energy inefficient buildings present a particularly difficult challenge and yet these buildings will form the majority of buildings for many years to come. Innovative approaches to the design and improvement of both new and old buildings are thus needed.

Introduction

Climate Change is one of the most serious issues currently facing mankind and it will require innovative and integrated ways to tackle the challenges ahead. In 2000 the Royal Commission on Environmental Pollution (RCEP, 2000) published a report indicating that the UK should adopt a policy to reduce carbon dioxide emissions by 60% by 2050. This was consistent with its recommendation 21:

> *"Our view is that an effective, enduring and equitable climate protocol will eventually require emission quotas to be allocated to nations on a simple and equal per capita basis. There will have to be a comprehensive system of monitoring emissions to ensure the quotas are complied with.".*

While imposing a tough regime on developed countries it allows some increases in emissions in developing countries to achieve the ultimate goal of equality. The UK Government (2003a) in their initial response was not so convinced that this was the approach that should be taken, but nevertheless in the White Paper later that year (UK Government 2003b) accepted the RCEP's recommendation for a 60% reduction in CO_2 levels in the UK.

> *"There will be much more local generation, in part from medium to small local/community power plant, fuelled by locally grown biomass, from locally generated waste, and from local wind sources. These will feed local distributed networks, which can sell excess capacity into the grid.''*

Fig. 1. Shows the current annual emissions of carbon dioxide per capita for several countries ranging from 19.7 tonnes for the USA, through 9 tonnes in the UK and 2.5 tonnes in China. Following the RCEP recommendations an average per capita emission of approximately 4 tonnes per annum would be the target for each citizen on the planet.

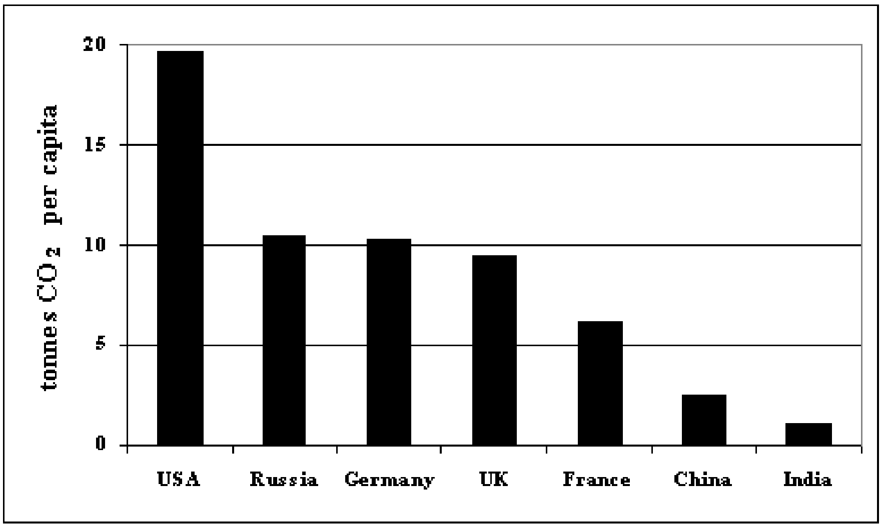

Fig. 1. Current annual emissions of CO_2 for selected countries. Data based on DTI (2005).

While the UK Government endorses the RCEP target, it gives little information on how the target will be met and thereby provide low energy, sustainable communities in the future.

It is essential that a multi-pronged approach be adopted which includes:

1. New and efficient ways of providing a diverse and secure supply of energy taking due account of any technical and physical limitations,
2. Raising awareness among businesses and individuals to demonstrate that every one has a role to play in reducing carbon emissions,
3. Innovative new low energy design of buildings,
4. Effective management of the infrastructure of buildings and distribution networks to ensure optimum performance,
5. Tackling the problem of energy inefficiency in existing buildings, particularly when many are historic symbols of our heritage,
6. Addressing issues of transportation and in particular personal mobility,
7. Providing solutions to an ever-increasing waste problem.

This paper begins with a discussion of the partnerships needed to promote a low carbon future and is followed by an outline of an innovative and visionary iconic concept for a novel integrated power station, which would be at the heart of the community. Initially it is envisaged such a project would be constructed in the city of Norwich in the UK. It is also intended that interest will be raised such that similar projects in other cities in the world, particularly those in China would also be developed. Finally there follows a brief review of some of the work undertaken by the University of East Anglia as it plays its part towards carbon reduction. Experience gained with some of these measures has promoted new ideas promoting low carbon futures.

The CRed (Community Carbon Reduction) Programme

The CRed (Community Carbon Reduction) Programme was established at the University of East Anglia in 2003. Its location in East Anglia is no accident as the University already housed the world renowned Climatic Research Unit, which had done much to confirm the existence of global warming, and the Tyndall Centre for Climate Change which is seeking ways to provide long term sustainable responses to climate change. The CRed programme takes up the challenge of the UK Government that significant progress must be made by the mid 2020s and is attempting to build an enlightened community which will reduce emissions by 60% by 2025 (not the Government target of 2050). If the programme suceeds then it will point the way whereby others can achieve the target by 2050. If it fails, then it will have identified the critical barriers so that these can be tackled in the period between 2025 and 2050.

The CRed programme approaches the issue of climate change and need for carbon reduction by promoting low carbon renewable technologies such as solar thermal, wind, and photo-voltaic, but also exploring the potential of biofuels like biodiesel and bioethanol. Furthermore there are projects within the CRed programme examining sustainable transport issues and the social, economic, and legislative barriers to the development of low energy buildings. The programme also attempts to provide integrated, "joined-up" solutions to the low carbon future and already a number of novel business opportunities have been identified. While there are several projects worldwide which are tackling some of these issues, most only tackle one, or at most two, of the key issues which must be resolved including the phsycial, technical, economic, political, social, and environmental challenges facing the world as it moves towards a low carbon future.

The CRed programme is somewhat unique in trying to tackle all of the above aspects. The programme has had some success in political lobbying, but has recognised that the social dimension is as important as the other aspects, and in many cases more so. Accordingly much effort is currently being directed towards this particular aspect. It was recognised that the correct language must be used if the general public are to be engaged in developing a low carbon, low energy, sustainable community.

The magnitude of the problem is demonstrated by Fig. 1 that the annual emission per person in the UK is 9 tonnes of carbon dioxide as a result of the energy they use. Few people have any comprehension of what 9 tonnes of the gas would look like in terms of volume, and a suitable visualisation is needed if the magnitude of the problem of global warming now facing the world is to be appreciated. Such a volume is almost exactly the equivalent of 5 hot air balloons and this has become the unofficial symbol of the CRed project and has been adopted readily by the local media in promoting low carbon strategies. In simple terms it means that in the UK the 5 hot air balloons must be reduced to 2 whereas in China there could be a per capita rise from the present 1.4 to 2 balloons. More recently CRed has realised that a smaller unit is also needed and a typical sized party-sized balloon equates to around 10g of carbon dioxide.

The CRed programme is also successful in conveying other important statistics in a simple way. For instance a typical small family car which is driven 15000 km in a year (typical distance in the UK) will emit around 1.2 hot air balloons of carbon dioxide demonstrating the ciritical issue of transport in combatting carbon emissions. With the correct and comprehensible language challenges can be set to the general public such as:

1. Leaving the TV on standby when not viewing can mean that the TV uses more electricity and emits more carbon dioxide when a person is asleep than when actually viewing. Alternatively, leaving the standby on causes the unnecessary emission of around 3500 party balloons of carbon dixoide.
2. Travelling just 2.5km in a small family car will emit as much carbon dioxide as heating an old person's room for 1 hour in winter.

Once messages such as these become known, CRed has found that people are willing to sign a pledge to make small changes to their daily lives to reduce carbon dioxide emissions. CRed has developed a unique pledging system which allows the tracking of how the project is performing (details may be seen on the website: www.cred-uk.org).

Educating social behaviour is as important as designing low energy buildings and a challenge set by the CRed team was to find out the potential savings that could be made by a concerted effort to switch off unnecessary applainces. This was aimed for a single day with publicity in the days beforehand as well as on the day itself. The results from a selected university building are shown in Fig. 2. While there is an obvious reduction in electricity use during weekends, there is also a general declinign trend during the month of April progressed as summer approached. This trend is highligted by the dotted line together with the grey band which shows the standard deviation of the daily readings. The targetted day was Friday 22nd April 2005, and there was a dramatic reduction (over 4 standard deviations from the trend line) indicating that this was indeed a real effect. On the following Monday there was also a noticeable reduction, but later that week the reduction was not so marked as people started to slip back into old habits. The magnitude of the reduction demonstrates the importance of such awareness raising. The University, together with CRed are now exploring ways where such savings may be made more permanent.

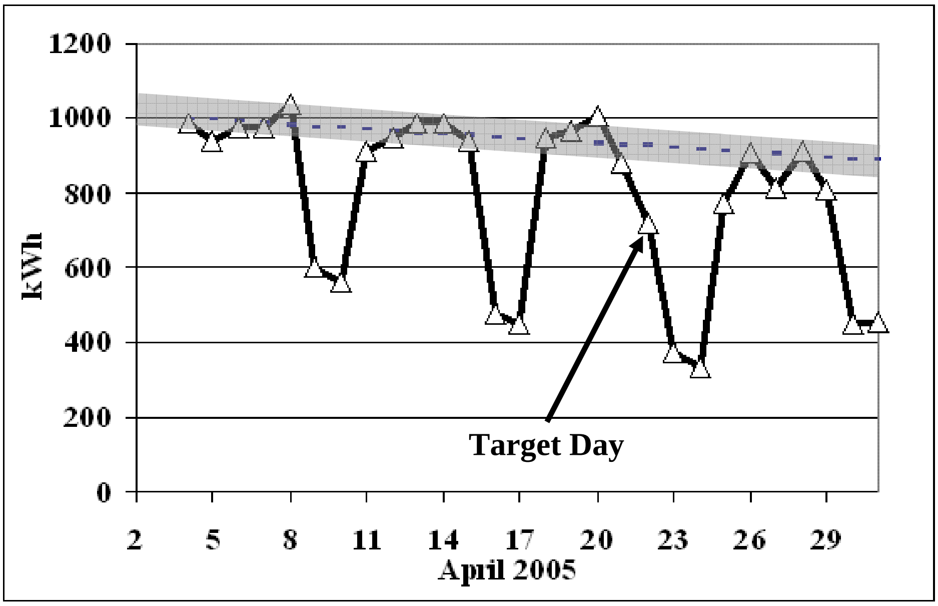

Fig. 2. The reduction in electricity demand in a building during a one-day campaign to reduce energy. Data from CRed (2005).

The CRed programme started at the University of East Anglia and focussed its initial efforts on the city of Norwich, the County of Norfolk, and the East and England Region. The interest from elsewhere has been such that there is already the nucleus of further CRed programmes elsewhere in the UK in towns and cities such as Ipswich and Cambridge, and District and County Councils such as West Midlands, Vale of White Horse, Hampshire etc. The message has also started to become international with developments focussed on the University of North Carolina, in Canada and also in Okinawa in Japan. More recently, through a Schools link project between the Xuhui District of Shanghai and Norfolk, a derivative of the CRed Project has started in China.

An Iconic Integrated International Exemplar of Low Carbon Practice

While the **CRed** Programme is being increasingly successful in engagement with the public and business, it is important not to let the momentum slip and to sieze all opportunities to promote low carbon practice. So frequently, ideas are fragmented and the full potential not realised. In older societies the production of power and energy was the responsibility of the local community. Today such provision is often so divorced from society as a whole that the general population do not always appreciate the consequences of their actions. It is important to provide user friendly educational facilities which can target both children and adults from all nations as it is our common future which can benefit from a concerted effort by all. Such a facility should be a "must-see" activity for all school children and demonstrate the link between climate energy generation, conversion and use and climate change.

CRed is ideally suited to the promotion of this education at the interface between society and technology and as part of the outreach programme has promoted an iconic, integrated, renewable power station which will not only be the focus for many businesses, but also a research centre and an exhibition and visitor attraction as well as a conference centre.

An exhibition centre and visitor attraction will be sited in proximity to an operating power station and will reinforce the link between climate change and energy providing the opportunity for visitors to become more informed on the difficult choices now facing us. The initial concept was envisaged for Norwich which is both a historic city and the most easterly city in England. As such it was promoted as the "Star of the East" and included an architecturally innovative wind turbine with six blades reprsenting the six counties in the East of England, a multi-channel biomass and waste plant and an extensive photovoltaic array. It is now recognised that such a concept could be ideally placed in many other cities around the world and be a major driving force towards a low carbon future. Several cities in China have a key element at the heart of their development plans the importance of renewable energy (e.g. Chongming Island). Indeed wind and biomass is part of the Master Plan for Expo 2010 in Shanghai. It is important that the power station is iconic and an archtectural featire in its own right rather than a basic energy generating facility. Birds-eye views of the scheme in Norwich which has been tailored to the site constraints are shown in Figs. 3 and 4.

