Sustainability in Cambridge: Planning the Development of a North West Site for the University of Cambridge

A report to the Cambridge City Council, the Cambridgeshire County Council and the University of Cambridge.
Summer, 2004

Summer Program in International Environmental Assessment and Energy Policy,
Carolina Environmental Program
University of North Carolina at Chapel Hill, USA

Jenna Cramer
Morgan Forester
Soo-Hyun Kim
Sara LaRocca
Cecilia Liszka
John Martin
Erika Petty
Jonathan Sugarman
Daniel Waxman

Faculty Advisor: Dr. Douglas Crawford-Brown
Mentor: Sally Pidgeon, Cambridge City Council
Preface

This report is presented to the City of Cambridge and its citizens in the hope that it will guide difficult decisions on the balancing of development and environmental quality. It is the first product of a summer’s work by a team of undergraduate students from the University of North Carolina at Chapel Hill and from the University of Cambridge, each dedicated in their studies to understanding how the environment works, how the heartfelt and diverse needs of people can be accommodated within that environment, and how policy tools can be applied in reaching the tripartite goals of sustainable development: environmental quality, social justice and economic vitality.

The report can be considered on three levels. First, it is a review of general issues to be considered whenever any town or geographic region, in England or the United States, is faced with the pressures of modern development while striving to maintain a quality of life affected by the environment. This is an issue facing communities around the world, and getting it right is one of the most pressing challenges of this next century.

Second, it is an examination of these issues within the context of Cambridge. Cambridge is one of the world’s jewels; a city as modern as any in England, with a university and businesses at the forefront of scientific and technological advances. But it is also a market town with a deep sense of a past disappearing into the mists of a thousand years. The quality of life to be protected here is informed by this past, and any understanding of environmental protection must reflect the fact that Cambridge is first and foremost a historic city. This requires a special sensitivity to connections between the people and their environment, between city life and the nature of rural areas, a sensitivity that should not be lost in the rush to modernity. To paraphrase a thought from that other great medieval university in the Cotswolds: In Cambridge, we move slowly enough so the past can catch up. Notions formed over a millennium on how people relate to nature, and how the design of a city can either foster or crush that relationship, should not be jettisoned solely in the name of modernity. Policies that ignore this link to the past, and the quality of life it entails, are not in the long run culturally sustainable.

Finally, this report needed a case study in which the abstract notions of analysis can be given flesh. The students chose, in collaboration with the Cambridge City Council and the Estate Management and Building Service of the University of Cambridge, to focus on the proposed North West development of the University. By focusing on such a case study, it is hoped that the following report will provide a glimpse not only of general principles for building sustainable communities, but of specific measures that can be taken to produce an environment worth living in after the North West development is completed. Cities rarely have the opportunity to let the principles of sustainable development have such a clear voice. Development is usually too piecemeal; a building here or road there usually doesn’t get the broad attention to environmental quality needed for a discussion of sustainability. A full development, such as the one proposed in the North West, offers a very different opportunity. It offers the possibility of creating a demonstration project of significant size built directly on the foundation of sustainability. It offers the opportunity to demonstrate to the rest of England how Cambridge intends to live up to its billing as the Sustainable City. It offers a setting in which this learned town can show the world that intellect
matters, that the resources of academic thinking can be a force for bettering the world and not only studying it. What makes this case study especially promising is that everyone we have met, from the City Council to the Estate Management and Building Services, is committed to finding the right path. Having the developer so clearly on the same page as the City Council in regards to environmental sustainability is a luxury few projects enjoy.

Before discussing the report itself, a note of expectation is in order. This is the first in a series of reports to be produced over several years by students from the University of North Carolina at Chapel Hill and the University of Cambridge. My own organization back in the States, the Carolina Environmental Program of the University of North Carolina at Chapel Hill (www.cep.unc.edu), has chosen Cambridge as the latest in a series of Environmental Field Sites. Students attend these sites for a semester in their final years of undergraduate study, demonstrating that they can put into practice what has been learned in the classroom. We will be back, summer after summer, to continue the project- with a different crop of students, of course. So this first report might be viewed as simply laying the foundation for the study of sustainability in Cambridge, and as providing the basis for the more detailed work of future groups of students. But I think you will find it much more than that, as the present students have moved quite a distance towards providing very concrete analyses and solutions for some of the most important issues surrounding the North West development. Still, read the report with an eye towards the future. We invite the reader to contact us with advice on how the next group of students should direct their studies.

What will you find in this report? It begins with the recognition that the North West development, both in concept and construction, will fulfil very real human needs. England as a whole is faced with a need for housing, and the East of England has been identified as a region to supply some of those needs. Cambridge is expected to bear its share of the burden, and so additional housing will come to Cambridge in one form or another over the next decade. Some of this housing must be for university faculty and staff, as current housing prices in Cambridge- as I’m sure you are all too painful aware- are as astronomical as the objects studied by the telescopes out the Maddingly Road. This has forced citizens to locate in the villages and towns surrounding Cambridge, causing an explosion in car traffic on the ring roads as these same people commute to and from town. Housing at the North West development could ease that problem, allowing people to live sufficiently close to town to use public transit or ride their bikes.

The University also has needs. It remains one of the top universities in the world, a name spoken in almost mythical tones back in my own country. That position, however, requires movement forward in facilities designed to house the newest areas of science and technology. These are not activities that can be wedged into medieval, Georgian or even Victorian buildings. They require new buildings, purpose-built for advanced research and teaching. The economic growth of the region is tied directly to such intellectual activities, and so Cambridge has a unique opportunity: stimulation of economic growth in a manner (university research) that is markedly more in line with environmental quality than typical industrial development.

This same growth must be married to the ambitious plans of the government to increase university enrolment. The University of Cambridge will not escape this call,
and so it will be expected to absorb a significant number of new students. These students must be housed and educated, which will require a few new colleges. The North West site offers the possibility of creating these colleges in a location reasonably close to the rest of the university so students can get back and forth to classes, while leaving the historic core of the city in the attractive form that drew us all to Cambridge in the first place.

But people also have needs unrelated to economic growth and affordable housing. They need an environment worth inhabiting. They need access to land that, while not necessarily pristine, is nonetheless pastoral. What would Cambridge be without the Backs, the stroll to Grantchester across the meadows, the bike jaunt out to Maddingly or Coton for a drink? In many ways, life in Cambridge today retains much of its medieval flavor because the countryside intrudes into or near the city, with cows grazing behind King’s College and fields of wheat a short jog away. A sustainable Cambridge is one that cherishes and retains this aspect of life. It is a particular pattern in the landscape that is sensed by all and portrayed in the paintings of Constable or the poems of the Romantics.

With these thoughts in mind, the students have examined different ways in which the North West development might take shape. The guiding principle throughout is one of sustainable development. Now that is a term bandied about, in danger of becoming more a bumper sticker than a concrete principle to be used in planning. It certainly involves the three pillars noted earlier: environmental quality, social justice and economic vitality. But what exactly do these terms mean? How are they to be measured? How can one potential development be compared against another if any one of the three terms is considered? And how is one to balance these terms as Aristotle taught us, with no one term having more influence than its rightful place in life’s deliberations?

Unfortunately, we have no answers for the town on this last point. It is not our role, or even right, to try to tell the citizens of Cambridge how to balance the three goals of sustainability. The students have, after all, only lived here for five weeks; while glorious, these five weeks are entirely too short a time to form any real sense of the culture that informs such complex decisions. What the students have done instead is to begin to construct a framework for thinking about these goals; to identify specific and measurable criteria that might be used to characterize sustainability; and to portray the characteristics of a North West development that would enhance or detract from some of these criteria. Future groups will return in later summers to move things along a bit further, adding new criteria, performing measurements, surveying the citizens of Cambridge to discover their values, and so on.

We didn’t, however, want the final product of this summer to be completely generic. The students needed some specific measures of sustainability as the starting point for their studies, and so they discussed development issues with the staff of the Cambridge City Council (special thanks to Sally Pidgeon, Peter Studdert and Jo Dicks) and with the University Estate Management and Building Service (John Clark and Leslie Downs). These discussions pointed them in several initial directions where help could be provided immediately as planning for the site went forward. Of all the measures of sustainability that might be considered, the one most on the minds of planners in Cambridge is the recent Energy White Paper commitment to a significant reduction in carbon dioxide emissions. And so one measure of sustainability
considered, one measure quantified in the present report, is the effect of different development plans on the emissions of carbon dioxide from Cambridge and on the extent to which Cambridge could meet its global obligation to reduce the threat of climate change. Central to this part of the report is the idea that a sustainable development is one whose carbon dioxide emissions are below those producing an unacceptable concentration of greenhouse gases in the atmosphere. We know it must seem odd for a group consisting largely of Americans to be lecturing the city on carbon emissions, given our country’s own abysmal performance and policies in that regard, but there you have it. And we do offer the promise that we will return to our own town of Chapel Hill, also a university town with the oldest public university in the country, and force it to live up to the same challenge we pose for you here.

The student team also considered some aspects of human health as a measure of sustainability. Surely a sustainable development is one that leaves human health in a condition judged appropriate and acceptable by the people affected by that development. In keeping with this thought, they assessed at least three representative health risks: (1) the risks that might occur from an electricity and heat co-generation facility located at the site, (2) the risks from indoor air in the buildings to be constructed, and (3) the health risks from particulates emitted from traffic that might be associated with the site. This isn’t to say that a co-generation facility is planned for the site; we have no evidence it is. But co-generation facilities often are placed in or near sustainable developments because they offer the possibility of reducing energy use and carbon dioxide emissions. It is natural to ask whether such facilities, so desirable from the standpoint of reducing carbon dioxide, might seem less so from the perspective of human health effects. Similarly, we don’t know whether the site will increase traffic in Cambridge or decrease it; the students present arguments in both directions. We can, however, make some estimates of the decrease or increase in human health if traffic intensity moves in one direction or the other. All of these are valuable pieces of information for planners to have in hand.

Having identified needs to be served by the new development, and having identified measures of sustainability to be assessed in this initial report (carbon dioxide emissions and human health), the students then considered a wide range of development patterns and technologies that might be used to fulfil those needs while improving the sustainability of the site and of Cambridge. They examined all of the sectors of Cambridge using energy-industrial, residential, commercial and transportation-and performed assessments of the impacts of each of these on the measures of sustainability. For each such policy, they have identified how the policy would be employed (e.g. through the construction of houses certified as energy efficient), the feasibility of that policy in the context of the culture of Cambridge, and the impact of that policy on at least the two central measures of sustainability (carbon dioxide and human health). They have provided examples of best practice from across England and around the globe. They have linked the efforts in Cambridge to those taking place elsewhere, such as the exciting Carbon Reduction project housed at the University of East Anglia. This will allow planners here to join forces with other communities and programs addressing similar problems, producing in sense “strength in numbers” against the forces that would declare sustainability a utopian dream. They have identified policy tools (trading, tax credits, education, etc) the parties might use in moving policies forward. And they have provided some ideas as to how Cambridge and the University might move hand-in-hand in implementing these tools. While town-gown struggles make for lovely tourist tales, they are anathema to the
development of sustainable communities. All in all, the students have taken quite a
first step on the path to a sustainable design for the North West development.

We trust you will find the report informative. It certainly has been a pleasure, and an
honor, to be welcomed into the life of Cambridge. I think you’ll agree that the
students have shown extraordinary initiative and maturity in performing their tasks.
Who learned more- Cambridge or the students- is a matter of debate. But there is no
doubt that they have laid the foundation for some truly creative partnerships as the
University moves forward with the essential development it seeks on the North West
site, and as the City Council ensures that this development represents the best of what
makes Cambridge the Sustainable City. We invite you to provide comments on the
report, to suggest new avenues of research, and to help us contact people and
organizations committed to the same causes. And we point you towards the web site
for this project (www.cep.unc.edu/cambridge), where you will find more information
and where you will see our commitment to twinning the Cambridge movement with
that in our own university and town. Our goal is to bring the lessons and commitment
we have seen here in Cambridge back to Chapel Hill, and to challenge our planners to
match the innovative thinking we see around us daily in this ancient yet so modern
town.
Section 1: The North West Site

The University of Cambridge is a world leader in research, technology development, and higher education. In order to maintain its status and facilitate further growth in these areas, the University must develop the infrastructure necessary to expand its research and teaching facilities. The proposed development of the North West Site will support the growth of higher education and economic development for the city of Cambridge and the larger East of England region. The site will accommodate the growing needs of the University by providing extra housing and colleges for the increased number of students and staff, and by building research and academic facilities for the development of higher education; it also will contribute to the economic growth of the surrounding region through the research activities. The challenge is to reach these goals without compromising the environmental quality of that region.