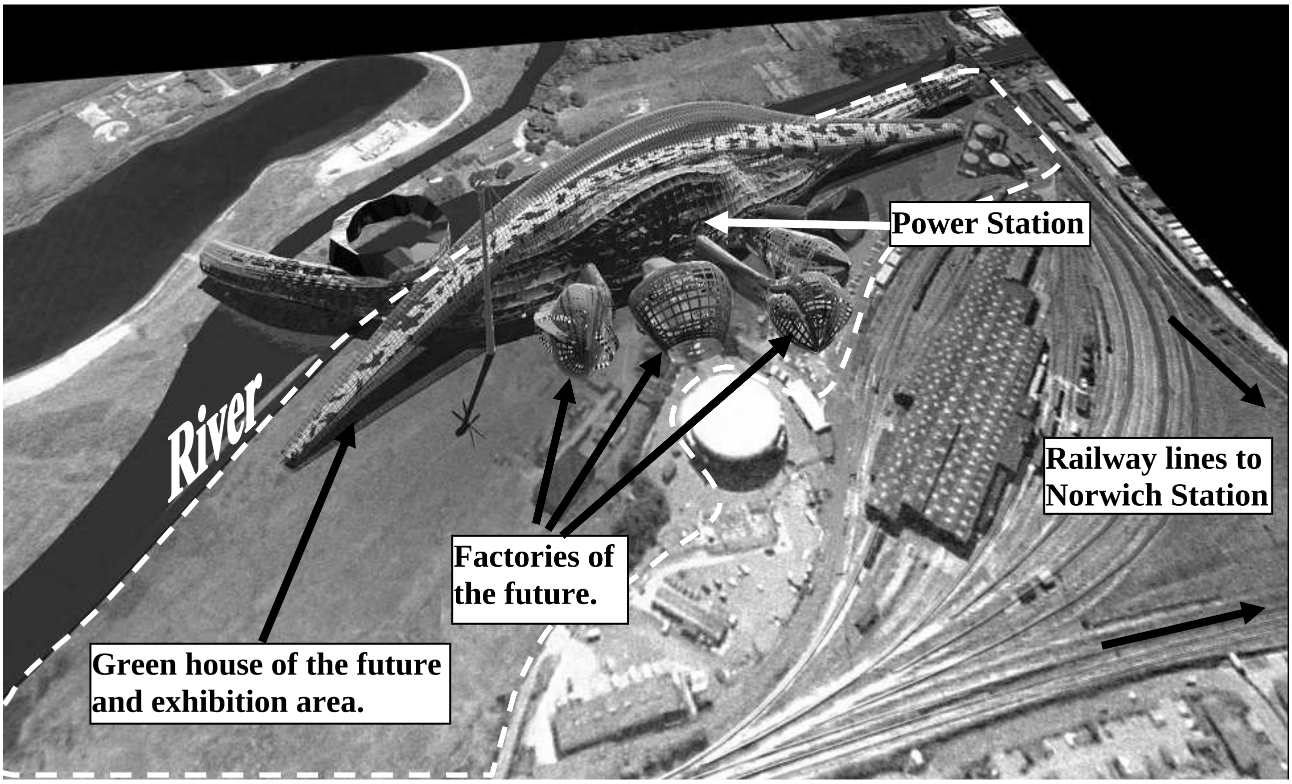

Fig. 3. A bird-eye perspective of the proposed innovative, integrated power station in Norwich viewed from the north-east. This is illustrative of what might be done elsewhere in China. The actual shape of the power station has been dictated by the land area available and shown by the dotted line.

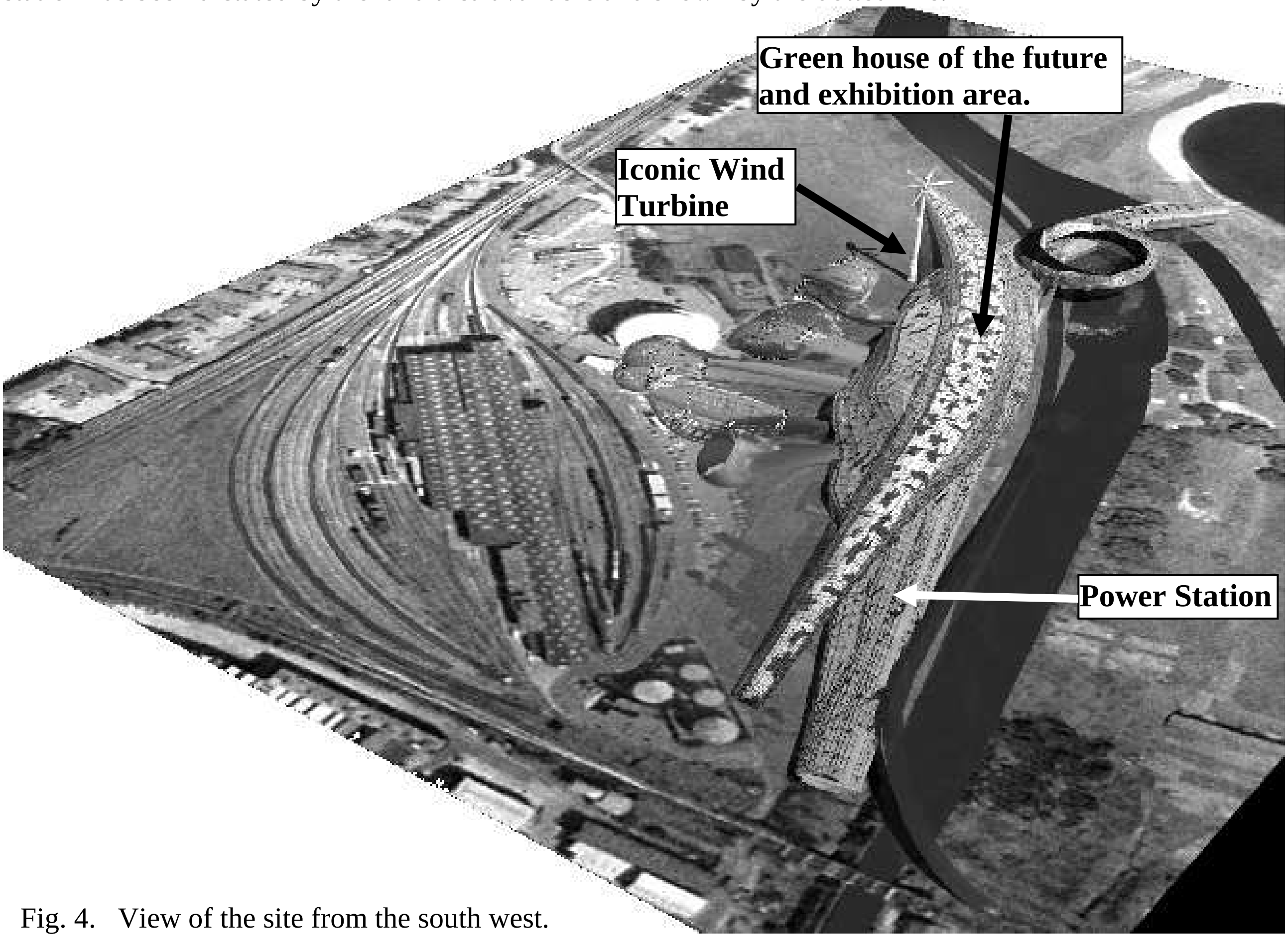

Fig. 4. View of the site from the south west.

The site in Norwich is particularly attractive for such a scheme as it covers 6 hectares and is the site of first a coal fired power station and until 2002 the site of a gas turbine station. It retains the grid connection and has a gas holder adjacent: transport connections are good with a railway line adjacent with connections to London and the Midlands and in particular through the Thetford Forest, a source of potential forest waste for the power station. While envisaged that it would provide an integral combined heat and power solution, the proximity of the river provides the opportunity for cooling should that be required. Furthermore it is less than 1 km for the city centre so that heat from the power station can be readily used for space heating in commercial and other developments nearby. It is envisaged that other cities, particularly in China will have similar attractive siting possibilities for such a scheme.

The Wind Turbine

The wind turbine (see also Fig. 5) will be around 90 m high and be a visible landmark which would be visible on the approaches by rail, river and road to Norwich and from many area of Norwich itself. It will be the second highest man made structure in the city being slightly lower than, and complementing, the magnificent gothic cathedral. While the cathedral was built in the first century of the second millennium and has been a symbol of Norwich ever since, so it is hoped that this project, built in the first century of the third millennium will be a symbol of man's move to a low carbon future. With six blades it will not be the most efficient design, but that is not the sole aim of the project. It is to promote awareness and be symbolic, and the wind turbine does just that. To emphasise its iconic nature it is intended that the tower will be transparent with the bare minimum of supporting steelwork. At night time it will appear that a star is floating in the sky. At the top will be visitors viewing platform which will give an unprecedented view across the countryside. On clear days the sea, which is less than 30 km distance, will be visible.

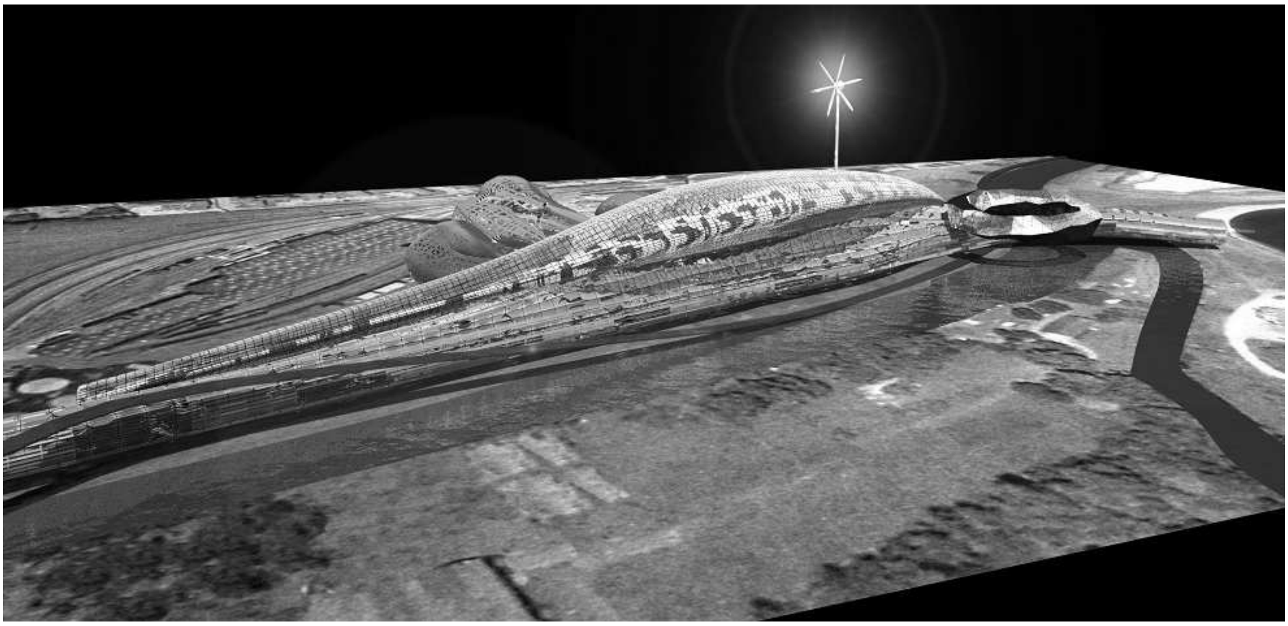

Fig. 5 The Wind Turbine provides a focal point to the complex.

The viewing platform will also allow visitor to appreciate the importance that carbon fuels have played in the development of mankind. Visible will be several stages in man's exploitation of energy resources:

1. The Broads: an area of world renown wetland which were formed in the middle ages as peat was cut to provide fuel - this can be referred to as the carbon-1 era
2. The carbon-2 era, or coal, which was never actually mined in Norfolk, but large reserves do remain under the landmass and out into the North Sea.
3. The gas rigs from the carbon-3 era (oil rigs in the north sea will not be visible)
4. Offshore wind turbines at Scroby Sands which point the way to the future post carbon era.

The turbine is shown as a six bladed machine and a symbol of the 6 counties in the East of England Region, but elsewhere other symbols might be used: for instance it might be appropriate for there to be 5 blades in a scheme built in China.

The Biomass Station

The main design of the power station is intended to be an architectural feature rather than a bulk standard box shape and is consistent with its function as a visitor attraction. In addition to the wind turbine, the power station would include a large photovoltaic array mounted on the roof of the "Greenhouse of the Future". The biomass/waste station will be modular in design and allow for new developments in technology and thus be future-proofed.. Being modular may raise the cost slightly, but the flexibility thereby achieved should ensure this is a particularly robust solution for the future. It is envisaged that one stream of the biomass station might initially be a mass burn incinerator, but with experience the other would incorporate pyrolysis and gasification to provide an efficient conversion of biomass to electricity and heat. An aim would be to design and operate a power station which could utilise several different biomass fuel sources. In appropriate locations it is envisaged that waste would be an important fuel source as this would provide an efficient and environmentally sound method for disposal if integrated with pyrolysis and gasification. The holding area for the fuel stock will be under the building fabric that will be maintained at a small negative pressure to avoid problems with smell etc.