![Figure 1. North West Site](www-building.arct.cam.ac.uk/NorthWest/site.html)

### Possible Uses of the North West Site

- One or more new colleges
- Housing for University staff
- Academic facilities
- Housing for sale
- Research and development space
- Community facilities such as a primary school, shops
- Public open recreational space
- Nature conservation areas
- Park-and-ride and park-and-cycle areas

The growth of the University of Cambridge will be accompanied by growth in the population of students and staff. It is expected that the number of students will increase by 4,900 between 2000 and 2005, encouraged by national higher education policies will a goal of 50% of the population attending universities or colleges. The increased admissions, as well as the growth in research, will necessitate an expansion of the staff by 2,700 people. This growth in the student and staff population will increase the need for affordable housing. The current lack of housing hinders the University in attracting and keeping staff.

At present, the University provides 126 units for staff and postgraduate students to rent. The site will facilitate the increase in students and staff by providing affordable housing in the vicinity of central teaching and research facilities. Many individuals must at present live in towns beyond Cambridge containing more affordable housing, thus contributing to commute times, traffic congestion, air pollution, and decreased quality of life.

The North West site will alleviate some of these problems for individuals living outside of Cambridge; it also will attract individuals wishing to pursue a career with the University or within Cambridge and the City Centre. The extra facilities will allow departments to expand and enable the University to fulfil the future needs of increased...
research and development. In addition to the need for increased research facilities, the 
increased admission rates and growth of the student body will require one new 
undergraduate college and two new postgraduate colleges at Cambridge by 2025.

The North West site is a prime location for university development due its proximity 
to the City Centre and other University and College sites. This encourages the 
interaction necessary for research and academic progress, and decreases the need for 
travel and personal car use – a need exacerbated by the current pattern of having 
faculty and staff living in outlying villages. The decreased travel that might 
accompany the proposed development will help alleviate social and environmental 
issues, such as quality of life and air pollution, present in the city. The location helps 
the city develop high quality travel plans and facilitates travel for cyclists and 
walkers, components of a sustainable travel infrastructure.

The development, therefore, brings with it benefits in regards to education, research 
and economic development. At the same time, it will be a significant development 
with the potential for far-reaching impacts on the environment and quality of life in 
Cambridge. Fortunately for the citizens of Cambridge, both the University and the 
Cambridge City Council have an evident commitment to balancing these issues and 
using the site as a demonstration project for sustainable design. This presents a unique 
opportunity for the City and the University to work together in creating a community 
that will show the world how environmentally sustainable designs are both necessary 
and feasible. Cambridge can be a leader- a guide- for other developments wishing to 
promote modern growth while preserving environmental quality.

This report focuses on alternative designs of the proposed development that promote 
environmental quality, social justice, and economic vitality. It also considers the 
policies that must be in place to foster those designs. It is the first in a series of reports 
to be produced in 2004 and 2005 that may act as a guidance tool for the officials of 
the Cambridge community to design and build this location sustainably. The 
discussion focuses on how alternative designs might affect several key indicators of 
environmental quality and human health, captured under the umbrella of 
sustainability. Primary stakeholders include the University of Cambridge, the 
Cambridgeshire County Council, the Cambridge City Council, other local government 
agencies, and local citizens; this and later reports are prepared with these groups in 
mind. While the examples are chosen from the North West development, the lessons 
learned can be applied in essentially any development where the stakeholders are 
serious about the goal of sustainability.

The report is divided into sections, each related to some aspect or theme of 
sustainability. The themes address sustainable development from the very beginning 
of the process- demolition and construction waste management- through to the actual 
design and construction. Renewable energy technologies, transportation options and 
legislation will be mentioned throughout to provide concrete examples of the more 
abstract points raised.

**Section 2. Sustainability**

A framework of sustainability is used here to assess the alternative designs for the 
development of the North West site. Using sustainable practices, the needs of the
What are causes of sustainability?

Sustainability may be traced ultimately to three aspects of society, each of which may be targets for policies:

- **Infrastructure**, or the ways in which material and energy are used in a community. An example is the transportation infrastructure of cars and roads.

- **Structure**, or the legal, economic, social, etc., systems that govern decisions and behaviour. An example is the set of laws available to communities in guiding development.

- **Superstructure**, or the beliefs held by a community such as Cambridge. An example is the belief that the freedom of travel offered by a car is or is not essential to well-being.

While sustainability is a noble goal, it also can be a rather abstract concept with little connection to the concrete decisions made in developing a site. It is necessary, therefore, to consider some of the specific measures of sustainability that might be used in assessing proposed developments. These measures might usefully be divided between environmental quality, social justice and economic vitality. We take the following to be some of the central measures of sustainability, each of which can be enhanced or degraded by material and energy use in a development:

**Environmental Quality; an environmentally sustainable design is one that promotes:**

- Public Health (an acceptable incidence and severity of disease in the Cambridge population);
- Ecosystem Health (the ability of ecosystems in the region to provide crucial natural services);
- Reduced emissions of carbon dioxide and other greenhouse gases (to alleviate the threat of global warming);
- Biodiversity (a rich of array of species in the surrounding countryside);
- Unfragmented ecosystems (significant areas of unbroken natural landscape);
- Rural landscapes (a mosaic of land uses characteristic of rural life);
Some likely impacts of global warming:

- Shifting boundaries of ecosystems
- Spread of infectious disease
- Loss of crop productivity
- Rising sea levels and loss of coastal land
- Greater extremes of climates, including increased frequency of heat waves

Social Justice; a socially sustainable design is one that promotes for all individuals in Cambridge:

- Access to public health (including protection against environmentally-related disease, and access to health care)
- A high quality of life (with that quality spread as fairly as possible within the population)
- Affordable housing (meeting the needs for shelter that is aesthetically pleasing, safe and healthy)
- Affordable heat (meeting the need for essential heating that does not compromise the budget for other needs)
- Social progress (providing opportunities for education and advancement)
- Healthy living and working environments (made available to all citizens regardless of income)

Economic Vitality; an economically sustainable design is one that promotes:

- High and stable levels of economic growth by industry and commerce (increasing both profits and the tax base of the community)
- High and stable levels of employment (increasing household income)

This initial report examines the North West development through the lens of two of these measures of environmental sustainability: reduced emissions of carbon dioxide and public health. Each of these may also be related to the efficiency of use of resources, which we take to include issues related to recycling, and so this theme also is touched upon. With respect to carbon dioxide emissions, we consider the impact of alternative development plans on both the emissions rate of carbon dioxide from the development-comparing this against specific government goals to reduce such emissions-and on the concentration of carbon dioxide in the atmosphere resulting from these alternatives. With respect to public health, we consider the health impacts from selected aspects of energy generation on-site (specifically, mercury from a Combined Heat and Power facility if one were built) and particulates from changes in anticipated transport patterns. Future reports in this series will focus on other measures of sustainability. The two selected here were identified as especially important by the student research team and the stakeholder groups.
In regards to carbon dioxide, this report draws on the Government’s new energy policy as summarized in the *Energy White Paper- Our Energy Future*. That document sets a goal of a 60% reduction in carbon dioxide emissions by 2050, an ambitious goal that would, if adopted by all developed countries, lead to what is believed to be a sustainable level of carbon dioxide in the atmosphere. The necessity for such a cut is attributed to the growing threat of global warming, which could bring significant direct and indirect impacts on human and ecosystem health. The issue of climate change is one of the most urgent environmental topics facing the world today. It poses a viable threat to each of the three components of sustainability: a significant decrease in environmental quality, the potential for social disruption spread inequitably around the globe, and great economic loss to agriculture, city infrastructures and developed coastlines.

Global warming is caused ultimately by the behaviour of individuals as they consume materials and energy. This applies to the individuals who eventually will live and work in the North West development, and so this report will examine strategies to reduce emissions of carbon dioxide from that development. A reasonable sustainability goal is to design that site so the carbon dioxide emissions are 60% lower than might be expected under more traditional, energy-intensive, designs.

The health risks considered will in part be driven by the population growth expected in South Cambridgeshire, which may see a 33 percent increase in population over the next 15 years. This increase places a large demand on the infrastructure and services of Cambridge, including new buildings and homes, the increased energy needs of a growing population, and increased transportation on local roads. In the future, Cambridgeshire County will be working on integrating land use policy and planning with public health issues in order to promote sustainability and maximize health. Development at the North West site should reflect the health implications for the community due to the material and energy use at the site; social justice requires that these implications be considered for all segments of the population. The concrete measures of health considered in this initial report are the probability of cancer and the likelihood of significant but nonetheless non-fatal effects such as asthma. A more detailed analysis of the human health impacts from exposure to emissions is planned for future reports.

The University has made the following principles central to their plans:

- Be sensitive to existing neighbours and enhance existing features such as the hedgerows and the brook and protect the Site of Special Scientific Interest
- Respect the wider landscape setting of Cambridge and acknowledge and retain key views of the countryside through the sensitive location and design of buildings
- Incorporate appropriate landscapes and planting schemes throughout the site and take account of the recommendations of the County Biodiversity Action Plan
- Create an attractive 'green edge' to the City and provide public access from the City into the countryside beyond develop a buffer zone alongside the M11 site boundary to reduce the impact of the motorway
- Identify areas to be designated as public open space and aim to link these with new and existing open spaces off-site.

(www-building.arct.cam.ac.uk/NorthWest/issues.html)
Section 3: Modelling the Carbon Cycle

3.1. Introduction

Despite its association with global climate change, the greenhouse effect is not inherently problematic. It is a natural process, without which our planet would be a very cold place – too cold even to sustain life. Some warming of Earth and its atmosphere is needed. The trick is to have just enough warming to sustain life while preventing the temperature from getting so high that it affects the quality of life for species.

After passing through our atmosphere, the sun’s heat becomes trapped near the surface of the earth. This results in a relatively stable global climate, with temperatures on Earth allowing life to exist. Recently, however, the composition of our atmosphere has begun to change due to the activities of humans. As greenhouse gases accumulate in the atmosphere, it becomes a more effective “heat shield”, trapping an increasing amount of the sun’s heat close to Earth.

The atmosphere is composed primarily of the gaseous forms of nitrogen (N\textsubscript{2}, ~78%), oxygen, (O\textsubscript{2}, ~21%), and argon (Ar ~1%). In addition, many other gases are present in the atmosphere in smaller amounts. Some of these compounds, such as carbon dioxide (CO\textsubscript{2}) and methane (CH\textsubscript{4}), are known as greenhouse gases because of their heat-trapping properties. These gases absorb specific wavelengths of light and then reradiate the energy as heat. Without greenhouse gases, nearly all the heat gained by the earth from sunlight would simply be lost directly back into space. Greenhouse gases act as a sort of lobster trap for the sun’s heat: sunlight can pass through them, but once it has, it can no longer escape. The higher the concentration of greenhouse gases in the atmosphere, the more heat is trapped. Greenhouse gases therefore play a critical role in determining the temperature and climate of our planet.

Humans have been releasing greenhouse gases into the atmosphere ever since the discovery of fire. The historical burning of biomass such as wood and plants does not cause a net change in atmospheric carbon levels, however; plants absorb carbon from the atmosphere during their lifetime, so the release of that carbon during combustion does not have any net effect. It was not until the Industrial Revolution during the 18\textsuperscript{th} century that atmospheric concentrations of carbon skyrocketed due to the burning of fossil fuels. The link between human activities and the accumulation of carbon in the atmosphere has been clearly established by the International Panel on Climate Change. Figure 3.1 shows the atmospheric concentrations of three important greenhouse gases over the last millennium. A sharp spike in the concentration of each of the three gases is evident beginning around the 1800s, consistent with the dramatic increase in the burning of coal and other fossil fuels that occurred during the Industrial Revolution.
Figure 3.1: Global atmospheric concentrations of three greenhouse gases\(^1\).