The plan for the biomass/waste section of the power plant must address the issue of waste heat disposal. There is little problem in winter when district heating is required, but in summer the low demand for space heating can create problems and the intention is to incorporate adsorption chilling to allow tri-generation and use part of the rejected heat. The waste heat will also be used for space heating the exhibition and adjoining conference facilities in winter and via the adsorption chiller for cooling as required in the summer.

As an alternative to advanced biomass pyrolysis and gasification it is planned that at least one of the processing channels would be used to deal with municipal waste and thereby reduce the need for landfill. An innovative design of this type has already been demonstrated at the commercial scale in Avonmouth in the UK. This plant developed by CompactPower (CompactPower, 2005) can deal with all types of non radioactive waste has proved to reliable and is modular and would be an ideal partner in such a project as envisaged in the integrated power station.

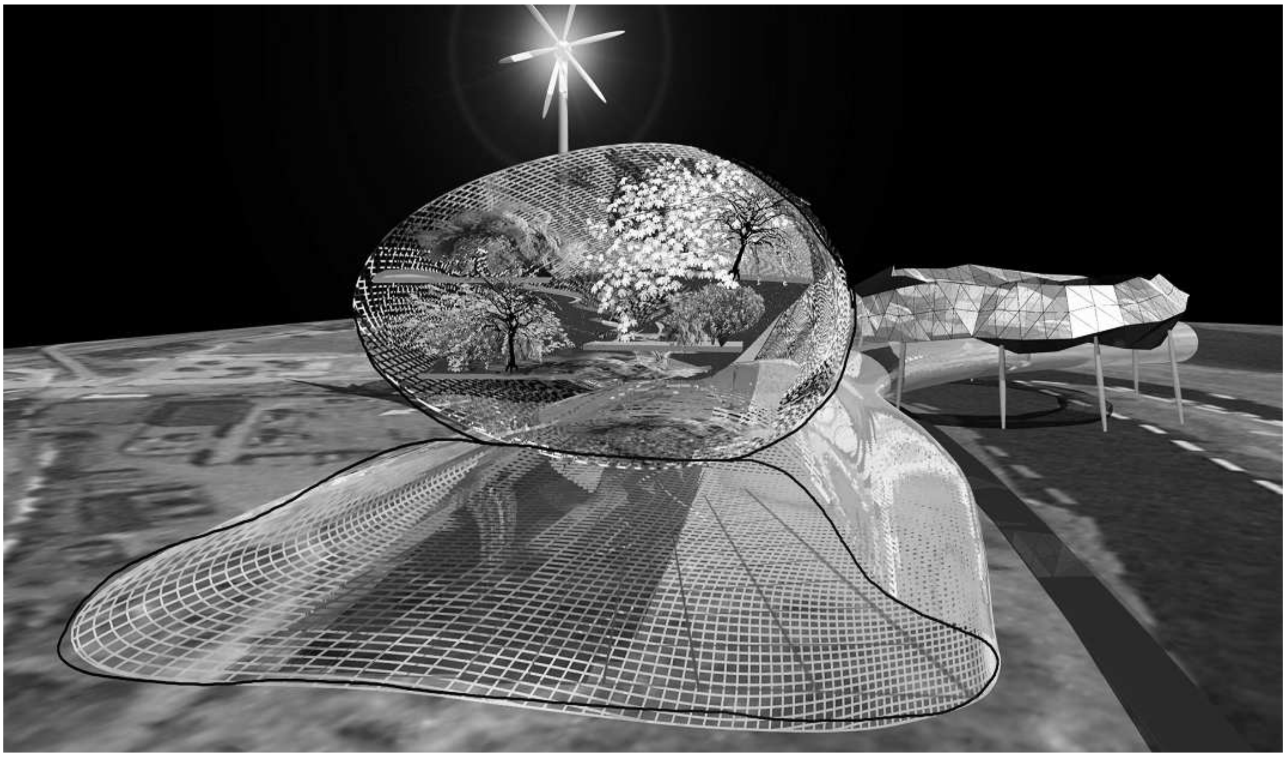

Fig. 6 A cross section of the power station and the "Greenhouse of the Future"

The Factories of the Future

The factories of the future are envisaged to be those which will develop as society moves towards a low carbon future. At an early stage, biodiesel and bioethanol as diesel and petrol substitutes will be included.

Unlike biofuel production elsewhere which requires fossil fuel derived process heat and electricity, it will take advantage of the adjacent renewable power station and thereby minimise the carbon emission associated with the full fuel cycle. Once the infra structure for bioethanol has been established such a complex would be ideal to explore newer developments including the production of bioethanol from Municipal Waste and in this way not only would reduce an every growing waste problem, but also provide a low carbon solution for transportation.

Greenhouse of the Future

It is envisaged that Greenhouse of the future will be partly devoted to the exhibition area and partly devoted to research to explore how vegetation and crops would respond to changes in climate. A cross section of this and how it might look partly superimposed on the power station is shown in Fig. 6. The temperature within the research area will be controlled from the excess heat (or chilling) from the power station itself.

Low Carbon Futures at the University of East Anglia

The University of East Anglia (UEA) has been proactive in promoting low carbon technical strategies for the last 15 years. The strategies adopted have included the construction of innovative low energy buildings and the development of integrated fuel efficient strategies for campus energy. The campus itself has many older energy inefficient buildings built in the 1960s which are now Grade 2 listed and these present a particular challenge to the University. While this is an important challenge, the current paper focus on the issues surrounding the new buildings and the energy supply.

One of the particularly innovative methods of building construction is the “Termodeck” principle which incorporates a highly effective regenerative heat exchanger which is 87% efficient in recovering heat from the mechanical ventilation system. Four buildings have so far been built using this system with a fifth to follow shortly, and these give the UEA Campus the highest concentration of such energy efficient buildings in a temperate climate. The construction uses lightweight hollow slabs for the floor through which both incoming and exhaust air can circulate. The principle of operation is summarised in Fig. 7.

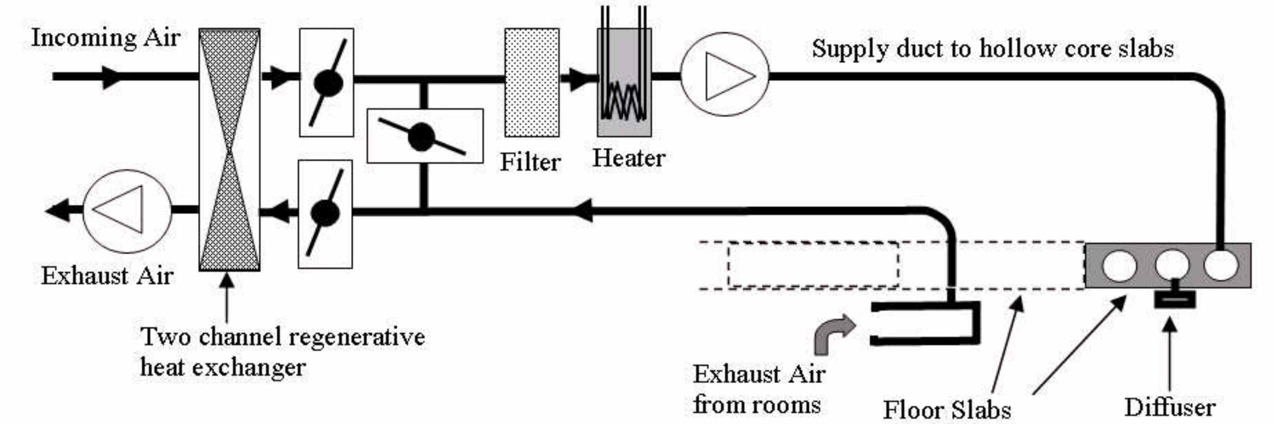

Fig. 7. Schematic diagram showing the principle of the "Termodeck" construction which results in a particularly low energy design.

Incoming air is first heated in the two channel regenerative heat exchanger before passing through a filter and a heater bank which might be supplied from any suitable source. The air passes through the hollow core sections and emerges through diffusers. Stale air from the occupied spaces is captured in separate ducts and taken back to the regenerative heat exchanger where the majority of the residual heat is extracted. The two channels of the heat exchanger switch over at approximately 90 second intervals to provide a very high heat recovery rate.

The first building of this type on the UEA campus was the Elizabeth Fry Building (Fig.8) which was first occupied in early 1995. When constructed it was hailed as “the best building yet” by Probe (1998) and, despite costing less than 10% more, achieves an impressive energy performance such that heating for the whole building is supplied by a single domestic heating boiler. Exhaust air from the rooms collects waste heat from the low energy lighting, and is passed through the ducts to the regenerative heat exchanger. Even when the outside temperature is as low as 9°C it is rare for any heat to be supplied by the boiler. The U-values for all these buildings not only exceeded the Building Regulations in force at the time of construction but are likely to exceed them also for several years and probably decades to come.

Fig. 8. The Elizabeth Fry Building completed in 1995.

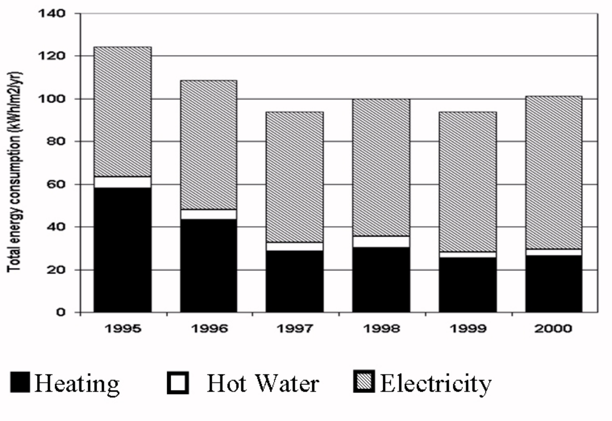

Fig. 9. Performance of Elizabeth Fry Building.

Since both the warm incoming air and stale air circulates through the building fabric the structure is close to the air temperature and this improves the perception of thermal comfort. The hollow core structure allows the full impact of the thermal mass of the building to be utilised in stabilising the temperature within the building even with quite large diurnal swings. In climates where the nights are cool in summer, but the days are hot, the fabric of the building can be pre-cooled over night thereby reducing and in many cases eliminating the demand for space cooling. In hot climates this can be an important consideration as the peak cooling requirement can be substantially reduced.

The building initially performed well, but by careful fine-tuning over the first two years the space heating requirement was reduced by a further 50% to just 33 kWh/ m^2 / yr (Fig. 9) and this was just 20% of the standard for academic buildings (PROBE, 1998).

Fig. 10. The ZICER building showing the photovoltaic array on the top floor.

An even more innovative building on the campus is the Zuckerman Institute for Connective Environmental Research (ZICER) shown in Fig. 10. This developed the concept of the Elizabeth Fry Building and included a 34 kW PV array on the façade of the top floor and the roof of the building. The lower four floors (including the basement) were constructed as a "Termodeck" construction with an exhibition area on the top floor which was designed to demonstrate the use of photo-voltaic cells. The heating requirement of this building was expected to be around 90% of that of Elizabeth Fry. The early results of the performance of the new building were not encouraging with heating requirements double that of the Elizabeth Fry building when expressed in terms of heat requirement per unit area. Careful analysis of the data suggested that a different management regime using control of the temperature of the slabs might be appropriate and this was implemented in the summer of 2004. The consequence has been a dramatic improvement in performance with the ZICER building substantially outperforming the Elizabeth Fry building for most of the winter (Fig. 11). This demonstrates that to achieve low energy sustainable buildings requires not only good initial design, but also careful management of heating strategies if the optimum performance is to be achieved.

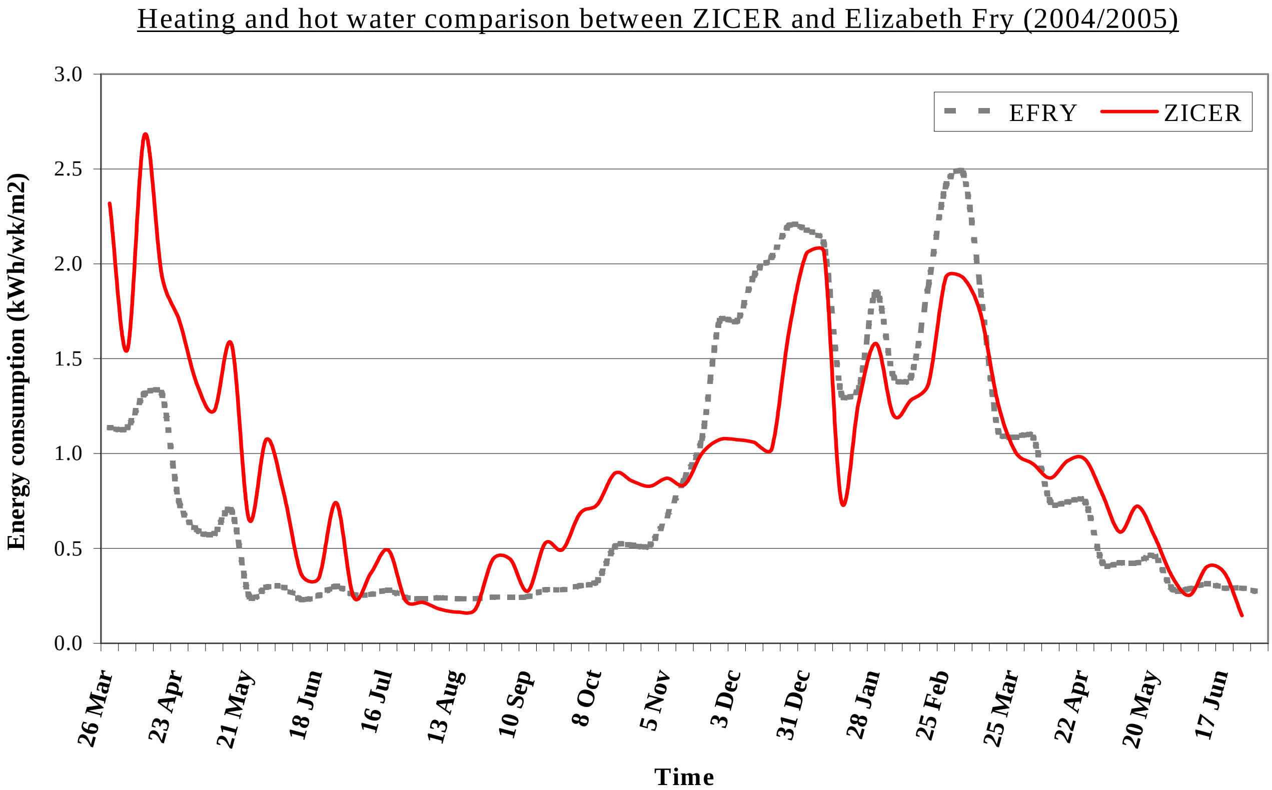

Fig. 11. The actual performance of the "Termodeck" section of the ZICER Building compared to the Elizabeth Fry Building.

All the "Termodeck" buildings are well sealed and rely for their performance on good air-tightness. There is provision for individuals to open the windows, although this facility is seldom used. However, it is important that such provision is available as acceptability of the working environment will become important as buildings of low energy standards are built. A survey of user satisfaction in the Elizabeth Fry Building demonstrated that in all the measured categories the perception of the building was above average as shown in Table 1.

Table 1. Perception of users of Elizabeth Fry Building

Criterion	Relative to a standard building
Thermal comfort	28% better than average
Air quality	36% better than average
Lighting	25% better than average
Noise	26% better than average

The low energy demands of the "Termodeck" buildings have been achieved through careful consideration of ventilation heat recovery. As standards of insulation increase, ventilation becomes an increasingly important part of the total energy requirement. It is essential that ventilation heat recovery becomes integral in the design of most new buildings. While natural ventilation can be effective, it should be tested against the option of ventilation heat recovery before being considered as a possible option.

Low Energy Strategies for supplying Heat and Electricity to Campus Buildings

The majority of buildings on campus have heat supplied from a central boiler house. In the late 1990s the option to install high quality CHP was taken. Three gas engines provide the motive power for the three 1 MWe generators (Fig. 12). A total of 4.2 MW of heat is also supplied while supplementary heat in winter is supplied from the existing boilers. At times the scheme is a net exporter of electricity, but since the introduction of the New Electricity Trading Arrangements (NETA), and their subsequent replacement by the British Electricity Transmission and Trading Arrangements (BETTA) on April 1st 2005, the financial viability of export has not been as great, particularly since the price of gas as the fuel source has risen so dramatically since mid 2003. Nevertheless after installation of the CHP units a saved around £400 000 per annum in energy bills compared to an original bill of £1 000 000. Table 3 shows the proportion of electricity generated by the CHP Units.

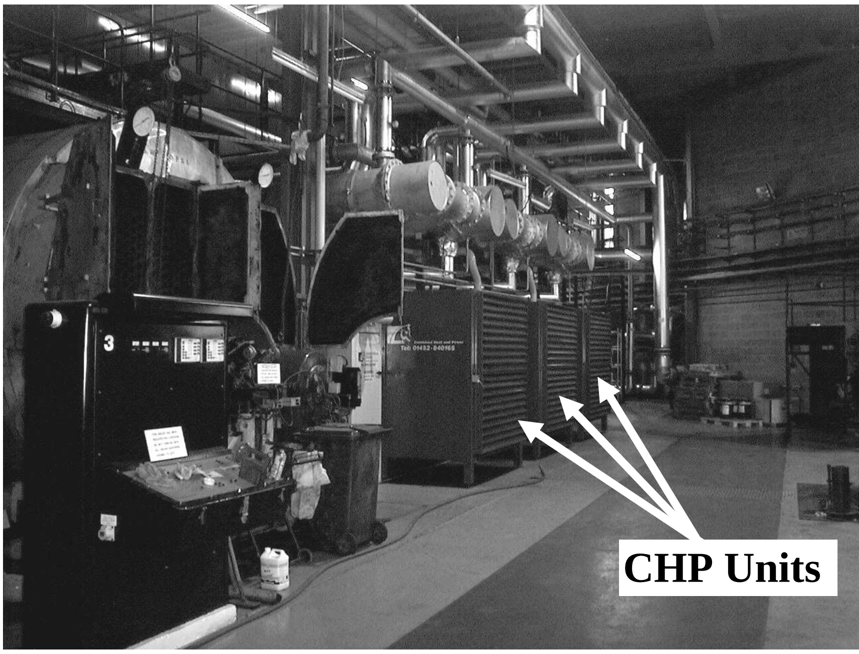

Fig. 12. The CHP units and one of the boilers in the main boiler house.

Table 3. Electricity generated on campus, total demand and percentage supplied by CHP

	CHP generated	Total Demand	Percent supplied
	MWh	MWh	
1999	16753	20432	82.0%
2000	15301	21410	71.5%
2001	18440	24756	74.5%
2002	15644	25611	61.1%
2003	15655	26277	59.6%
2004	17567	26961	65.2%
2005	01/01/2005 to 31/07/2005		
	11198	16422	68.2%

Notes:
i). values for 2000 were affected by a major overhaul of units
ii). after 2001 financial viability for export was affected by NETA.

The electricity generated in schemes such as these are particularly beneficial in promoting low energy communities as the electricity is used locally and avoids the normal losses of electricity associated with transmission. Tables 4 and 5 show a comparison in the carbon dioxide emissions in the last full year before installation and the first full year after installation. A reduction in carbon dioxide emissions from 15699 tonnes to 10422 tonnes was achieved - a saving of 33%.

Fig. 13 shows the utilisation of the CHP units over the period from installation in mid February 1999 to 31st July 2005. The average load factor is 67% but this falls to below 40% during the summer months when there is little demand for heat (Fig. 13). To improve the utilisation of the CHP units an adsorption heat pump is being installed and is due for commissioning in late September 2005. This will provide much of the ever increasing demand for cooling by scientific equipment during the summer months and also allow a increased generation of electricity. It will also decrease the amount of electricity imported for chilling and this represents a "win-win" situation and should allow an increased amount of electricity to be exported. It is estimated that a further 350 – 400 tonnes of carbon dioxide will be saved by this means.

Table 4. Energy use and annual CO_2 emission at UEA Campus before installation of CHP.

1997/98		electricity	gas	oil	total
	MWh	19895	35148	33	
emission factor	KWh/kg	0.46	0.186	0.277	
carbon dioxide	Tonnes	9152	6538	9	15699

Table 5. Comparable data for first complete year after installation of CHP

		Electricity				Heat			
1999/ 2000		total site	CHP generation	export	import	boilers	CHP	oil	total
	MWh	20437	15630	977	5783	14510	28263	923	
emission factor	kWh/kg			-0.46	0.46	0.186	0.186	0.277	
carbon dioxide	tonnes			-449	2660	2699	5257	256	10422

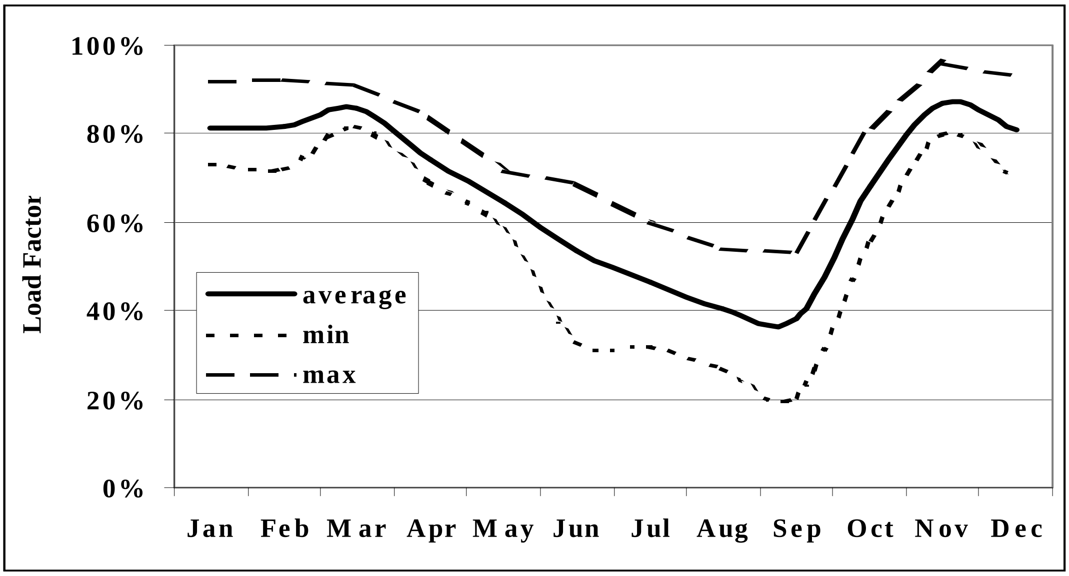

Fig. 13. Variation in load factor for electricity generation by the CHP units. The graph demonstrates the under utilisation of units in summer because there is limited demand for heat.

In addition to the adsorption chilling, the University is planning to start a feasibility study into the installation of a biomass CHP unit in late 2005. This unit will be larger than the existing units at 1.4 MW electrical and 2 MW heat. Biomass may be considered to be carbon neutral if it comes from sustainable growth. However, the growing, harvesting and transportation of such biomass will entail energy use, much of which will be as fossil fuel, and so there will still be some emissions of green house gases even though on a lower scale than normal fossil fuels. Initial estimates of such a scheme suggest that a further saving in carbon dioxide emissions of 3500 – 5000 tonnes per annum is possible.

Conclusions

Sustainable low energy communities will be most successful if a multi-pronged approach is adopted. While innovative new low energy design is a necessary first step, engagement with the local communities is equally important. The Community Carbon Reduction Programme (CRed) has identified several important issues which are needed ensure the most successful outcome to low carbon strategies. These include the following points.

1. Effective innovation should be at the heart of all new sustainable development and building design. However it is important recognised that ventilation issues are becoming increasing important as tighter fabric regulations are adopted.

2. Highly efficient heat recovery is possible using regenerative heat exchangers.

3. Low energy design is not enough by itself, it is possible to improve on actual performance by careful monitoring and analysis of the energy profile over the first 12 – 24 months and adapting the energy management strategy accordingly.

4. Tri-generation incorporating CHP and adsorption chilling should become an integral part of energy supply to many building complexes – significant savings in carbon dioxide emissions are possible.

5. Legislation such as that currently in force in the UK relating to the supply and distribution of electricity can be counter productive to an effective promotion of low energy strategies.

6. Appropriate education campaigns can lead to substantial savings in energy even in existing buildings, but thought is needed to ensure gains are not lost through subsequent back-sliding.

7. There is the need to engage with the general public in a manner similar to that now adopted by **CRed** in and increasing number of places around the world. To do this requires careful thought on the units to be used. The **CRed** programme has found that using volumes equivalent to every day items is often a compelling way to engage people. This engagement can be backed up with a Pledge scheme similar to the **CRed** Pledge system which individuals and corporations are now adopting in increasing numbers.

8. An iconic integral renewable energy power station combined with exhibition, educational, and conference facilities would be an excellent way to further engage the public.

Acknowledgements

The author wishes to thank Charlotte Turner, a Post Graduate student in Environmental Sciences at the University of East Anglia, and Mel Pascoe, the Energy Manager at the University of East Anglia for providing data presented in this paper.