Historical and scientific records show that global average surface air temperatures also began to increase upon the dawn of the Industrial Revolution. This comes as no surprise to climate scientists, given that greenhouse gases prevent heat from escaping from the atmosphere. Figure 3.2 shows variations in surface temperatures of the earth since 1860, when thermometer measurements were first recorded globally, and over the past 1,000 years. Again, the increase in temperatures that has occurred over the past 150 years is striking; the global average surface air temperature has increased by 0.6 ± 0.2\(^\circ\)C during the 20\(^{th}\) century.

Average surface air temperature is the most concrete measure of the state of the global climate; however, it is not the only measure. Temperature strongly impacts many important aspects of climate, including precipitation and extreme weather events. The table following Figure 3.2 summarizes changes in climate observed during the 20\(^{th}\) century as well as changes projected to occur in the future.

---

\(^1\) Intergovernmental Panel on Climate Change, Working Group I. *Climate Change 2001: The Scientific Basis.*
Figure 3.2: Variations of the Earth’s surface temperature over time\(^2\).

\(^2\) Intergovernmental Panel on Climate Change, Working Group I. *Climate Change 2001: The Scientific Basis*. 
### Table: IPCC estimates of confidence in observed and projected changes in extreme weather and climate events.

<table>
<thead>
<tr>
<th>Confidence in observed changes (latter half of the 20th century)</th>
<th>Changes in phenomenon</th>
<th>Confidence in projected changes (during the 21st century)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelya</td>
<td>Higher maximum temperatures and more hot days over nearly all land areas</td>
<td>Very likely</td>
</tr>
<tr>
<td>Very likely</td>
<td>Higher minimum temperatures, fewer cold days and frost days over nearly all land areas</td>
<td>Very likely</td>
</tr>
<tr>
<td>Very likely</td>
<td>Reduced diurnal temperature range over most land areas</td>
<td>Very likely</td>
</tr>
<tr>
<td>Likely, over many areas</td>
<td>Increase of heat index over land areas</td>
<td>Very likely, over most areas</td>
</tr>
<tr>
<td>Likely, over many Northern Hemisphere mid- to high latitude land areas</td>
<td>More intense precipitation events</td>
<td>Very likely, over most areas</td>
</tr>
<tr>
<td>Likely, in a few areas</td>
<td>Increased summer continental drying and associated risk of drought</td>
<td>Likely, over most mid-latitude continental interiors (lack of consistent projections in other areas)</td>
</tr>
<tr>
<td>Not observed in the few analyses available</td>
<td>Increase in tropical cyclone peak wind intensities</td>
<td>Likely, over some areas</td>
</tr>
<tr>
<td>Insufficient data for assessment</td>
<td>Increase in tropical cyclone mean and peak precipitation intensities</td>
<td>Likely, over some areas</td>
</tr>
</tbody>
</table>

3.2. Implications for the United Kingdom

As temperatures rise and the global climate changes, there is no doubt that every corner of the globe will be affected in some way. It is important that countries and individuals understand how their local climate might be affected, in order to prepare for the inevitable political, economic, and social impacts of climate change. The U.K. Climate Impacts Programme (U.K.CIP) was established in 1997 by the U.K. Government “with the aim of providing a framework for integrated national assessment of climate change impacts.” The U.K.CIP has developed a description of the future U.K. climate based on scenarios from the Special Report on Emissions Scenarios published by the Intergovernmental Panel on Climate Change\(^2\). Figure 3.3 shows the mean annual temperature change predicted to occur in the U.K. under

---

\(^a\) The Summary for Policymakers uses the following words to indicate judgmental estimates of confidence: virtually certain (greater than 99% chance that a result is true); very likely (90-99% chance); likely (66-90% chance); medium likelihood (33-66% chance); unlikely (10-33% chance); very unlikely (1-10% chance); exceptionally unlikely (less than 1% chance).

\(^2\) Intergovernmental Panel on Climate Change, Working Group I. *Climate Change 2001: The Scientific Basis.*
assumptions of both low and high emissions. The box above that figure summarizes the climate changes that the U.K. can expect to see in the near future.\textsuperscript{4}

\begin{boxed_text}
Potential effects of climate change in the UK:
\begin{itemize}
\item UK climate will become warmer.
\item High summer temperatures will become more frequent and very cold winters will become increasingly rare.
\item Winters will become wetter and summers may become drier everywhere.
\item Snowfall amounts will decrease throughout the UK.
\item Heavy winter precipitation (rain and snow) will become more frequent.
\item Relative sea level will continue to rise around most of the UK’s shoreline.
\item Extreme sea levels will be experienced more frequently.
\item The Gulf Stream may weaken in the future.
\end{itemize}
\end{boxed_text}

\textbf{Box:} Implications of global climate change for the U.K..

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig3_3.png}
\caption{Predicted mean annual temperature change in the UK during the 21\textsuperscript{st} century\textsuperscript{5}.}
\end{figure}

\textsuperscript{4} UK Climate Impacts Programme. \textit{Climate Change Scenarios for the United Kingdom: the UKCIP02 Briefing Report, April 2002.}
3.4. Anthropogenic greenhouse gas emissions

Greenhouse gases have a wide range of sources, both natural and anthropogenic. Carbon dioxide, methane, nitrous oxide, and ozone are present in the environment naturally, but are also released as a result of human activities. Other greenhouse gases, such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, are emitted solely as a result of human use\(^5\). Because there is little that can reasonably be done to control the natural presence of greenhouse gases in the environment, it is important to focus on methods of reducing anthropogenic emissions of such gases. Carbon dioxide emissions resulting from the combustion of fossil fuels are by far the most significant anthropogenic source of greenhouse gases. In the United Kingdom, carbon dioxide emissions account for five-sixths of all greenhouse gas emissions\(^6\). It is therefore logical to focus efforts at reducing emissions of greenhouse gases on carbon dioxide emissions.

<table>
<thead>
<tr>
<th>Greenhouse gas</th>
<th>Primary sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO(_2))</td>
<td>Fossil fuel combustion</td>
</tr>
<tr>
<td>Methane (CH(_4))</td>
<td>Landfills and waste, natural gas distribution, coal mining</td>
</tr>
<tr>
<td>Nitrous oxide (N(_2)O)</td>
<td>Agricultural soil management (fertilizer)</td>
</tr>
<tr>
<td>Hydrofluorocarbons (HCFCs), perfluorocarbons (PCFs), sulfur hexafluoride (SF(_6))</td>
<td>Production of HCFCs, electrical transmission and distribution</td>
</tr>
</tbody>
</table>

**Box:** Major greenhouse gases in order of significance and their primary anthropogenic sources.\(^7\)

3.5. Carbon dioxide as a measure of sustainability

In this report, we have chosen carbon dioxide emissions as one of the two measures of sustainability to be used in evaluating proposals for the North West development. The carbon dioxide released into the atmosphere as a result of the behaviour of the people living and working in the North West site will affect the future of each person on the planet. Therefore, in order to ensure that the principles of sustainability are upheld in the North West development, this report will examine strategies to reduce emissions of carbon dioxide.

To reduce the rate at which carbon accumulates in the atmosphere we have two options; to decrease emissions and to increase sequestration (the removal of carbon from the atmosphere). At present, actively removing carbon from the atmosphere in quantities large enough to significantly impact the total concentration is not a realistic solution. Instead, we focus in this report on controlling the rate at which carbon enters the atmosphere (future reports in this series will consider carbon sequestration). Once the decision has been made to do this, policies encouraging or requiring a decrease in emissions must be implemented. These policies must target societal infrastructure; the use of materials and energy (and therefore the emission of carbon) ultimately occurs at the level of the residential, commercial, industrial, and transport sectors of society.

\(^7\) United States Environmental Protection Agency. *In Brief: The U.S. Greenhouse Gas Inventory.*
3.6. The Model

To develop and test policy scenarios aimed at reducing the rate of accumulation of carbon dioxide in the atmosphere, it is important to understand the flow of carbon through the environment after its release by humans in the form of carbon dioxide. Mathematical models can be used to predict the impact of a particular policy. Models such as those used by the Intergovernmental Panel on Climate Change (IPCC) have been developed to simulate the emissions of greenhouse gases, their dynamics in the earth system, the resulting concentrations in the atmosphere, and the effect on temperature and climate. These models, however, are too complex to be used to assess policies specific to Cambridge and the development of the North West site. Instead, our analysis employs a simpler reduced-scale global warming model that mimics the more complex models (the complete model may be obtained from the authors of this report). In addition, several variations of the global model have been developed for use at the level of the United Kingdom, Cambridge, and the North West site.

Scientific understanding of global warming begins with the study of how carbon dioxide moves throughout the environment once it is released from the infrastructure. This movement is described by the carbon cycle, as shown in the upper left portion of Figure 3.4. The cycle depicts the flow of carbon regardless of its chemical and physical form, since the model used in this paper predicts total carbon content of a compartment. Carbon content in the atmosphere can be converted to carbon dioxide in the atmosphere by multiplying the carbon content by approximately 44/12 (the ratio of the mass of a carbon dioxide molecule to that of carbon).

![Figure 3.4: The compartments and processes of the reduced-scale model.](image)

While the cycle is more complex than shown in the figure above, the reduced scale model used here focuses on six primary compartments of the earth system (soil/litter, atmosphere, flora, mixing ocean, deep earth and society) because they dominate the carbon fluxes. The flows of carbon (in units of billions of metric tonnes of carbon per year, or BMT/year) represent emissions from the infrastructure to the atmosphere; movement from the atmosphere to soil; exchange between the atmosphere and flora; movement from flora to soil; movement from soil to sequestration in the earth;
exchange between the atmosphere and mixing ocean; and movement from the mixing ocean to the deep earth. Fauna are not included because they do not contribute significantly to the overall carbon flux in the global system.

In the model, movement from the atmosphere to flora is governed by land use, modelled as the net rate of flow and related in turn to net primary productivity, or NPP. NPP is a measure of the capture of atmospheric carbon by the flora, equal to the difference between the rate of flow from the atmosphere to the flora and the rate of flow back from the flora to the atmosphere. While there are literally thousands of values for NPP across the wide array of species, the present model reduces these to six categories to simplify calculations: barren land, cropland, grassland, forest, marshland, and rain forest. For each of these, both the value of NPP (in units of BMT/m²-year) and the total land area (in m²) are determined. The product of these two quantities, summed over all six categories, equals the net rate of flow from the atmosphere to flora in Figure 3.4 (in units of BMT/year).

The emission term from society to the atmosphere contains two components: the per capita emissions of carbon (carbon released to the atmosphere per person per year, with units of BMT/person-year) and the population size (units of “people”). These two quantities are specified separately for the developed and developing worlds, as they differ significantly. The product of these two components for the developed world yields the emission rate from society to the atmosphere for the developed world (in units of BMT/year), with a similar product for the developing world. The per capita emissions term may be broken down into terms from the industrial, commercial/residential and transportation sectors, and into fuel types in these energy sectors. The per capita emission rate is a function of per capita energy needs, the efficiency at which these needs are met, and an emissions factor (mass of carbon released as carbon dioxide per unit fuel consumed). Population size is dependent on the rate of birth, the survival of infants and the rate of mortality in a population (the two populations of the developed and developing worlds).

3.7. Model performance

In order to verify that the predictions of a model are reasonable, it is necessary to compare them with real world data or with the predictions of other accepted models. The IPCC Special Report on Emissions Scenarios (SRES) presents a set of scenarios describing the range of paths that might be followed under different assumptions about population growth and per capita production. By comparing the projections of the reduced-scale model with those of the IPCC, it has been established that the predictions of the reduced-scale model fall within an acceptable range of differences between the present model and the IPCC models (see Figure 3.5).
The 1997 Kyoto Protocol aims to stabilize atmospheric carbon concentration at a level no higher than twice the level present in the atmosphere prior to the Industrial Revolution. This means that the concentration of carbon in the atmosphere should not exceed 550 ppm, or approximately 1160 billion metric tonnes of carbon. At the current rate of increase, concentrations may exceed this level in less than forty years (see Figure 3.6). It has been determined that a reduction in carbon dioxide emissions of 60% by 2050 in the developed world will be necessary to achieve stabilization at or below 550 ppm. Figure 3.6 also shows the predicted effect of reducing carbon dioxide emissions by 60%, using the reduced scale model employed in the present report.

---

As is evident from Figure 3.6, with no policies in place to reduce emissions or stabilize population globally, atmospheric carbon will exceed a doubling of the pre-industrial level between approximately 2070 and 2110. A 60% reduction in carbon dioxide emissions of the developed world prevents a doubling of the pre-industrial level for at least 200 years, assuming that per capita production does not increase in the future. Stabilizing the global population also has a significant impact on atmospheric carbon; a world with a stable population and no emissions reduction does not reach a doubling of pre-industrial levels until after 2100 so long as there is no increase in per capita emissions (although it does reach it shortly after that time). However, this does not mean that we should simply forget about reducing emissions and instead focus on population control, since per capita emissions are in fact increasing rapidly in both the developed and developing world.

Because of its economic and political power, the United Kingdom has the capability to be a world leader in reducing greenhouse gas emissions. The Government’s Energy White Paper states: “the U.K. should put itself on a path to a reduction in carbon dioxide emissions of some 60% from current levels by about 2050.” In addition, by signing the Kyoto Protocol, the U.K. committed to reducing CO₂ emissions 12.5% below 1990 levels by 2008-2012; a national goal to move towards a 20% reduction by 2010 has also been set\textsuperscript{10}.

Carbon dioxide is emitted in its gaseous state, and therefore it mixes freely with the other contents of the atmosphere. This means that the amount of carbon in the atmosphere is relatively constant around the globe; the concentration of carbon dioxide above the United Kingdom is the same as the concentration of carbon dioxide above Botswana. However, the average person in the U.K. is clearly responsible for producing far more carbon dioxide emissions than is the average person in Botswana. This detail raises the issue of social justice and global equity. Is it fair for the U.K. to contribute nearly ten times more CO\textsubscript{2}\textsuperscript{*} to global emissions than would be expected based on its land area and population? Should a developed country be allowed to emit unlimited amounts of CO\textsubscript{2} simply because another country is not producing any (and can, therefore, use the atmosphere above its land to dilute the excess carbon dioxide produced in the developed world)?

In assessing strategies by which Cambridge and the North West development can help to prevent a doubling of pre-industrial atmospheric carbon levels there are two approaches that can be taken. The first is to focus on meeting the goal of a 60% reduction in carbon dioxide emissions as presented in the Energy White Paper. By meeting this goal, Cambridge will be doing its part to reduce emissions of the developed world and stabilize carbon dioxide concentration in the atmosphere below 550 ppm. The second approach is to imagine placing a closed box around Cambridge and then striving to prevent a doubling of CO\textsubscript{2} levels within the box. This is analogous to asking: what would the world be like if it were identical in all respects to the population density, energy use and carbon absorbing properties of Cambridge? This approach should require a significantly larger reduction in emissions, because the high emissions level of Cambridge will no longer be countered by dilution in the atmosphere above areas in the undeveloped world producing little or no carbon dioxide.

To determine the amount by which “Cambridge in a box” would need to decrease its emissions, a reduced-scale carbon model for Cambridge was developed. In the model, Cambridge was assigned a percentage of the land area of the U.K. based on the ratio of its population to the U.K. population. Each of the compartments in the model was assigned the percentage of the world’s land area represented by Cambridge (discussed above). Calculation of per capita production was based on energy consumption in the U.K.; demographic information was specific to Cambridge. Figure 3.7 shows the predicted level of atmospheric carbon inside the “box” with no policies in place to control emissions. The red horizontal line represents the doubling of the amount of atmospheric carbon present in this “box” prior to the Industrial Revolution. Note that the goal here is exactly the same as that of the IPCC: to stabilize atmospheric carbon at a level below a doubling of the pre-Industrial Revolution level. The sole difference is that Figure 3.7 considers only a closed box above Cambridge while the IPCC approach allows the developed world to dilute its excess carbon dioxide emissions into the atmosphere above developing nations.

---

\textsuperscript{*} The UK is responsible for around 2% of global emissions; the ratio of UK land area to world land area is approximately 0.002.
With no policies in place, the amount of carbon in the atmosphere inside Cambridge’s “box” exceeds a doubling in less than ten years. If a policy requiring a 60% reduction in emissions were to be implemented in accordance with the goal of the *Energy White Paper*, a doubling of atmospheric carbon attributed to Cambridge would still occur in less than thirty years. To prevent a doubling of pre-industrial levels of atmospheric carbon from occurring before the year 2050, a 76% reduction in current CO$_2$ emission levels is necessary; to prevent a doubling from occurring before 2100, at least an 86% reduction of emissions is required (see Figure 3.8). Again, these much more stringent requirements are the result of considering the air above Cambridge to be a closed box, for which the citizens of Cambridge are solely responsible. This is a tall order indeed! However if every region of the world adopted the same strategy of keeping their own atmospheric “boxes” below the limit, the global atmosphere also would remain below the limit!

**Figure 3.7**: Atmospheric carbon attributable to Cambridge with no policies in place.
3.8. The North West development

The development of the North West site in Cambridge presents a unique opportunity to utilize strategies and technologies which reduce carbon dioxide emissions from the very beginning. Mathematical modeling can be a particularly useful tool for determining the effectiveness of policies. The model developed for the North West site is similar to that used for Cambridge, as described in the previous section. With no emissions reduction policies in place, atmospheric concentrations of carbon for which the North West development is responsible will exceed a doubling of pre-industrial levels in less than ten years (Figure 3.9). Once again, the red horizontal line represents the doubling of the amount of atmospheric carbon present in this “box” prior to the Industrial Revolution. To prevent a doubling by 2050 and by 2100, emissions reductions of 68% and 81% respectively are needed (Figure 3.10).
Figure 3.9: Atmospheric carbon attributable to the future North West development with no policies.

In this report, a number of policy options for the North West development have been explored. From the analysis above, it is evident that the site design must reduce per capita emissions by at least 12.5% (relative to the current U.K. average) to meet the
Kyoto requirements; by 60% to meet the ambitious Energy White Paper goal; and by slightly more than 80% to meet the goal of preventing a doubling of the carbon dioxide in the atmosphere of a closed box placed above the site. Figure 3.11 shows the effect of the different policies described in the present report, which in sum amount to a reduction of on the order of 25%. Note that even the “All policies” line (the combined effect of policies in all sectors) still results in a rapid doubling of the atmospheric carbon dioxide in the “box”, indicating that the policies described in this report are only the minimum acceptable. Future reports in this series will detail more measures that might be taken to produce more dramatic reductions.

Figure 3.11: Atmospheric carbon attributed to the future North West development under policy scenarios presented in this report.
Section 4: Educational and Research Sector

The long-term vision for the North West Cambridge Site is based on the academic tradition of the University of Cambridge. This development will embrace the core scholastic tradition of the University while upholding the physical planning and design principles that the university has valued to this point. The 21st century will require additional needs from the university sector. The following section illustrates how sustainable development policies can balance the needs of the university with the concerns of CO₂ emissions and increased health risks.

4.1. The Educational and Research Needs

The University of Cambridge is an academic institution that honours and respects its past. The University also values the importance of innovation and progress in order to maintain future academic success as one of the world’s premier institutions. At the forefront of this progressive movement stands the need for scientific and technological advancements. Academic activities in Cambridge have proven to have a direct impact on the economy, as demonstrated by the “Cambridge Phenomenon” characterized by the trend in high-technology companies located in the Cambridge region.11 Thus, the university needs modern facilities that are capable of accommodating contemporary areas of research and development in health, technology and science.

4.2. Satisfying Educational and Research Needs

Part of the answer to Cambridge’s academic needs is an expansion in its research facilities, laboratories and colleges in the North West portion of Cambridge. The University, in collaboration with the Cambridge City Council and Cambridgeshire County Council, has planned two new academic developments to fulfil these needs. The West Cambridge site, which has been under construction since January 2000, will house physical science and commercial research facilities. The North West Cambridge site will house a variety of science and technology research sectors, as well as higher education and knowledge-based industries research. The present assessment will focus solely on the University buildings of the proposed North West Cambridge site.

The North West development’s academic sector will include modern research facilities, as well as three colleges (two graduate colleges and one undergraduate). While initial designs for development at the North West Cambridge site are still in the planning stages (the proposal is currently being created by the University’s governing body), it is understood that the site will have to satisfy many significant needs of the university.

These needs will be met through research facilities and colleges that are best suited for an effective and efficient academic environment. First of all, the North West site’s buildings will include floor space for a variety of different academic uses, including laboratories, computer labs, classrooms, and multi-purpose rooms. These spaces will have to be equipped for variable uses. According to the Best Practice Programme for Energy Efficiency, research laboratories and workshops have a “variable occupancy

11 http://www-building.arct.cam.ac.uk/NorthWestc/facilities.html
pattern with the potential for high process loads. These research facilities will be designed to meet the needs for such loads, including what may be some rather energy-intensive activities.

Secondly, the academic buildings in the North West Cambridge development will require services for a successfully functioning building. Laboratories and academic buildings require temperature control (heating and cooling), HVAC systems, utility equipment, lighting, pumps, water utilities, and many other features. Computer networks and technology will be a high priority for the development’s needs.

It is evident that the University’s needs in the academic sector require the physical expansion of the campus through the construction of the North West development. The creation of these new buildings allows for immense flexibility in terms of research and academic use. Therefore, the North West development will allow the university to fill their needs for the 21st century. The task before us here is to determine whether those needs can be met without compromising the environmental quality of the area.

4.3. Associated CO₂ Emissions

The university buildings will cover a significant land area of the North West site. The estimate of land space currently allocated to research facilities at the site is 100,000 m². The large floor space and utilities that will be built to accommodate the university research, as illustrated in the previous section, will potentially require large amounts of energy (and CO₂ emissions) to keep the buildings in workable order. Moreover, scientific laboratories, due to their energy-intensive activities, often require a disproportionately high level of energy for operation. For example, the University of Toronto’s Earth Sciences Centre, which houses modern laboratories, computer rooms, and a greenhouse, consumes on average, 11 million kW-h annually. This scientific facility’s electrical consumption per square meter is 1.8 times the University of Toronto campus average.

Likewise, the University sector has the potential to release disproportionately high levels of carbon dioxide emissions into the atmosphere. For example, the 200 universities in the United Kingdom emit a total of 3 million tonnes of CO₂ into the atmosphere each year. On average, 25% of this CO₂ is attributed to the research sector of each campus, yet a significantly smaller fraction of floor space is allocated to research uses. It is apparent that research facilities generally release a significantly larger amount of CO₂ per square meter of floor space than the rest of the campus.

What is the cause of this discharge of CO₂ in the university research sector? First, an overwhelming percentage of the energy use on university campuses is created from the burning of fossil fuels. The University of Cambridge, for example, gets 73% of its energy from oil, coal or natural gas. These energy sources release CO₂ into the atmosphere. A second reason for the high-energy usage (and high levels of CO₂ emissions) is the relatively large numbers of energy-intensive instruments, equipment and devices that are used in laboratories. Many of these modern-day research facilities

---

12 Energy Efficiency in Further and Higher Education
13 http://www-building.arct.cam.ac.uk/North West/site_map.html
14 University of Toronto
are still housed in campus buildings that have very little in the way of energy efficient infrastructure to offset these activities.

The production of CO$_2$ which results from the operation of a “standard” research facility would not be suitable for the modern needs of the University of Cambridge or England as a whole. If standard designs and equipment were employed, it would be impossible to reach the ambitious energy and carbon dioxide reduction goals considered in this report. The University has set a goal to reduce both energy use and CO$_2$ emissions by 5% in the next 5 years. The United Kingdom, in contrast, has set its goal to achieve a 20% reduction of 1990 levels by 2010 and a 60% reduction by 2060. With high energy prices and increasingly stringent CO$_2$ emissions requirements on the horizon, the proposed designs for the academic sector at the North West development must take energy consumption into account. Fortunately, the following policies prove that energy usage can be significantly reduced in the university sector of the North West site while meeting the justified needs described earlier.