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为我们的社区创造一个低能耗、可持续发展的未来：

中英合作的低碳未来

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摘要

我们必须采取大的措施，解决二氧化碳向地球大气中的排放不断增加的问题，以及由此导致的地球变暖问题。许多著名的科学家认为，发达国家必须在 2050 年以前减少 60%的排放量，这样才能避免出现最坏的结果。我们一方面在尽力消除贫困，一方面又要为我们的后代着想，保护地球的环境和资源，这是我们全人类共同面临的一个挑战。要解决这一问题需要创新和创造性的解决方案，然而最重要的是要有一个多元化的方法。仅仅考虑技术上的解决方法是远远不够的，还需要正确的立法和管理结构，以及不断评估并且改进以往做法的强烈愿望。最重要的是必须在企业和公众之间加强对这一问题的重视程度。这就需要一个没有术语的展望未来的对话。

2003 年，在东英吉利大学建立了社区减碳项目(CRed)，提供解决气候变化问题的综合方法。本论文回顾了这项计划所采取的方法，通过其中的一些方法，既让社区参与，同时又尽量突破那些阻碍低碳可持续发展社区发展的障碍。在这种方法中，重要的是要认识到虽然已经有效地促进创造低碳的未来，但是这些工作往往都是孤立的，而综合各种想法恰恰是至关重要的。社区减碳项目认为尽管未来的社区将需要通过创新的新设计、计划和管理来解决这个问题，但在解决许多方面的问题上还存在重大的社会障碍。诸如老式的能源效率低的建筑就是一个很难解决的问题，而在未来的很多年内像这样的建筑仍将占主导地位。因此，不论是新建筑还是老建筑，其设计和改善都需要创新的方法。

引言

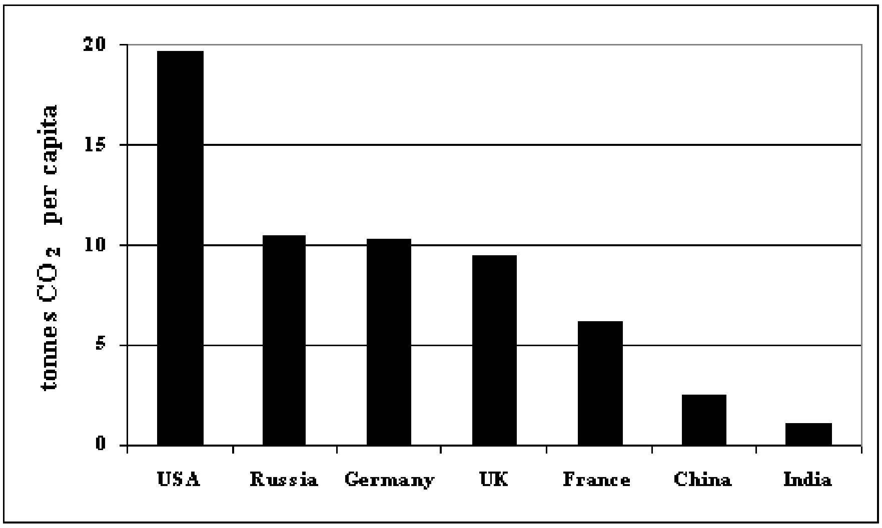
气候变化是目前人类面临的最严重的问题之一，需要采用创新的综合的方法来解决。2000 年皇家环境污染委员会发布了一份报告，报告指出英国应该在 2050 年前减少 60%的二氧化碳排放量。这是符合其建议 21 条的：

> *“ 我们的观点是一份有效、持久和公平的气候议定书将最终要求以一种简单的平等的人均为基础，对各国的排放量限额进行分配。必须有一个监控排放的综合机制，确保不超出配额的限制。”*

建议 21 条在对发达国家施以严格控制的同时，允许发展中国家的排放量有一定的增加，以实现最终的平等目标。英国政府(2003a)最初并不认为应该采取这样的措施，不过在当年晚些时候的白皮书中(英国政府 2003b)接受了皇家环境污染委员会提出的英国减少 60%的二氧化碳排放量的要求。

> *“将会更多的采用当地发电，一部分来源于中小型的地区/社区发电站，这些发电站以当地生长的生物质作为能量，而这些生物质则来自于当地产生的废弃物和当地的风能资源。这将满足当地配电网的需求，剩余的电能还可以卖给电网。”*

图一：显示了一些国家二氧化碳的人均年排放量，从美国的 19.7 吨，到英国的 9 吨，再到中国的 2.5 吨。根据皇家环境污染委员会的建议，全球人均每年排放量的目标为大约 4 吨。



(图中：从左到右依次译为“ 人均二氧化碳排放量，单位：吨” 、美国、俄罗斯、德国、英国、法国、中国、印度)

图一：目前一些国家二氧化碳的年排放量。资料来源：英国贸工部(2005 年)。

虽然英国政府同意了皇家环境污染委员会提出的目标，它并没有透露将如何实现这一目标，进而在未来创造低能耗、可持续发展的社区。

采取多元化的方法是至关重要的，其中包括：

8. 适当考虑技术和自然限制的基础上，高效地提供多样化而又安全的能源的新方法，
9. 提高企业和个人对于此问题的重视程度，证明降低碳排放量人人有责，
10. 建筑设计走低能耗的创新路线，
11. 有效管理建筑和配电网的基础设施，确保性能得到最大程度的发挥，
12. 解决现有建筑中能源效率低的问题，尤其那些是作为名胜古迹的建筑，
13. 解决交通问题，尤其是个人出行方式的问题，
14. 解决废弃物不断增加的问题。

本论文首先讨论了为了创造一个低碳的未来所需要的进行的合作，然后给出了一个将位于社区中心的新型综合发电站的创新的设想图纲要。最初的设想是将在一个英国的诺威治建立这样一个项目。同时也希望世界其他城市，也能对类似的项目感兴趣，尤其是希望在中国的一些城市开展这样的项目。最后，简要回顾了东英吉利大学为降低碳排放所做的一些工作。通过这些方法获得的经验引发了一些有助于创造低碳未来的新观点。

社区减碳项目

2003 年东英吉利大学建立了社区减碳项目。选在东英吉利大学绝非偶然，那里设有世界著名的气候研究小组，该小组对于证实气候变暖做出了巨大贡献，此外那里还设有廷德尔气候变化中心，该中心正在努力寻求长期的可持续发展的方法，解决气候变化问题。社区减碳项目承担了英国政府面临的挑战，即在 21 世纪 20 年代中期以前必须取得显著进展，该项目还试图建立一个开明的社区，这个社区将在 2025 年以前降低 60%的排放量(而不是政府设定的 2050 年)。如果这个项目能够成功，那么它将指明一条道路，使其他地区也能在 2050 年实现目标。如果这个项目失败了，那么它将可以凸显一些重大障碍，那么这些问题可以在 2025 年到 2050 年的期间内得以解决。

社区减碳项目解决气候变化问题、减少碳排放量，一方面是靠是推广低碳的可再生能源技术，例如太阳能、风能和光电能等，另一方面是靠发掘生物燃料的潜力，例如生物柴油和生物酒精。此外社

区减碳项目内还包括许多项目，调查可持续发展的交通问题，以及阻碍低能耗建筑的发展的社会、经济和立法障碍。该项目还试图为创造低碳的未来提供综合、联合的解决方案，而且已经出现了许多新的商机。虽然全世界有不少项目正在解决这些问题，大多数项目只是解决主要问题中的一个，或者只多两个，这些必须解决的主要问题包括全世界朝着低碳未来前进的过程中所面临的物质、技术、经济、政治、社会以及环境等方面的挑战。

社区减碳项目试图解决上述各方面的问题，这是独一无二的。这个项目在政治游说方面已经取得了一些成功，但同时也认识到社会领域与其他方面一样重要，而且在很多情况下甚至更加重要。因此，目前在社会领域这个方面投入了很大的精力。该项目还认识到，要想让公众参与到发展低碳、低能耗的可持续发展社区的活动中，必须采用正确的语言风格。

这个问题的重要性从图一中可以证明，在英国，使用能源导致的二氧化碳排放量人均每年为 9 吨。几乎没有人知道 9 吨气体的体积看起来有大，因此如果想让人们充分理解人类面临的全球变暖问题的严重性，就需要对此加以适当的形象化。最准确的说法是，9 吨气体的体积相当于 5 个热气球。这一比较已经成为了社区减碳项目的非官方标志，而且为当地媒体欣然接受，用于宣传低碳战略。简单的说，在英国 5 个热气球应该减少为 2 个，而在中国人均量可以从目前的 1.4 个热气球上升到 2 个。最近，该项目又意识到还需要更小的单位，即派对上一个典型大小的气球中的气体相当于约 10 克的二氧化碳。

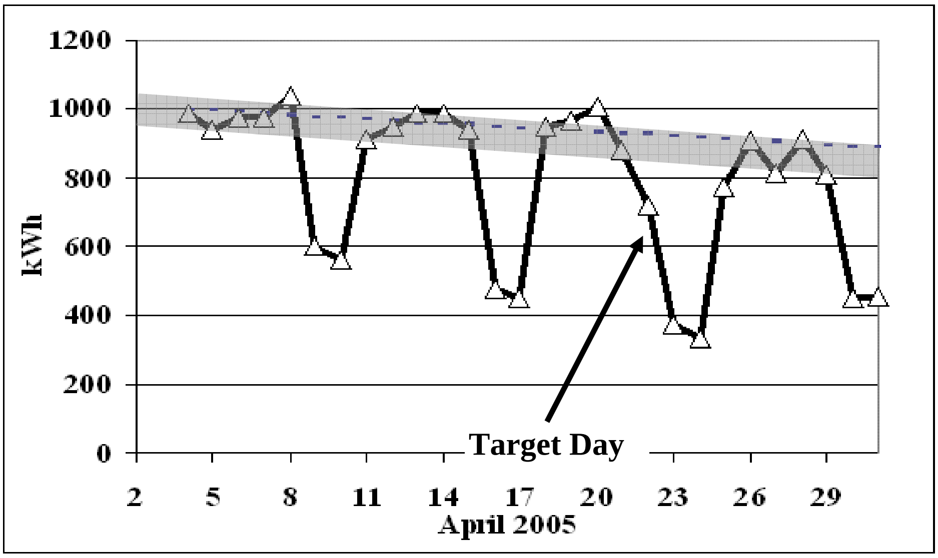
社区减碳项目在运用简单的语言传达其他的重要数据方面也取得了成功。比如，一辆每年行程 15,000 公里(这在英国比较典型)的典型的小型家用轿车将排放约 1.2 个热气球的二氧化碳量，显示了降低碳排放量时解决交通问题的重要性。由于使用了正确的、易于理解的语言，可以向公众传递以下信息：

3. 不看的时候让电视机处于待机状态意味着人在睡觉的时候电视机比人看电视的时候消耗更多的电力，并且排放更多的二氧化碳。换句话说，让电视待机造成的二氧化碳排放量相当于 3,500 个派对气球。
4. 开着小型家用轿车行 2.5 公里排放的二氧化碳相当于冬天老人房间一个小时的暖气。

社区减碳项目发现，人们一旦了解到这些讯息，便愿意签名保证对他们的日常生活做一些小小的改变，以降低二氧化碳的排放量。该项目发展了一套独特的保证体制，能够对项目的执行情况进行跟踪调查(欲知详情，请登陆网站：www.cred-uk.org)。

培养社会行为的重要程度不亚于设计低能耗的建筑，社区减碳项目小组的一项任务就是寻找共同努力关掉不必要的电器所能达到的节能潜力。这项活动项目一天内举行，不过在活动当天和那之前都将举行宣传活动。来自大学里一座建筑的结果如图二所示。除了周末的用电量明显减少外，随着夏天的临近，整个四月份都呈现出总的下降趋势。图中的虚线和灰色带突出显示了这一趋势，灰色带表示每日读数的标准差。目标日期是 2005 年 4 月 22 日，星期五。当天出现了显著的下降(偏离趋势线超过 4 个标准差)，表明这确实效果明显。在接下来的星期一，同样也出现了显著的下降，不过那周的其他时间减少并不显著，这是因为人们又开始按老习惯行事。如此显著的减少量表明提高人们的这种意识是非常重要的。该大学和社区减碳项目正共同探索方法，使这样的节能能够更加持久。

社区减碳项目始于东英吉利大学，最初的工作重点在诺威治、诺福克郡以及东部和英格兰地区。其他地区对这个项目也非常感兴趣，以至于在英国的其他地方也形成了社区减碳项目的核心，城镇中例如伊普斯威奇和剑桥，行政区和郡议会例如中英格兰西部、白马谷(Vale of White Horse)以及汉普郡等。随着工作渗透到北卡罗来纳州立大学、加拿大和日本的冲绳岛，这个项目开始成为一项国际性的活动。近期，通过在上海的徐汇区和诺福克建立校际联系，社区减碳项目开始了它的中国之旅。