4.4. Policies to Reduce CO$_2$ Emissions

If the academic sector at the site were constructed with a “standard” design (along plans from past research facilities), the CO$_2$ emissions and energy costs will have a considerable impact on the goal of reaching sustainability in the region. The answer to this dilemma lies in the practice of sustainable development. The process of sustainable development for the academic sector at the North West site requires the consideration and analysis of both energy efficiency and energy production policies. Policies 4.4.1 through 4.4.5 introduce energy efficiency strategies for university buildings. Policies 4.4.6 through 4.4.8 discuss energy production methods that are viable for universities.

4.4.1 Heating Efficiency

The heating sector of higher academic institutions accounts for an average of 49% of the total energy used in those institutions. Such a significant fraction of the usage allows for greater reduction in energy consumption through energy efficient temperature control. The following is an inventory of heating and cooling efficiency strategies for the North West Development:

Energy Efficient Building Design: The North West development’s academic buildings can be designed and constructed in a manner that provides for the needs of the University while still minimizing energy use. For example, the Queens building at De Montfort University was constructed with a “high insulated, thermally massive envelope with generous ceiling heights, which promoted natural ventilation and daylight”. It was estimated that this building design resulted in a 13% increase in efficiency. Energy efficient building materials, such as wide internal insulating block work, double-paned glass (with at least a 20 mm gap) and 200 mm thick roof insulation, can also significantly reduce the energy bill and CO$_2$ emissions.

15 University of Cambridge Energy and Utilities Management
16 Presentation by Jamie Goth, University of Leicester
17 De Montfort University Case Study
Moreover, the location and orientation of a building can decrease the heating costs. According to the Smart Communities Network, “properly sited buildings, those that are placed on an east-west axis with the longest wall facing south, will benefit from solar heat, natural shading and natural lighting and thus reduce energy requirements”\textsuperscript{19}. Keeping this green building strategy in mind, the University of East Anglia opened the Zuckermann Institute of Connective Environmental Research building in July 2003.\textsuperscript{20} This mixed-use research facility was effectively heated, in many rooms, by a passive solar method.\textsuperscript{21}

*Thermal distribution systems:* The most prominent energy efficient thermal distribution scheme available is the Swedish-designed Thermodeck system, which has achieved great success in many higher education facilities across Europe.\textsuperscript{22} The Thermodeck system is an energy efficient environmental control structure, which “utilizes a building’s thermal mass to provide balanced ventilation with passive heating and cooling”.\textsuperscript{23} The system circulates 100% outside air through parallel hollow cores within the structural floor slabs. The Elizabeth Fry Building at the University of East Anglia has successfully operated the Thermodeck system since the building’s completion in 1995. The air within the walls is first heated by two 24 kW residential direct vent gas boilers, and then distributed throughout the building via fans. This system results in a total heating energy demand of 25 kW-hr/m\textdegree{}2/year.\textsuperscript{24}

*A heat exchanger:* A heat exchanger is a device specifically designed for the “efficient transfer of heat within fluids over a solid surface.”\textsuperscript{25} It operates as an energy efficient device for boilers, furnaces and other heating systems by recovering waste heat and reusing it in the system. The Geochem building at Cornell University, for example, implemented a free cooling and heat exchanger. This device resulted in an annual savings of approximately 400,000 kW-hr and 298 tons of CO\textsubscript{2}.\textsuperscript{26} Additionally, the Beddington Zero Energy Development (BedZED) utilizes a heat exchanger in their wind-driven ventilation system, which recovers between 50% and 70% of the warmth from the outgoing stale air”.\textsuperscript{27}

**4.4.2 Cooling and Refrigerant Efficiency**

Even in England, where the climate remains generally cool, research facilities still require cooling devices and refrigerant technology to maintain required temperatures in the laboratories. The University of Leicester, for example, found that cooling and refrigerant sources account for 24% of the entire research facility’s energy budget. More energy efficient cooling methods can be targeted as a means of minimizing the CO\textsubscript{2} attributed to the university sector.

*High-Efficiency High Capacity Cooling and Refrigerant System:* This system, designed by the Environmental Technology and Education Center (ETEC) in

\textsuperscript{19}http://www.sustainable.doe.gov/buildings/gbinto.shtml
\textsuperscript{20}http://www.uea.ac.uk/zicer/
\textsuperscript{21}http://www.vision.uea.ac.uk/zuckerman.html
\textsuperscript{22}Gloucester’s Oxstalls Campus (www.newbuilder.co.uk)
\textsuperscript{23}Gloucester’s Oxstalls Campus (www.newbuilder.co.uk)
\textsuperscript{24}http://www.coldhamarchitects.com/greenbuilding/greengrandtour/UK_ElizFry/uk_elizfry_desc.htm
\textsuperscript{25}http://www.heatexchangersonline.com/
\textsuperscript{26}Cornel Energy Website http://eco.pdc.cornell.edu/sustain/energy.htm
\textsuperscript{27}BedZed
Albuquerque, NM, uses an innovative compressor system to accommodate variable loads, resulting in a 30 to 40% cooling capacity and 10% great energy efficiency. This increased energy efficiency creates a smaller demand for electricity from the grid, and therefore releases less CO₂.

4.4.3 Equipment Efficiency

According to a study at the University of Leicester, approximately 12% of the total energy consumed by research laboratories is used by the lab’s equipment. With respect to CO₂ emissions, “lab equipment” is defined as the apparatus or machines that require electricity for operation. Computers, data collection equipment, scientific instruments and any other types of technology are all categorized as part of the “equipment” sector. Although the performance of the science and technology equipment generally cannot be compromised, the following two strategies demonstrate that the energy usage (and CO₂ emissions) can be efficiently controlled in the future design and implementation of the University sector at the North West Cambridge site.

*Computers Programmed for Sleep Mode:* Desktop computers consume approximately 120 watts of power. It is anticipated that the new university buildings at the North West site will emphasize computer technology. An effective means to minimize extra energy waste is to target the idle computer time. The University of Vermont, for example, is sponsoring a program as part of the "10% Challenge" campaign, in which sleep mode software is installed on every university and personal computer on campus. This software automatically turns off the computer’s monitor, which conserves 80% of the energy that would have been used in a screen saver program or standard monitor operation. It is estimated that this program can save 1.6 million kW-hr per year for all the 8,000 PCs on campus that have the program installed. Such a policy at the new North West site would lay the groundwork for more energy efficiency in the academic equipment.

*Modern Technology Alternatives:* The design, construction and maintenance of the North West site’s research facilities will require many equipment and facility decisions. The energy manager will need to continue to evaluate the benefits from different equipment options. A commitment to energy efficient devices, even in the seemingly minute details, can have a large impact on the CO₂ emissions from the North West site. Stephen Pucino, the utilities engineer at the University of Rhode Island, utilizes energy efficient exit signs in all of the university buildings. He states that exit signs are “on 24 hours a day, 365 days a year…most signs use 17 watts each, but this new technology uses just one quarter watt, so it will save us about 170,000 kilowatt-hours of electricity every year.” Such technological innovation will help move the North West site in a sustainable and energy efficient direction.

---

29 http://www.tufts.edu/tie/tci/pdf/Computer%20brochures.PDF
30 http://www.energy-solution.com/off-equip/technical.html
31 http://www.uvm.edu/~energy/?Page=Energy%20Efficiency%20Projects.html#Sleep_Mode
32 University of Rhode Island
4.4.5 Lighting Efficiency

The lighting of research facilities accounts for approximately 9% of the total energy consumption. However, university energy managers often regard this sector as a prime area for improvements in cost effectiveness and efficiency, as solutions are so readily available. Well-planned lighting can create a more comfortable and proficient working environment, decrease energy bills as well as reduce the levels of CO₂ entering the atmosphere.

*Ultra-Efficient Light Bulbs:* A standard 100-watt incandescent light bulb uses only 10% of its electricity for lighting, as the other 90% is converted to heat. Such a light bulb generally receives an energy rating of 17 lumens/watt. This inefficient use of electricity can be reduced through the installation of ultra-efficient lighting technology. The University of Vermont, for example, uses ultra T8 light bulbs. These bulbs are recognized as the most efficient bulbs on the market, as they receive a rating of 90 lumens/watt. A lighting policy, which includes the use of T8 light bulbs instead of standard fluorescent bulbs, will result in a 50% increase in energy efficiency for lighting in the academic sector.

*Light Sensor Technology:* As detailed in section 4.2, the research facility and academic sector at the North West Cambridge site will likely have “variable occupancy”, with different levels and patterns of use. A feasible policy option for the lighting scheme in the academic buildings should include the use of light sensor technology, which will decrease CO₂ emissions by monitoring lighting levels and current usage. The Gloucester’s Oxstalls Campus, for example, uses “automated blind and lighting systems with computerized feedback systems [which] can operate independently of people using the building”. According to a study by the University of Michigan, such sensor applications can save 20-75% of the energy in classrooms, 30-60% of the energy in corridors and 30-75% of the energy in restrooms.

4.4.6 Pumps and Fans Efficiency

The final component of an academic building’s operation and efficiency management is the analysis of the building’s pumps and fans. These devices are used for managing the flow of air or liquid within the infrastructure of the buildings. With respect to research facilities, pumps and fans are often used for fluid control in scientific and technological operations. The following policies can be considered and utilized in the design of the research facilities and academic buildings at the North West site:

*Variable Speed Control:* Recent advances in microelectronics and control technology have resulted in the ability to use variable shaft speed controls on pumps and fans to manage the speed and flow throttling of the fluid load. Variable speed control technology can conserve energy by adjusting the velocity of flow, which minimizes

---

33 http://www.energymanagement.umich.edu/utilities/energy_management/Lighting_Guide.html
34 http://forest.fireshui.com/home/lighting.html
35 University of Vermont
36 Gloucester’s Oxstalls Campus
37 University of Michigan
the static pressure of the flow over the fluid loop.\textsuperscript{38} Thus, variable speed controllers typically reduce the compressor electrical use by 20-50\%.*\textsuperscript{39}

System Cohesiveness: Design, installation and use of pump and fan systems are key factors in sustaining energy efficiency in this sector. The position and location of pipes and ducts in relation to the respective pump or fan, have a major impact on the energy required for the transport of the fluid. This is because pumps and fans are designed with particular pipe dimensions in mind, and straying from these specifications necessitates more energy use. Also, leaky valves or improper filters can greatly reduce the efficiency by which the fluids flow in the system, and therefore require more energy for daily use.\textsuperscript{40} The transport of fluids in the proposed academic buildings at the North West site should be viewed as a system which can be tuned to operate in the most cost effective and energy efficient manner, thereby decreasing the CO\textsubscript{2} emissions.

4.4.7 Solar Energy: Photovoltaic Cells

University campuses around the world have begun to harness the power provided by the sun’s radiation. For example, the 275 m\textsuperscript{2} of photovoltaic panels installed on the roof of the Zuckermann Institute at the University of East Anglia provide 33 kW of peak power for the university. Such case studies illustrate the increasing development of photovoltaic technology, and its ability to provide CO\textsubscript{2}-free energy for academic institutions. Therefore, the university buildings at the North West Cambridge site should consider the policy option of operating a sustainable photovoltaic facility. For a complete analysis of the feasibility and policy options for photovoltaic solar power, please refer to Section 8.

4.4.8 Co-generation Plant

The compatibility of co-generation plants and the university sector has been proven; such facilities work very efficiently and successfully to produce energy. Moreover, the production, transmission and utilization of energy from these facilities are much more energy efficient and sustainable in terms of the levels of CO\textsubscript{2} released into the atmosphere. Please refer to Section 6 for a partial analysis of the policy options for a co-generation plant at the North West site.

4.5 Summary Reduction of CO\textsubscript{2} Emissions With Implemented Policies

The table below summarizes the percentage of energy use in five sectors of the university buildings, with an estimate of the potential gain in efficiency, reduction in energy use, and reduction in carbon dioxide emissions, using the policies described previously in this section.

\textsuperscript{38} http://greenbuildings.santa-monica.org/controlsys/fanspumps.html
\textsuperscript{39} http://www.energy.wsu.edu/ftp-ep/pubs/engineering/motors/MotorDrvs.pdf
\textsuperscript{40} http://dsm.eskom.co.za/industrial/enrg_eff/fans_pumps.php
### Efficiency Measures

<table>
<thead>
<tr>
<th>Efficiency Measures</th>
<th>% of Total Energy Used-Research Facilities</th>
<th>Potential Energy Efficiency Gain*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>49 %</td>
<td>35 %</td>
</tr>
<tr>
<td>Cooling and Refrigerant</td>
<td>24 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Equipment</td>
<td>12 %</td>
<td>15 %</td>
</tr>
<tr>
<td>Lighting</td>
<td>9 %</td>
<td>40 %</td>
</tr>
<tr>
<td>Pumps and Fans</td>
<td>6 %</td>
<td>25 %</td>
</tr>
</tbody>
</table>

### 4.6 Health Risk Implications of Education and Research Buildings

Significant sources of indoor air pollution are present in educational and research buildings. The European Commission (EC) released a study on 22 September 2003, showing that human exposure to indoor pollution can in some cases be at least twice that from outdoor pollution. European Union (EU) research shows that Europeans spend 90 percent of their time indoors. Hundreds of toxic, mutagenic, or carcinogenic indoor pollutants have been identified, many associated with respiratory effects. For example, at least 20 percent of Europeans suffer from asthma exacerbated by exposure to indoor air pollution.  

Indoor air quality is an important determinant of human health, and is therefore a measure of sustainability.

The United States Environmental Protection Agency (U.S. EPA) has created an *Indoor Air Quality Building Education and Assessment Model* (I-BEAM) as a guidance tool for managing indoor air pollution; this is a potential tool for use in assessing the site. Within that assessment system, the air quality in buildings is measured by the concentration of pollutants as well as by temperature and relative humidity conditions. The comfort, health, and performance of students, faculty, and staff will depend on the air quality in the University buildings. One of the major needs for the North West site, therefore, is the adoption of designs for buildings that ensure quality indoor air for an optimal environment.

A building’s indoor air quality is the result of many factors, including the climate, the site, the design and structure, construction techniques, building materials and furnishings, moisture and activities within the building. The risks imposed also depend on the building occupants, as subpopulations can differ significantly with respect to their sensitivity to pollutants. Four elements of a building determine indoor air quality and risk:

- **Sources**: pollutants are associated with sources of contamination either within the building or outdoors; these must be identified and characterized as to the nature of the pollutant, the source term (amount emitted per unit time), and the location of the source.
- **Heat, Ventilation and Air Conditioning System (HVAC)**: the ability of the HVAC system to control air pollutants and maintain comfortable temperature

---


and humidity conditions must be characterized to understand how a source term results in a given concentration of the pollutant in indoor air.

- **Pathways**: people are exposed through a variety of pathways, including direct inhalation, contact with contaminated surfaces, and ingestion of contaminated food; these pathways must be characterized to determine the most effective point of control of exposure.
- **Occupants**: building occupants can differ significantly with respect to their sensitivity to specific pollutants; it is important that indoor air quality and risk be assessed for the more sensitive individuals likely to occupy those buildings.

These four issues are addressed further below.

**Source Term**

The risk of indoor air pollutants depends on the concentration of the pollutant in the air, which in turn is a function of the source terms for the pollutants, the ventilation rate, and the size of the building. This relationship can be described by the following equation:

\[
\text{Concentration of Pollutant} = \frac{\text{Source Term}}{\lambda \times \text{Volume}}
\]

The source term refers to the amount of pollutant released into the air per unit time, usually expressed in grams per hour. The term \(\lambda\) represents the ventilation rate, or the rate at which air inside a building is completely replaced (units of time\(^{-1}\)).

Planning and design of buildings can prevent high concentrations of indoor pollutants by either decreasing the source term or increasing the ventilation rates. The volume of the building can also be increased, but this will increase overall energy consumption and carbon dioxide emissions, and so is not considered further here as a viable policy for attaining sustainability. Examples of sources of air pollutants include:

- **Outdoor air sources**: industrial pollutants, vehicle exhaust, re-entrained building exhaust, pollen, dust, fungal spores, radon, pesticides, landfills
- **Building equipment**: HVAC system, emissions from office equipment (volatile organic compounds, ozone), solvents, toners, emissions from labs, mechanical systems
- **Cleaning and maintenance products**: air fresheners, paint, varnishes, wax, disinfectants
- **Human Activities**: smoking, cooking, cleaning materials, trash, paint, adhesive, pesticides
- **Building Components and Furnishings**: textured surfaces (carpeting, curtains, textiles), microbial growth in areas of surface condensation, chemicals released from components and furnishings (volatile organic compounds, inorganic compounds)

---

These sources produce a wide range of indoor air pollutants. The following list includes only those pollutants that can be controlled by building design and practices.

- **Combustion Contaminants**: generators, furnaces, gas or kerosene space heaters, outdoor air, vehicles, tobacco products
- **Biological Contaminants**: Wet or damp materials, cooling coils or drain pans, cooling towers, humidifiers, condensation, re-entrained sanitary exhausts,
- **Volatile Organic Compounds (VOCs)**: Stains, paints, solvents, varnishes, pesticides, adhesives, wood preservatives, waxes, polishes, lubricants, cleaners, dyes, fuels, sealants, air fresheners, plastics, copy machines, printers, perfumes
- **Formaldehyde**: plywood, cabinetry, furniture, fabrics, particle board
- **Soil gases, including radon, sewer gas, VOCs, methane**: Soil and rock, sewer drain leak, dry drain traps, leaking underground storage tanks, land fill
- **Radon**: a colorless, inert gas associated with lung cancer and generally produced by soil and rocks under the foundation and/or building materials
- **Particles and Fibers**: printing, paper handling, deterioration of materials, construction/renovation, vacuuming, insulation

**HVAC System**

Another important contributor to indoor air pollution is the HVAC system, which can increase the ventilation rates of the building, as well as reduce concentrations through filtering. The HVAC system includes all heating, cooling, and ventilation equipment in a building. A well-designed system provides thermal comfort, meets the ventilation needs by circulating sufficient amounts of outdoor air, and uses pressure control, filtration, and exhaust fans to isolate and remove pollutants and odors.

Controlling the indoor climate of a building depends on the HVAC system and affects the comfort level of the occupants. Often the temperature discomfort leads to increased sensitivity to other factors in the building. At higher temperatures, chemicals inside the building are released at a greater rate. Therefore, a warmer environment leads to a greater exposure to indoor pollutants. The design and maintenance of the HVAC system can reduce these problems. Unfortunately, optimizing the HVAC system with respect to energy efficiency may be at odds in some instances with the goal of reducing indoor air pollution. As seen in Equation 1, increasing ventilation rates decreases air concentration, but this is at the expense of energy efficiency if the circulated air is vented directly outdoors without re-capturing the heat.

---

The relationship between the ventilation system and the concentration of pollutants is shown by the graph below. As the air exchange rate increases, the relative concentration of the pollutants within the building decreases. Thus, the ventilation system is a very important consideration in controlling indoor air quality.

![Graph showing the relationship between ventilation rates and relative concentrations of pollutants](image)

**Figure 4.1: Ventilation Rates and Relative Concentrations of Pollutants**

**Pollutant Pathways**

The airflow patterns in a building result from mechanical ventilation systems, natural forces, and human activity. Contaminants are moved through the building by pressure differences resulting from the mechanical ventilation. The distribution of pollutants through these pathways is determined by the design and maintenance of the building. Exposures will tend to be primarily through inhalation of the pollutants, with secondary exposures through contact with surfaces that become contaminated as pollutants settle out of the atmosphere. Generally, the inhalation pathway would be considered dominant.

**Building Occupants**

In order for a building to be classified as sustainable, it must provide a high quality of life for all individuals working within the facility. The faculty, staff, and students will have different exposure times due to the time spent within the buildings, and different sensitivities to any pollutants that might be present. Especially sensitive groups will be those with pre-existing allergies, asthma, respiratory disease (e.g. chronic obstructive pulmonary disease), heart disease, and suppressed immune systems. The developers and planners should design buildings for the North West site that will produce target concentrations of pollutants that will be safe even for these more sensitive subpopulations.

---

4.7. Health Effects

The adverse human health effects from poor indoor air quality differ in severity and symptoms. The effects can be categorized as follows:

- **Acute Effects**: these occur immediately after exposure, usually in the form of headaches or temporary respiratory difficulty.
- **Chronic Effects**: these are long-term effects due to extended and/or frequent exposure. Cancer is the most commonly associated long-term health effect due to exposure to indoor air pollution, but this category includes chronic respiratory distress and heart disease.
- **Discomfort**: this usually is caused by climatic conditions (heat and humidity), but can arise at times from contaminants at levels below those needed to induce obvious acute and chronic effects discussed above. The effects can lead to absenteeism and loss of employee morale, in turn affecting the economic performance of an organization.
- **Performance Effects**: these are significant measurable changes in people’s ability to concentrate or perform mental or physical tasks. They can be produced by changes in temperature and relative humidity, and/or by indoor air pollution. Losses can be on the order of several percent or more in poorly designed buildings.

New terms have recently been created to describe adverse health effects associated with exposure to poor indoor air quality. These include:

- **Sick building syndrome (SBS)**: this refers to many acute complaints with no clear cause. The symptoms, including nose, eye, and throat irritation, headache, stuffy nose, mental fatigue, lethargy, and skin irritation, are only present when occupants are inside the building. Causes are likely to be related to sources of physical, chemical and biological pollutants; poor climate control; poor ergonomic design of work spaces; etc.
- **Building Related Illness (BRI)**: this refers to a defined illness with a known causative agent, chemical or biological, present in the indoor air. Biological sources include mold and bacteria in humidification systems, drain pans or filters, cooling towers, wet surfaces, and water damaged building material. Symptoms include fever, chills, cough, and flu symptoms. Several serious illnesses can occur, including lung and respiratory conditions, Legionnaires’ disease, hypersensitivity pneumonitis, and humidifier fever.
- **Multiple Chemical Sensitivity (MCS)**: Some individuals are more sensitive to low levels of pollutants which do not affect the general population. Exposure to a chemical at high levels may lead to increased sensitivity to the chemical at low levels. MCS refers to human sensitivity to low levels of a broad range of chemicals often seen in homes and building environments. It is the cumulative effect of these chemicals, acting through shared mechanisms, that produces the health problem; this occurs even though the concentration of each chemical individually may below levels generally thought to be of concern.

Buildings within the North West site should provide healthy working and learning environments, without posing risks of the above adverse health effects in the most sensitive subpopulations likely to occupy those buildings. Fortunately, the most
sensitive individuals tend to be the very young (the first year of life) and the elderly, neither of whom are likely to spend significant time in the academic and research buildings (a possible exception might be on-site day care facilities for the young children of employees). Future reports in this series will quantify the health benefits of improved building design on the occupants likely to be located in the North West buildings.
Section 5: Residential and Commercial Sector

Development at the site will include housing for university staff, as well as a significant number of dwellings for the open market. In addition, there will be at least some commercial buildings providing essential services to the residents. Since residential and commercial buildings are similar in their energy use, they are combined here into a single sector. Solutions that work in residential buildings generally are applicable to commercial buildings. Throughout the remainder of this section, lessons will be drawn from advances in sustainable home construction, as this is where the greatest advances have been made. The same lessons, however, may be extended to the design and construction of commercial spaces.

The University wishes to demonstrate its commitment to making these buildings sustainable, demonstrating not only to Cambridge, but also to the citizens of Cambridge, the U.K., and to the world that sustainable buildings are both technologically feasible and economically viable. All homes in the North West development are, therefore, intended to provide healthy living environments for their residents. In addition, innovative design and construction strategies can reduce energy use and carbon dioxide emissions by up to 60%, helping Cambridge and the U.K. meet the laudable goal of reducing carbon dioxide emissions by 60% before 2020. Through their example, the University of Cambridge can challenge all Universities around the globe, many of which are planning or constructing similar developments, to reduce carbon emissions. These efforts will place the University of Cambridge in a position as a leader among Universities in creating sustainable campuses, as an instructor to the City of Cambridge on the merits of sustainable designs, and as a mechanism for progress.