（自上而下依次为千瓦时，目标日期，2005 年 4 月）

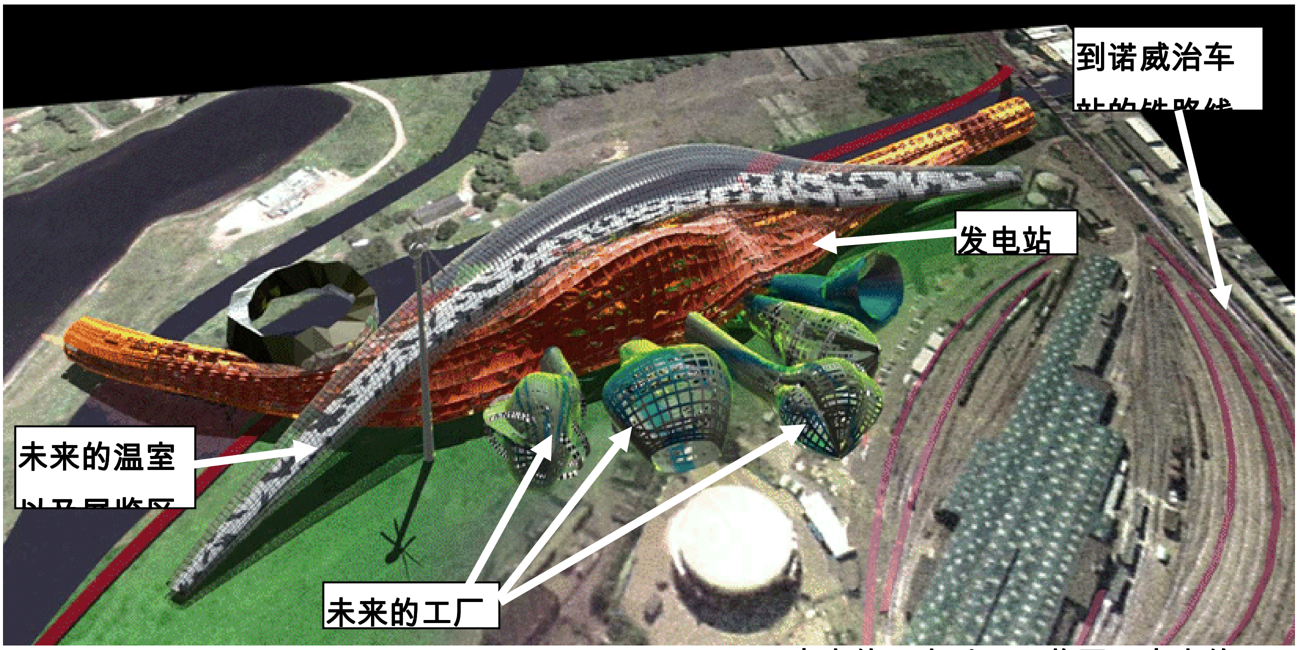
图二：在为期一天的减少能源的宣传活动举办期间一座建筑中的电力需求的下降。资料来源：社区减碳项目(2005 年)

低碳实践图标式的综合国际样本

社区减碳项目正在获得公众和企业支持方面取得越来越大的成功，在这种情况下，保持这种势头不减退，并且抓住一切机会推动低碳行动是非常重要的。很多时候，大家的观点各不相同，而潜力也未能充分发挥。以前，电力和能源的生产是当地社区的责任。如今，这样的供给从社会中分离，以至于公众并不总能意识到他们行为的后果。提供对使用者有利的教育设施，面向各国的儿童和成人是非常重要的，因为能够得益于共同努力的是我们全人类共同的未来。这样的设施应该是所有学校学生应有的，显示能源的生产、转化和使用与气候变化之间的关系。

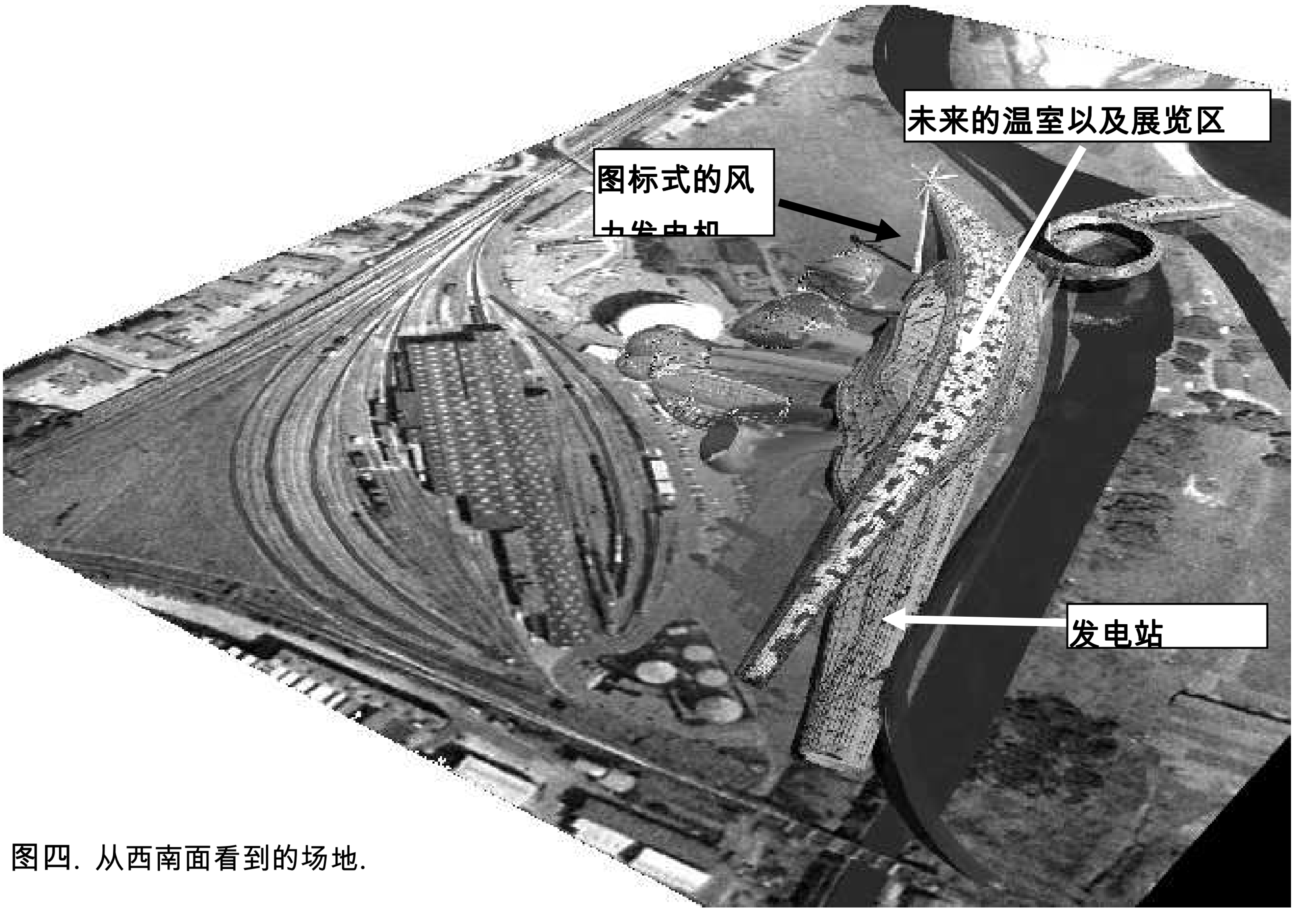
理想的情况是，社区减碳项目用来推广介于社会和技术之间的这种教育，作为扩大项目的一部分，已经推动建立了一座综合的可再生资源发电站。这座发电站不仅将成为许多企业关注的焦点，而且将作为一个研究中心、展览中心、旅游景点以及会议中心。

一个展览中心和旅游景点将座落于发电站附近，强调气候变化和能源之间的联系，提供一个机会让游客们更加了解我们目前面临的艰难抉择。最初的设想是在诺威治，她是一座历史古城，并且位于英国的最东面。因此，她被称为“ 东方之星” ，包括一个建筑上具有创新意义的风力发电机。这个风力发电机有六个叶片，代表英国东部的六座城镇，还有一个多通道的生物质和废弃物工厂以及一个大范围的光电阵。目前已经认可这样的装置可以很好地安置在世界许多其他城市，并且作为创造低碳未来的主要推动力量。中国一些城市发展计划中心的一个重要组成部分就是可再生资源的重要性(例如崇明岛)。实际上风能和生物质正是 2010 年上海世博会总体规划的一部分。发电站是图符式的，是建筑艺术品而不仅仅是一个基本的发电设备。诺威治方案作了调整，以适应场地限制，其鸟瞰图见图三和图四。



（由于图标不能复制所以只能把话写在此处）从左到右依次译为：**未来的温室以及展览区，未来的工厂，发电站，到诺威治车站的铁路线）**

图三：从东北方向看到的提议的创新综合发电站的鸟瞰图，该发电站位于诺威治。这幅图也说明了在中国其他地方可能做到的情况。发电站的实际形状由可利用的土地面积决定，如图中虚线所示。

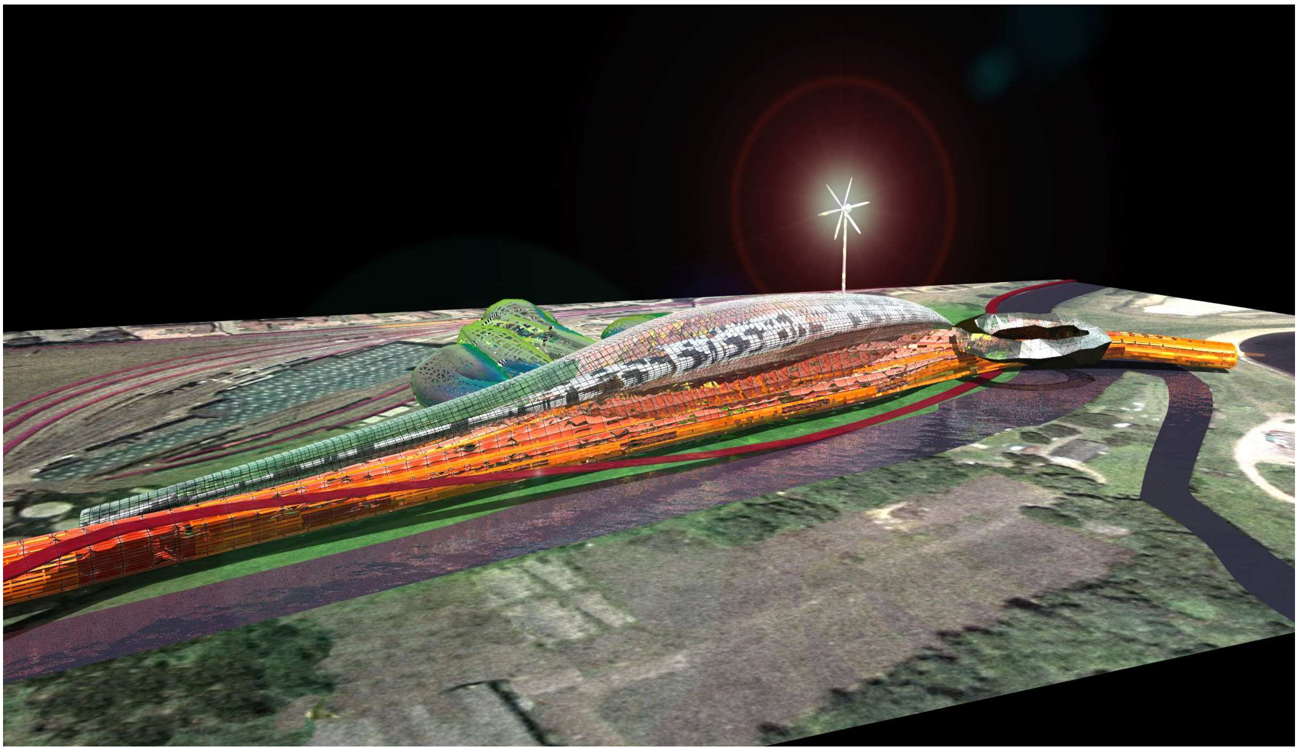


图四. 从西南面看到的场地.