Sustainable housing encompasses a wide range of issues from energy use to affordability to aesthetic quality. This initial report focuses solely on sustainability as it relates to energy use, carbon dioxide emissions, and sustained health of the individuals residing in the homes. As the health effect issues are the same here as in the educational and research buildings discussed in Section 4, they are not described further. The reader is referred to Section 4 for details.

5.1. Residential Needs

Houses and commercial spaces are responsible for up to a third of the carbon dioxide emissions in the U.K. This energy, and its emissions, goes to satisfying some of the most basic needs of individuals: shelter from the weather; shelter from danger (e.g. crime); regulation of climate within a comfortable range (heating and cooling); light for carrying out chores; refrigeration and cooking of foods; provision of entertainment (TV, stereo, etc); and cleaning (including provision of hot water). These is little doubt these needs are genuine, even if the specific level required by any individual, generation or culture may change over time. Policies must, therefore, continue to satisfy residents at a reasonable level if the buildings and associated lifestyle are to be sustainable.

The policies examined in this initial report focus solely on the provision of energy needs in residential and commercial buildings. Other issues, such as cost, aesthetic pleasure and what can only be described as the “neighborliness” of communities are not considered further, other than to admit that they are aspects of life that cannot be
sacrificed by designs that are cruelly efficient in the use of energy but ignore other dimensions of living. There is a quality to building design in Cambridge, rooted in centuries of evolving architectural perspectives, which must be respected if the new buildings are to be found acceptable to the residents. We believe the policies below will produce buildings meeting all of these criteria.

5.2. Policies for Residential (and Commercial) Buildings

The following discussion lays out a series of guidelines, the use of which will help the University and City of Cambridge achieve their sustainability goals for the North West development. Most of these have been chosen because there is a recognized body of experts who have developed the criteria, are practiced in assessing whether a structure meets these criteria, and can be hired for a reasonable fee to do an assessment and certify the designs as sustainable. The criteria seem to us sufficiently concrete to allow translation into daily planning and construction decisions. If desired, either the University or the City might consider having someone on staff trained in performing the necessary assessments.

The overall goal is to build homes on the North West Cambridge site that are as sustainable as is feasible. It is recommended that the indicator of sustainability be the BREEAM (Building Research Establishment Environmental Assessment Method) EcoHomes assessment and certification system. BREEAM is an assessment method that rates buildings on their degree of sustainability using a variety of measures of energy efficiency, water use, pollution potential, materials use, etc. A final score is based on the summation of points earned across all of these measures, with a final score from Good to Excellent. Specific goals should be to ensure that:

- All residential/commercial buildings receive a BREEAM EcoHomes rating of Very Good.
- All residences attain the maximum points possible in the EcoHomes Energy Use sector, and as a result reduce energy use by no less than 50% below that associated with standard designs in the U.K..
- All residences attain the maximum points possible in the EcoHomes Human Health sector.

The first goal ensures the buildings are generally sustainable, while the latter ensure this sustainability is achieved with maximum attention paid to energy use and human health criteria.

The University of Cambridge already uses the Bespoke BREEAM rating system for all University buildings; since the development at North West Cambridge is the University’s first development including housing, we suggest that the University simply expand their adoption of BREEAM criteria to incorporate the EcoHomes component of that assessment system into this and all future developments which include housing. The University has set a goal of achieving no less than a rating of Very Good for new construction; we too suggest that this practice be extended to the construction of housing and commercial spaces on the North West site.

There are numerous best management practices that will increase the energy efficiency of a home. When the University and the project architects meet with a BREEAM certified EcoHomes assessor, the specifications for the EcoHomes Energy
Use sector will be covered in detail. Proper planning and design will allow the development to achieve all possible points in this Energy Use section, reducing the energy use and carbon emissions of each residence to 40% of the value for an average U.K. home. The following are some but not all of the best management practices that will, when incorporated into a home, increase the energy efficiency of that structure.

- **Reduced Air Infiltration:** Air leakage accounts for 25% to 40% of the energy used for heating and cooling in a typical home. There are many products available for air sealing including caulks, foams, weather-stripping, gaskets, and door sweeps. These can reduce energy use in heating and cooling by 25% or more.

- **Value Engineered Framing:** Wood loses and gains heat more quickly than insulation. Wood-framing members must be placed at regular intervals inside walls; however by increasing the size of the wood-framing members, it is possible to lessen their frequency within the walls and therefore have more efficient insulation (higher R-Value).

- **Efficient Air Ventilation:** In order to ensure sufficient fresh air flows into a well-sealed house, an active air ventilation system must be installed in the home. The design of that ventilation system, and its maintenance, determine its efficiency. Typical ducts can be so leaky that more than 35% of heated or air-conditioned air is lost before it arrives in the room for which it was originally destined. Duct tape, which is commonly used, is an insufficient sealant; instead, UL listed tapes or duct mastic should be used to seal all joints and seams in the ductwork.

- **Duct Location:** Home builders often do not heat or air condition the rooms in which the ductwork is placed, such as attics, garages and unfinished basements. Installing ductwork in spaces in which the temperature is regulated will significantly decrease temperature loss within the ducts in a home.

- **Duct Insulation:** If ductwork is placed in rooms where the temperature is controlled, the need for duct insulation is reduced; however some insulation is still necessary. The insulation will prevent condensation on duct walls and ensure that air is delivered to the living spaces at the desired temperature.

- **Duct Sizing and Design:** It is important that ductwork be appropriately sized for each individual household. Ducts should have smooth interior surfaces and the least number of direction and size changes as is possible.

- **Improved Insulation:** The thermal resistance rating given to types and quantities of insulation is referred to as the R-Value. The higher the R-Value of a given material, the better its ability is to resist heat flow. The U-Value is the reciprocal of the R-Value, and is instead a measure of heat loss.

- **High Performance Windows:** Heat gain and loss through windows accounts for up to 50% of a home's heating and cooling needs. The use of window technologies such as double or triple glazing and the application of low energy coatings can substantially decrease the transfer of heat and cold, reducing energy use for heating and cooling by as much as 15%.

- **Framing Materials:** The use of low conductance window framing materials such as wood, vinyl and fibreglass is much more efficient than using aluminium. Insulated frames as well as insulated spaces between glazings can also reduce the transfer of heat and cold.

- **Window Tightness:** Windows must be properly sealed using caulks, foam and weather-stripping in order to prevent drafts.
- **Energy Efficient Heating & Cooling Equipment**: Since heating or cooling a home can account for over 50% of the home's total energy use, the efficiency of heating and cooling equipment must be maximized to the extent feasible.

- **Energy Efficient Appliances**: These choices often are outside the control of the university and developer. To the extent they are made prior to sale of a structure, however, the university is encouraged to require that the most energy efficient models of light fixtures and appliances be used.

The measures above relate to design decisions associated with structures at the development. Taken together, they can reduce energy use, and carbon dioxide emissions, by as much as 30 to 50% compared to homes that would not achieve BREEAM certification as being energy efficient. The energy efficiency over the lifetime of a building depends, however, not only on design but on the daily decisions of individuals living in that building. While this report does not focus on those decisions, it will be important for those residents to commit to maintaining, and even improving, the energy efficiency of those homes through proper maintenance and through the selection of energy efficient versions of lights and appliances. Many of these measures have been summarized in publications by the Cambridge City Council and by the Carbon Reduction (CRed) project at the University of East Anglia.

**The CRed Program**
The Carbon Reduction Program was developed at the University of East Anglia through their School of the Environment. It is dedicated to working with industries, towns and citizens in East Anglia to find effective strategies for reducing carbon dioxide emissions by 60%. They provide a series of tools, including a Carbon Indicator, that help organizations and individuals assess their energy use and resulting carbon dioxide emissions.

As stated on their website: “each of us in the UK produces about nine tonnes of carbon dioxide (CO₂) each year through energy consumption in the home, at work and transport, that’s enough to fill about five hot air balloons! The CRed Challenge is to reduce the number of hot air balloons of CO₂ we produce from five to two by 2025 - we call this the 60% challenge and we invite you to explore our website and to join us in meeting the challenge.”

*The City of Cambridge should become a CRed site, and use the North West development as the first demonstration project!!*

http://www.cred-uk.org/index.aspx

Similarly, the mix of energy sources used to provide heating, cooling and electricity to buildings plays a central role in the degree to which that building contributes to the government’s goal of reducing carbon dioxide emissions. BREEAM provides some incentives - in the form of additional points - for designing buildings so they make maximal use of heating by the sun when needed, and shading to avoid the need for cooling in the summer months. The present section does not consider further the application of carbon-neutral, and sustainable, energy sources. Instead, the reader is referred to Section 8 on Renewable Energy to review some of the options for developments in Cambridge. Future reports in this series will focus on assessment of
the application of specific sources in the various energy sectors of the proposed North West development.
Section 6. Industry

The development of the North West site does not include significant industrial activity. It will, however, increase the overall energy needs of Cambridge, which in turn will increase the carbon dioxide and pollutant emissions if that energy is supplied by traditional means. It is reasonable to ask, therefore, whether those energy needs might be met in a creative way that is more sustainable than simply linking the new development to existing energy systems. One possibility, discussed below, is the creation of a separate Combined Heat and Power (CHP) facility to supply much of the energy needed by the site. This section examines the sustainability of a CHP facility through the lens of carbon dioxide emissions and health risks.

The houses and academic buildings of the North West development alone will require about 6 million kilowatt-hours per year. Whether this energy comes from an off-site or on-site power plant, the energy consumption by the new development will increase overall CO_{2} emissions and human health impacts in Cambridge. In order for the North West site to be sustainable, the infrastructure and energy source should follow the new energy policy set by the Government in the Energy White Paper. These goals include decreasing CO_{2} emissions by 60 percent by 2050, maintaining reliability of energy supplies, promoting competitive markets and increasing sustainable economic growth, and ensuring every home is adequately and affordably heated.\(^{*}48\)

An important goal of England for the future is to become energy independent. Along with the threat of global climate change, the reduced production of oil, gas, and coal in the U.K. causes concern for future energy supplies. Creating a new energy infrastructure at the North West site would bring the opportunity to create new businesses and jobs and design, and install new energy efficient technologies.\(^{*}49\) By moving towards a low carbon economy and energy independence, Cambridge can be a leader for England and international countries in the realm of sustainable development.

Fuel poverty is a major issue in the U.K., affecting about three million people. Providing heat and electricity to all homes, and thereby promoting social justice, is an important sustainability goal. Figure 6.1 shows the fuel expenditure for houses of different incomes in 2001/2002. A household in the highest income decile spends more than twice as much on fuel as a household in the lowest decile. However, lower income houses spend a greater percentage of total expenditures on fuel. About three million households in the U.K. are considered to be in fuel poverty, with the figure indicating that individuals with lower incomes are barely able to afford heating or are spending a great proportion of total expenditures to obtain heat and electricity.\(^{*}50\)

The increasing energy needs of Cambridge with the new development increase the problems of energy dependence, fuel poverty, carbon dioxide emissions, and human health impacts of power generation. These problems can be reduced with the implementation of a sustainable power source for the North West site.

---


6.1. Satisfying the Needs

The current electricity needs of Cambridge are fulfilled by power plants using several different fuel types. The use of gas (40%), coal (32%), and nuclear (22%) dominate the fuel use in the U.K., a mix similar to that in Cambridge. As of 1997, only 1.8 percent of electricity was produced by CHP facilities and 0.9 percent from renewable sources. The remaining sources of electricity and/or heat did not have as high an energy efficiency, or as low an emission rate of carbon dioxide, as either CHP or renewable energy sources. It is worthwhile considering development of a CHP facility at the North West site as a means to increase energy efficiency and reduce carbon dioxide emissions, so long as this is not offset by unacceptably high health risks from other emissions from such a facility.