图中自上而下依次翻译为：**未来的温室以及展览区，图标式的风力发电机，发电站**

风力发电机

风力发电机（见图五）高 90 米，在通往诺威治（英格兰东部）的铁路，水路和公路线上，以及诺里奇很多地区都将是显而可见的地标。它是诺威治城第二高人工建筑，略略低于宏伟的哥特大教堂。后者修建于 11 世纪，一直是诺威治城的标志建筑。因此我们希望建造于 21 世纪的这一工程将象征着人类迈向低碳时代。六片电机叶片的设计不是最有效率的设计，但是效率并不是本项目的唯一目标。我们的目的是增强人们的认知度，并使其成为一个标志，风力发电机组正是可以做到这一点。为了强调其象征性，塔架将通透可视，采用尽可能少的钢铁支撑结构。在夜里，就好像悬在天空的一颗星星。在塔架顶端，游客观景平台将提供前无仅有的乡村美景。晴朗的日子里可以看见 30 公里以外的海岸。



图五：风力发电机将是整个综合体中的焦点。

观景平台还将使游客们认识到含碳燃料在人类发展历程中扮演的重要角色。在这里，他们亲眼见证人类开发能源的几个阶段：

5. 布罗兹地区：世界闻名的湿地区，其形成源于中世纪开采泥煤用做燃料，这可被称为碳一代
6. 碳二代，或煤炭，在诺福克郡从来都没有真正开采过煤炭，大量的储备存留在了陆地和北海的地下。
7. 碳三代的天然气钻井架（北海的石油钻井架是看不见的）
8. 近海的史阔碧沙洲风力发电机组，指引了通向的后碳时代的道路。

风力发电机拥有六片风叶，象征着英格兰东部地区的六个郡。在其他地区，也许可以采用其他象征形式，例如在中国的项目也许采用五片风叶会比较恰当。

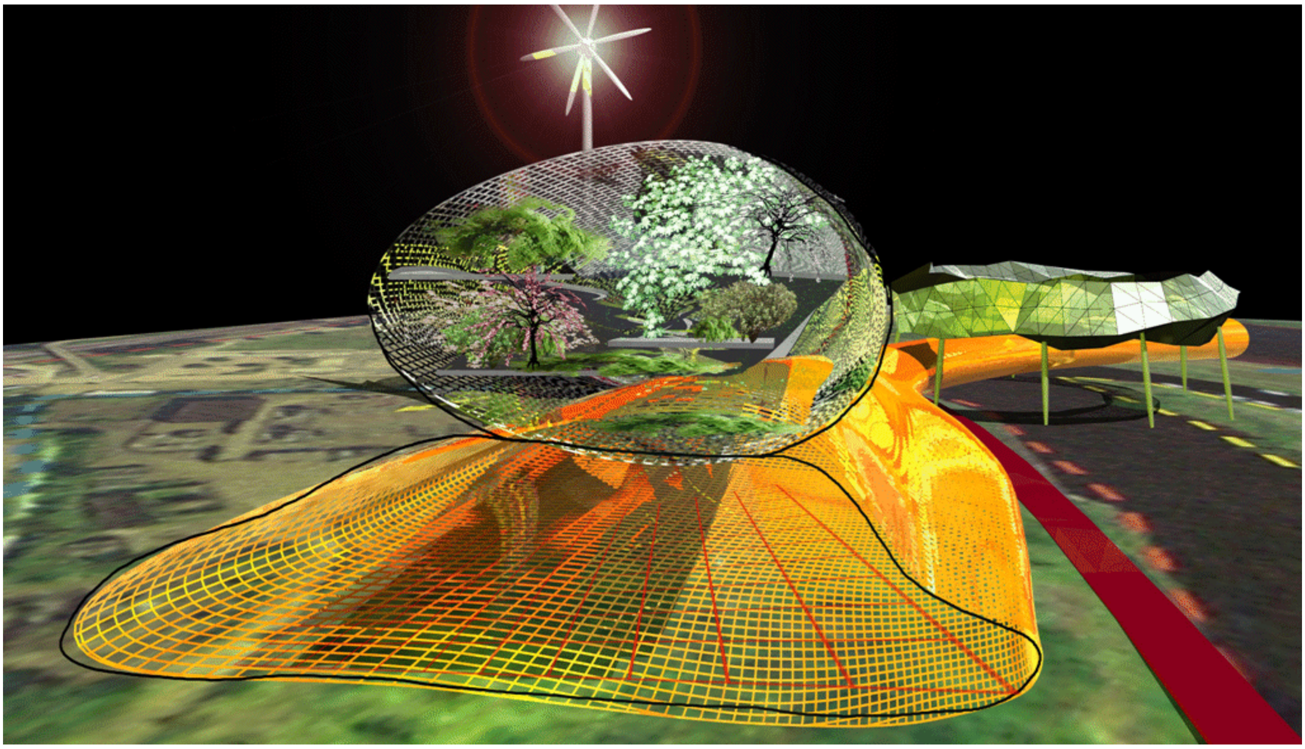
生物质发电站

发电站主体设计的意图是突出其建筑特色，而不只是一个巨大的盒子，这也是与其吸引观光客的功能相符合的。除了风力发电机之外，发电站还包括一个屋顶上覆有光伏发电板阵的“ 未来温室”。整个生物质/垃圾（废物）发电站的设计为组合式，考虑到了将来技术的新发展，因此是符合未来发

展要求的新型发电站。组合式的设计也许会稍稍增加成本，但是因此得到的灵活性确保了其经久耐用的特质，是最适合于未来发展的解决方案。有一种设想是发电站首先建成一个焚化炉，但是经验表明其他的发电站会结合裂解与气化工艺使得生物质有效的转化为电能和热能。我们的目标是设计并运营一个可以利用多种生物燃料资源的发电站。如果地点选取恰当，我们设想垃圾废物会是一种重要的燃料资源，因为这样一来通过结合裂解与气化工艺，可以实现有效而又环保的垃圾处理。燃料储备的置放点将设在建筑物的地下，并保持一定的负压力，以解决味道等问题。

发电站的生物质/垃圾部分要着重考虑的问题是垃圾热能的处理。冬天没有什么问题，有地区供暖的需求。但在夏天，低供暖需求会造成问题。我们的计划是采用吸附冷却来实现（气电冷）三生制程/热电冷三联产，利用部分废弃的热能。垃圾燃料的热能还会被用来为冬天的展览会以及会议设施供暖，夏天则通过吸附冷却机制冷。

作为可供选择的生物质裂解气化方案，至少有一个处理通道会被用来解决市政垃圾，从而减少垃圾填埋的需要。在 UK 的埃文茅斯这一创新设计已经以商业化的规模得以展示。由(CompactPower, 2005)公司建造的这个组合式工厂可以处理所有种类的非放射性垃圾，并已证明安全可靠，是这一综合发电站项目的理想合作者。



图六：发电站与“ 未来温室” 的交接区域。

未来的工厂

未来工厂的设想是它们会随着社会进入低碳时代而不断发展。在初级阶段，生质柴油（生物柴油）和生物酒精作为柴油与汽油的替代品将被采用。与别处的生物燃料生产不同，这里不需要从化石燃料中获取热能和电能，而是利用毗邻的可延续发电站，从而最小化燃料循环环节中的碳排放量。一旦生物酒精的基础设施建造完毕，这一综合体就能成为探索能源新发展的理想之所，比如从市政垃圾制造生物酒精，不但可以改善不断增加的垃圾问题，还可以为交通运输提供低碳的解决方案。

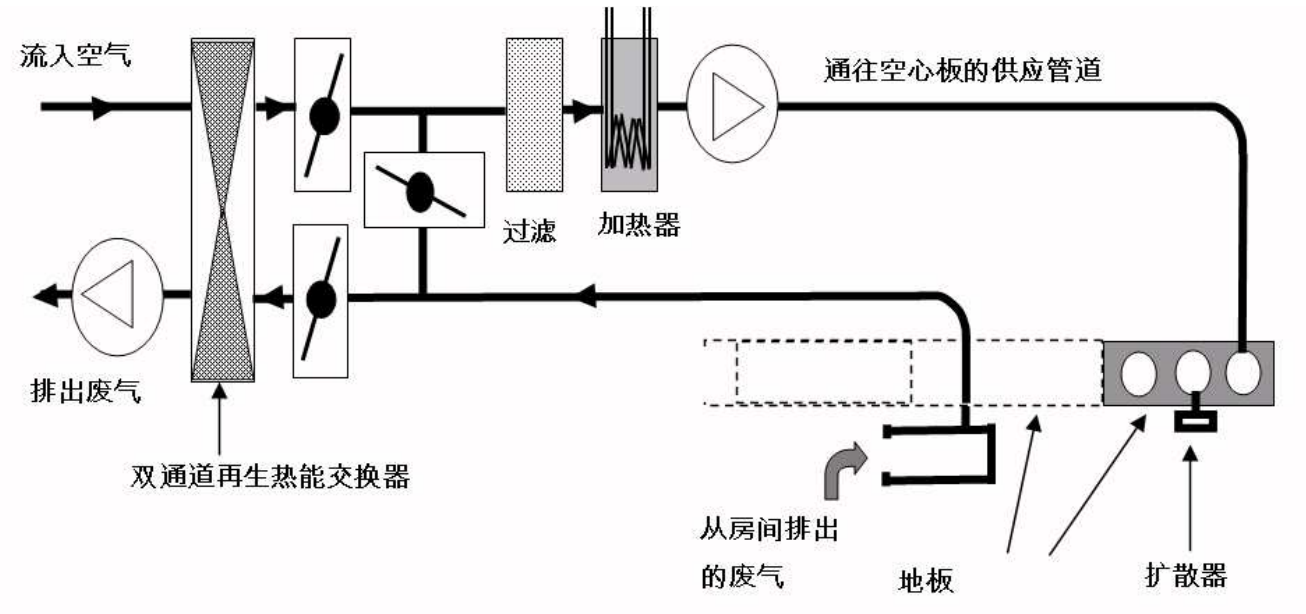
未来的温室

未来温室的设计设想有两点，一部分用作展览区，一部分用于研究植物与作物对于气候变化的反应，图六展示的就是这一交接部分，还有部分温室建于发电站之上的设计。研究区域的温度将由发电站剩余热能或冷气来控制。

东英吉利大学的低碳未来

在过去的十五年中，东英吉利大学（UEA）一直积极致力于推广低碳技术策略。包括建造创新的低能耗大楼，为校园能源发展综合燃料高效策略。在校园有很多上世纪六十年代建造的效能差的老楼，现已被列为二级建筑，这些给学校带来特别的挑战。但是本文强调的是围绕新楼以及能源供给的问题。

在建筑设计中最具创新性的是一个“ Termodeck”原则，包括一个高效的再生性热能交换器，可以恢复 87%从机械通风系统流失的热能。已经有四幢使用该系统的大楼建成，第五幢也在建设当中，形成了 UEA 校园中一个高能效建筑的密集区。建筑采用轻集料空心板座位地板的材料，使得流入和流出的空气可以循环流动。图七概略的展示了这一过程的运作原理。



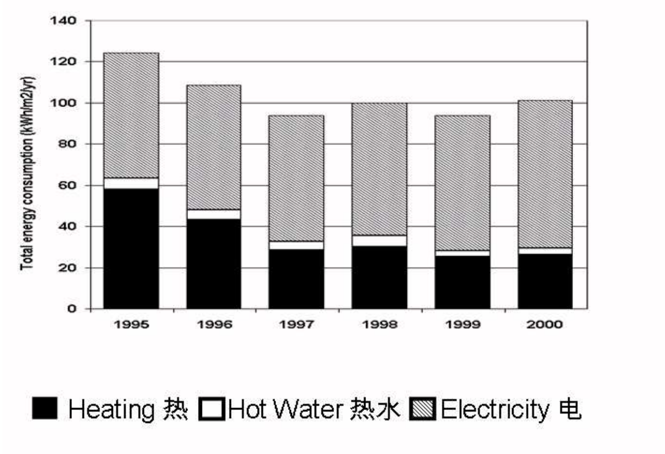
图七：Termodeck 建设原理概图，达到一种低能耗的设计。

流入空气首先通过双通道再生热能交换器，接着经过过滤器和一排加热器，加热器可以采用任何适合的能量来源。然后空气通过空心板部分再从扩散器中扩散开来，房间内的废气通过各个管道集中起来，被运回再生热能交换器，在那儿，大部分残余的热量被再次提取。热能交换器的双重通道每 90 秒转换一次通道，从而提供了十分高的热能回收率。

UEA 最早采用该技术的建筑是 1995 年开始投入使用的 Elizabeth Fry Building（图八）。在建造期间，它就被 Probe(1998)承认为“ 至今为止最棒的建筑”。而且虽然指出超出了预算不到 10%的数目，却达到了令人惊叹的能耗绩效：整座大楼的供暖仅来自于一个家用锅炉。房间里排出的废气能收集低能耗照明制造的废热，通过管道传输到再生热能交换器，即使室外温度低至九度，也很少需要家用锅炉来供热。所有这些建筑的保热系数（U-values 绝缘材料等阻挡热量通过墙壁、屋顶等的阻力计量单位,通常用 1 平方英尺*1 小时*1〔1337〕 的温度差的 btu 值表示）不仅达到了当时现行的建筑法规标准，而且有可能在几年甚至几十年的时间内都超过该标准。

由于流入大楼的空气和废气都在建筑结构内循环，整个建筑的温度接近于气温，提升了热舒适的概念。即使在昼夜交替温差很大的情况下，空心的结构也使得大楼内热容量可以完全用于保持楼内的温度。在夏天昼热夜冷的气候中，建筑的结构可与在夜间得到预冷，从而减少甚至在很多情况下消除了空间制冷的需求。在炎热的气候中，这是很有价值的，因为制冷高峰需求可以得到大大的降低。

图八：1995 年完工的 Elizabeth Fry Building

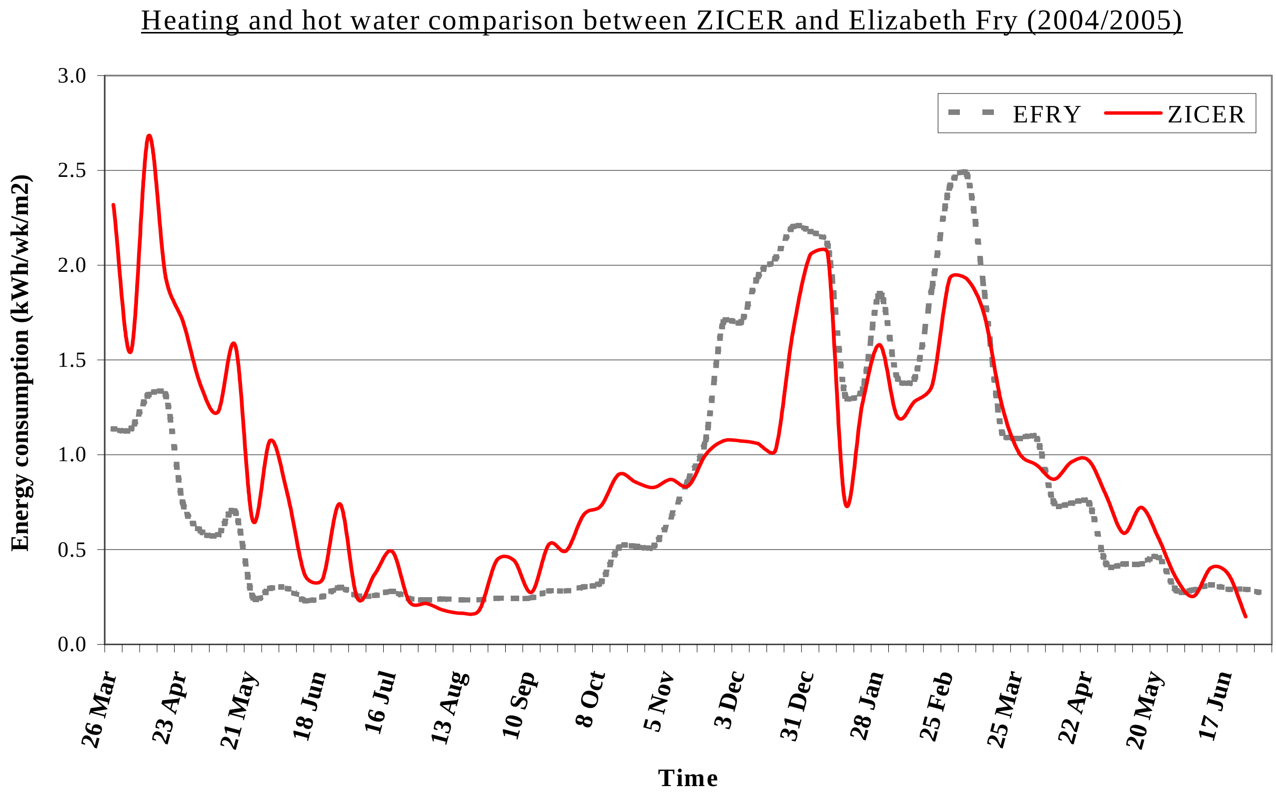


图九： Elizabeth Fry Building.的绩效

图十：屋顶覆有光伏发电板阵的 ZICER

这幢楼从一开始就运作良好，但是在开始的两年里，通过仔细的精细调试，供暖的需求降低了 50%之多，达到 33 kWh/ m^2 / yr（每年每平方米 33 千瓦小时），仅为学院建筑标准的 20%。（PROBE, 1998）

校园内另一幢更具有创新意义的建筑就是 Zuckerman Institute for Connective Environmental Research (ZICER)，如图十所示。它进一步发展了 Elizabeth Fry Building 的理念，在屋顶的表面覆盖了 34KWPV 的光伏电板。包括地下室在内的下面四层采用了 Termodeck 的结构，而最高层设计成了展示光电池原理的展览区。这幢建筑的预计供暖需求只有 Elizabeth Fry.的 90%。但最初的运作结果并不令人乐观，以每单位面积的供暖需求计算，ZICER 达到了 Elizabeth Fry. building 的两倍之多。对数据的分析表明换一种用控制地板温度来管理的方式也许会更适合。在 2004 年的夏天，这一方案得以实施。结果 ZICER 的运作得到了惊人的改善，在大半个冬天里，它的效率都要远远高于 the Elizabeth Fry building（见图十一）。这表明要实现低能耗建筑，不仅需要好的初期设计，还需要精心的管理供暖方案，才能够达到最佳的效果。



图中自上而下分别是：

标题：ZICER 大楼和 the Elizabeth Fry 之间供暖和热水的对比

Energy consumption(kWh/wk/m2) ：能源消耗量（千□□/星期/平方米）
EFRY：the Elizabeth Fry 大楼
ZICER：ZICER 大楼

时间：

26 Mar：3 月 26 日	23 Apr：4 月 23 日	21 May：5 月 21 日
18 Jun：6 月 18 日	16 Jul：7 月 16 日	13 Aug：8 月 13 日
10 Sep：9 月 10 日	8 Oct：10 月 8 日	5 Nov：11 月 5 日
3 Dec：12 月 3 日	31Dec：12 月 31 日	28 Jan：1 月 28 日
25 Feb：2 月 25 日	25 Mar：3 月 25 日	22 Apr：4 月 22 日
20 May：5 月 20 日	17 Jun：6 月 17 日	

图十一：ZICER 大楼和 the Elizabeth Fry 大楼的 Termodeck 运作绩效比较

所有的 Termodeck 大楼都具有良好的密封性，它们的优秀表现也都有赖于其出色的气密性。当然针对有人开窗的相应预防措施，虽然这种情况并不多见。然而，这种措施还是有必要存在的，因为在低能耗的建筑里，工作环境的可接受性是十分重要的。对于 Elizabeth Fry Building 的使用者满意度调查表明，在所有衡量项目中，对这栋大楼的评价都要优于平均水平。见表一。

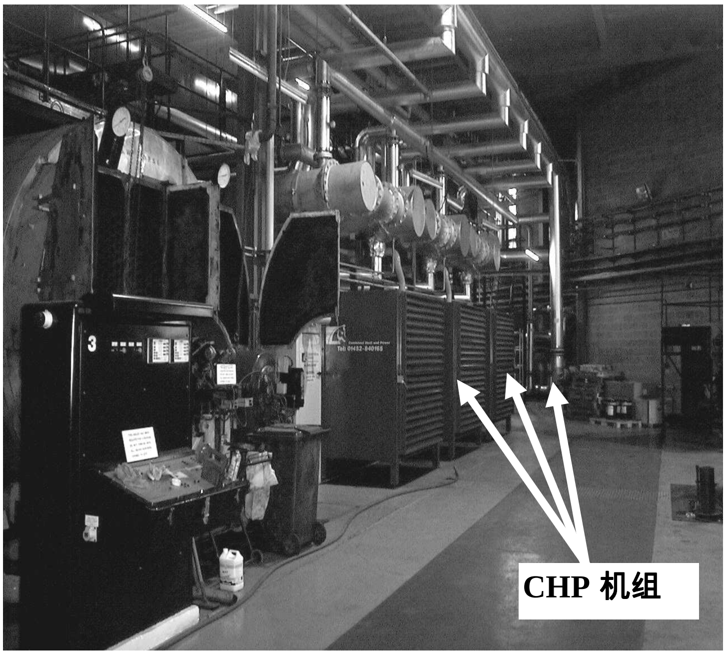
表一：使用者对于 Elizabeth Fry Building 的看法

评判标准	与标准建筑相比
热舒适度	优于平均水平 28%
空气质量	优于平均水平 36%
照明	优于平均水平 25%
噪音	优于平均水平 26%

Termodeck 建筑的低能耗要求是通过对流通空气热能的回收利用而实现的。由于隔热标准的提高，流通的空气成为能量需求中越来越重要的一部分。关键是流通空气的热能回收要和建筑的设计融为一体。虽然自然的空气流通也是有效的，但在考虑实施之前，应该和空气热能回收进行比较测试。

校园建筑供热供电的低能耗战略

校园中的大部分建筑都由中央锅炉房供暖。在二十世纪九十年代,采纳了安装热电联合发电机组 CHP(Combined Heat and power)的方案。三台燃气机为三台 1Mwe 的发电机提供推动力（见图十二）。冬天，有从现有的锅炉提供的补充热能，一共可以提供 4.2Mwe 的热能。当时，这一方案只是电力的净输出者，但是自从实施了新电力贸易协定 New Electricity Trading Arrangements(NETA)，以及继而于 2005 年 4 月 1 号取代它的英国电力传输与贸易协定(British Electricity Transmission and Trading Arrangements(BETTA))，输出的经济可行性变强了，特别是作为燃汽价格在 2003 年中期大幅上升之后。然而，在安装 CHP 机组之后，与之前的每年 1,000,000 英镑相比，能源费用节约了 400,000 英镑。表三显示了 CHP 机组制造的电力比率。



图十二：主锅炉房的 CHP 机组和锅炉之一

表三：校园的电力产量，总需求和 CHP 供应的比率

	CHP 产量	总需求	供应比率
	百万瓦特小时	百万瓦特小时	
1999	16753	20432	82.0%
2000	15301	21410	71.5%
2001	18440	24756	74.5%
2002	15644	25611	61.1%
2003	15655	26277	59.6%
2004	17567	26961	65.2%
2005	2005 年 1 月 1 日至 2005 年 7 月 31 日		
	11198	16422	68.2%

注：

iii).2000 年的数值受到了机组大检修的影响

iv).2001 年后，电力输出的财务可行性受到 NETA 的影响

这一方案生产的电力特别有利于推广低能耗社区，因为电力都用于本地，避免了传输过程中的电耗。表四和表五显示了在安装前几年和安装后第一年的二氧化碳排放量。二氧化碳排放量由 15699 吨降至 10422 吨，降低了 33%。

图十三显示了从 1999 年二月中旬安装到 2005 年 7 月 31 号这一段时间 CHP 机组的利用状况。平均的荷载率为 67%，但在夏季的几个月中由于供暖需求减少而降至 40%（见图十三）。为了提高 CHP 机组的利用率安装了一个吸热泵，将于 2005 年 9 月投入使用。这样可以满足夏季科学仪器不断增加的制冷需求，并提高电力产量。同时，还能降低制冷所需的电力输入，增加电力输出数量，标志着双赢局面的产生。据估计，通过这一手段还能进一步减少约 350-400 吨的二氧化碳排放量。

表四：安装 CHP 机组前 UEA 校园的能耗及年 CO_2 排放量

1997/98		电	气	油	总量
	百万瓦特小时	19895	35148	33	
排放率	千瓦小时/千克	0.46	0.186	0.277	
二氧化碳量	吨	9152	6538	9	15699

表五：安装 CHP 机组后第一年相关数据比较

		电				热			
1999/2000		总量	CHP 产量	输出	输入	锅炉	CHP	油	总量
	百万瓦特小时	20437	15630	977	5783	14510	28263	923	
排放率	千瓦小时/千克			-0.46	0.46	0.186	0.186	0.277	
二氧化碳量	吨			-449	2660	2699	5257	256	10422

图十三：CHP 机组发电荷载率变化。图表显示出夏天的利用率较低，因为供热需求有限。

除了吸收制冷之外，在 2005 年下半年，大学还计划开始对安装生物 CHP 机组的可行性研究，这一机组将大于现有的机组，电能和热能产量分别为 1.4 MW 和 2 MW。可持续增长的生物质供应被视为碳中性能源。但是，不断增长的生物质收获和运输又必须使用能源，而且大多数是化石能源，因此仍然会有一定的温室气体排放，只是数量会低于正常的化石能源。这一计划的最初估计表明在将来每年能够减少 3500-5000 吨的二氧化碳排放量。

总结

如果能采用多方面的措施，可持续低能耗社区将会是十分成功的设想。创新的低能耗设计当然是必需的第一步，但与当地社区的结合也十分重要。社区减碳项目(CRed)指出了一系列重要问题，只有做到这些，才能确保低碳策略取得最有效的成果。包括以下几点：

9. 任何新的可持续发展计划和建筑设计的核心是有效的创新技术。但是由于建筑结构法规日趋严格，应该意识到空气流通的问题将日趋重要。

10. 通过利用再生热交换器可以实现高效的热能回收。

11. 单独的低能耗设计是不够的，通过在实际运转过程中的仔细监控，对头 12 到 24 个月的能耗数据分析，相应地修改能源管理战略，能够改善绩效。

12. （气电冷）三生制程/热电冷三联产与 CHP 及吸收冷却设备相结合将成为许多综合大楼能源供给的综合方案，这样一来可以大幅的减少二氧化碳排放量。

13. 与英国现行的一些法规相似，有关电力供应与分配的规定有可能会成为推广低能耗方案产生的阻碍力量

14. 适当的教育活动可以大幅的减少能源浪费，尤其是在现有的建筑中。但还需要意识到因此而来的退步并不会带来利益的流失。

15. 现在社区减碳项目在世界各地所采取的态度有必要在公众之中进行推广。那就是对即将使用的机组进行慎重的考虑。该项目发现采用与日常项目相符的规模常常能赢得公众的参与。这种参与还可以通过一个抵押计划给与加强，就像越来越多个人与公司所采用的社区减碳项目抵押系统。

16. 综合了展览、教育、会议设施等多功能，并具有象征意义的可更新能源发电站是更好的联系民众的绝佳方式。

感谢：

作者要感谢东英吉利大学环境科学学院的硕士生 Charlotte Turner，以及提供本文数据的东英吉利大学能源经理 Mel Pascoe

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