---

6.2. Associated CO₂ Emissions

The total CO₂ emissions for the U.K. were 543 million tons per year, and 161 million tons were produced by power plants. This is equivalent to a per capita rate of approximately 9 tons of CO₂ per person per year from all uses of energy (2.5 tons of carbon), and 2.7 tons of CO₂ per person from electricity generation alone. Electricity generation, therefore, contributes approximately 30% of the overall emissions of CO₂ in the U.K. If the North West development were to use a similar mix of energy sources, the per capita figures above could be expected to apply. Clearly, there is significant room for improvement in the emissions figures for this site if alternative, energy-efficient, technologies such as CHP were adopted.

6.3. Policies to Reduce Energy Use

The Government’s new energy policy contained in the *Energy White Paper – Our Energy Future* states, “We must address the growing threat of climate change, maintain the reliability of energy supplies, promote competitive energy markets and work towards eradicating fuel poverty.” CHP plays a significant role in the commitment to achieving these goals. The Department for Environment, Food & Rural Affairs (DEFRA) carries out the Quality Assurance aspects for Combined Heat and Power to achieve the Government’s target of at least 10,000 MW of installed Good Quality CHP capacity by 2010. CHP schemes offer substantial environmental, economic, and social benefits, as well as security of energy supply. In 2001, there

---

were 1,573 CHP Schemes with capacity of 4,801 MWe, producing six percent of U.K.'s electricity requirements and saving about 4.4 mega tons of carbon (MtC) annually. The use of CHP can increase fuel efficiency to 75 percent, compared against the 40 percent for conventional electricity generation. The new energy target will help England and Cambridge move towards a competitive, thriving, low-carbon economy.

The graph below shows the trend of use of CHP within the U.K. since 1977, as well as the government’s goal for 2010. It illustrates a large, but attainable goal for CHP installation in the next six years.

![Graph of Combined Heat and Power in the U.K., 1977 to 2010](image)

**Figure 6.3: Combined Heat and Power in the U.K., 1977 to 2010**

A desirable feature of CHP is that it can reduce the overall fuel use while satisfying energy needs.

Along with CHP, renewable sources of energy are significantly more sustainable than fossil fuel based energy sources. The government has set a goal of 10 percent of energy from renewable sources by 2010. This report does not extensively discuss renewable options for the North West site; however there is a potential to power a CHP through renewable resources and to supply other electricity needs at the site through renewable energy sources. Future reports in this series will further discuss renewable energy for satisfying the growing energy needs of Cambridge without reducing environmental quality. Installing a CHP at the North West site would help reduce overall CO₂ emissions. Because CHP is locally provided, it reduces transmission and distribution losses. It also significantly increases fuel efficiency by capturing waste heat and distributing it to local buildings, thus reducing the need to

---

heat those buildings using energy produced off-site. Many areas and universities around the world have shown that CHP can provide the required energy to satisfy needs, while reducing CO₂ emissions.

The University of North Carolina at Chapel Hill (UNC) installed a CHP that provides one third of the electricity and all of the heat for the campus (that campus is approximately 50% larger than the entire University of Cambridge). That CHP facility captures the 60 percent of heat lost in traditional systems and uses it to heat nearby homes and buildings.⁵⁷ The facility at UNC has been recognized twice, in 1999 and 2003, by the U.S. EPA with the Energy Star’s Combined Heat and Power Award given to leaders who increase the electric generation efficiency of the nation through CHP projects.⁵⁸ UNC has reduced their CO₂ emissions by 10,620 tons annually as a result.⁵⁹ A highly efficient CHP facility can reduce CO₂ emissions by 50 to 60 percent and effectively reduce other pollutants.⁶⁰ A CHP facility at the North West site could provide similar reductions in CO₂ emissions relative to more traditional technologies, as well as create recognition for the University of Cambridge and the community as a leader in installing a sustainable energy source and helping England move towards a low carbon economy.

6.4. Health Risk Implications

While placing a CHP facility at the North West site will reduce the problems of CO₂ emissions, energy dependence, and fuel poverty, it may pose a health risk to individuals living and working near the plant. Coal-fired and other stand-alone power plants release sulfur oxides, nitrogen oxides, ash particles and mercury. By providing power and heat from the same source, CHP plants reduce such emissions, but at the expense of placing the source closer to the community.

A pollutant of particular concern from CHP facilities- as for all sources of heat based on coal, oil or natural gas- is mercury, which is often the dominant risk factor amongst emissions. Mercury is classified as a hazardous air pollutant due to the possible detrimental effects on human health. Therefore, to determine the risks posed by a CHP facility, a risk assessment of mercury emissions and its effects on individuals was performed for this report. In order for a CHP facility at the North West site to be considered sustainable, the generation of energy should not produce elevations of environmental mercury that pose a great health risk to individuals near the energy source.

The U.S. EPA identifies mercury as a hazardous air pollutant, receiving the strictest regulation by technological control systems. Mercury is associated with adverse health effects including cancer, reproductive effects and birth defects, as well as ecological effects. It is of particular concern in populations ingesting fish, as it

---

⁵⁸ United States Environmental Protection Agency, Energy Star CHP Award, http://www.epa.gov/chp/energystar_chp.htm#what_is_the_energy_star_chp_award

For the present report, a risk assessment was performed by assuming a standard CHP facility is placed at the centre of the proposed development. Mercury emissions from different fuel sources (coal, oil and natural gas) were modelled and the associated human health risks estimated for the surrounding population. Filter efficiencies (for removal of mercury from the stack gases) of 0, 0.3 and 0.6 were modelled separately, as these encompass the range of efficiencies that might be reasonably expected. Risks of both cancer (characterized as the lifetime excess probability of cancer) and non-cancer effects (characterized by a hazard quotient, or ratio of the actual exposure to an individual divided by the exposure deemed to have the potential to produce health effects) were estimated to determine the public health measure of sustainability. The goal is to determine whether these health risks might have the potential to outweigh the clear advantages of CGPs with respect to carbon dioxide reduction.

The table below shows the risks of mercury exposure from a CHP facility as calculated by the risk assessment model (For a description of the model, see Appendix B). The top row shows the assumed efficiency of the filter for mercury. Fuel types of natural gas, coal and oil were considered, and results shown in separate columns of the table.

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>0.00</th>
<th>0.30</th>
<th>0.60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel type</td>
<td>Natural gas</td>
<td>Coal</td>
<td>Oil</td>
</tr>
<tr>
<td>Highest lifetime probability of cancer</td>
<td>4.13E-08</td>
<td>2.96E-05</td>
<td>1.48E-07</td>
</tr>
<tr>
<td>Total number of cancers</td>
<td>0.005</td>
<td>3.252</td>
<td>0.016</td>
</tr>
<tr>
<td>Total number of non-cancers</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

A lifetime excess risk of cancer below $10^{-6}$ generally is considered acceptable. All of the values reported above satisfy this criterion. In addition, there appear to be no reason for concern over non-cancer effects, as the predicted inhalation and ingestion of mercury from such a facility is below that likely to produce adverse effects, even in individuals who ingest fish from the Cam. This initial analysis, therefore, indicates no significant problems with health risks from a CHP located at the site.
Section 7: Transportation

As Cambridge proceeds into the 21st century, many problems associated with growing populations will become prevalent. The city is already addressing the current need for more housing in Cambridge by developing areas such as the North West site. It is predicted that there will be a 21% increase in housing in the Cambridge sub-region in the period of 2001-2016. This equates to 42,000 new homes. With an average of 2.5 persons per household, the sub-region can expect approximately 100,000 new residents in the aforementioned time period. One of the major issues associated with such growth is and will continue to be transportation, specifically road transport. The North West site has the potential to either aid or hinder Cambridge’s carbon dioxide emission and public health goals, depending on how the transport systems develop.

With the influx of new Cambridge residents come many things that we deem necessary for living. These people will need access to work, schools, restaurants, grocery stores, shopping, and entertainment establishments, to name a few. Travel to these places includes access by road, such as with cars and buses, as well as bicycle and footpaths. Needless to say, the looming population growth corresponds to a potentially major increase in the numbers of automobiles on the road, leading to traffic congestion and increases in the amount of pollutants emitted into the atmosphere. Additionally, many residents of the North West development will choose to cycle or walk, which requires its own infrastructure network allowing for safe travel. If the North West development is designed with facilitation of sustainable travel in mind, the goal of meeting carbon dioxide reduction targets can be realized. However, it is crucial that such programs be implemented in the development phase, as it will only become more difficult once the development is in place.

Marcial Echenique of the Cambridge Futures program estimates an average of eight (8) trips per household per day. Of these, an estimated 36 percent will be in and around the city, with the remaining 64 percent being trips outside the city. Additionally, an estimated 50 percent of trips in and around the city and 83 percent of those trips outside the city will be conducted using a car. Therefore if we estimate that there will be 1300 new houses in the North West development, we can expect 8 trips per day per household * 1300 households, or 10,400 trips per day from the residents of that development. This is in addition to travel to and from the site by employees and students. Using the percentages given above, this will correspond to 0.36 (36%) * 8 trips per day per household * 1300 households or 3,744 trips per day within the city; and 0.64 (64%) * 8 trips per day per household * 1300 households or 6,656 trips per day outside of the city. Assuming 50% of the in town trips are by car and 83% outside are by car, we can estimate that the development might produce an additional 1,872 car trips per day within the city and 5,524 car trips per day outside the city.

7.1. Satisfying the Needs

Cambridge is a historic city faced with the issues of accommodating a growing population. The transportation sector has the challenge of providing access to all necessities for the residents and employees of the city. As in most places in the world, personal vehicles are meeting most transportation needs. Additionally, Cambridge has significant bus participation with approximately 25,100 patrons in 2003 on radial routes\textsuperscript{63} and around 9 percent of employees in Cambridge cycle to work.\textsuperscript{64}

7.2. Associated CO\textsubscript{2} Emissions

In the transportation sector, road transport provides the overwhelming majority of pollutant emissions. According to Figure 7.1, road transport contributes 22% of the United Kingdom's carbon dioxide output, with other transport contributing only 2%. For this reason, the present analysis will focus on road transport. Additionally, DEFRA states that carbon dioxide accounts for 96 percent of greenhouse gas emissions from road transport; as a result, this analysis will focus largely on carbon dioxide with respect to global warming measures.

According the Air Quality Strategy for England, Wales, and Northern Ireland, the majority of new vehicles produce from 150 to 250 g/km of carbon dioxide, the average being around 185 g/km. Depending on gas mileage, which in turn depends on the amount of time an vehicle is idling in traffic, this equates to about 20 pounds of carbon dioxide for every gallon of gasoline.\textsuperscript{65}

Using the figures from the previous section, it is estimated that the North West site represents a potential increase of 10,400 trips from Cambridge residents, of which an estimated 7400 will be accomplished in a car. It is assumed that an average car trip is about 6 miles. At 20 pounds of carbon dioxide per gallon, that corresponds to about 40,760 pounds of carbon dioxide per day from the car trips from those living in the North West development.

Distance driven is not the only contributor to carbon dioxide emissions from the road transport sector. A car sitting idling still consumes gasoline, thus emits carbon dioxide. Therefore, in order to reduce carbon emissions in the transport sector, we must limit not only distance driven but also time in a running car. Control of traffic congestion, therefore, is an essential component of transport-related policies.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{carbon_dioxide_emissions.png}
\caption{Carbon dioxide emissions by sector. Source: The environmental impacts of road vehicles in use (www.dft.gov.uk)}
\end{figure}

7.3. Policies to Reduce CO₂ Emissions

England has established a goal of reducing carbon dioxide emissions by 60 percent. The U.K. has reduced carbon dioxide emissions already by 22 percent since 1970 (which dates back to before the 1990 Kyoto Protocol). However, emissions from road transport have increased by a staggering 92 percent due to increased travel per person. Clearly, if the U.K. has reduced carbon dioxide emissions but road transport emissions have soared, the transportation sector is due for emission improvements. With more attention, the transportation sector has ample opportunities to reduce emissions.

By observing the calculations above, it becomes easier to isolate areas for reducing the emission of pollutants. Effective tactics could focus on, but are not limited to, improving:

- Increasing the percentage of trips accomplished using public transportation.
- Increasing the percentage of trips accomplished on foot or with bicycles.
- Reducing the average distance of trips by reducing the need for travel to satisfy essential needs.

These goals can be met in a number of ways. One can focus on discouraging personal vehicle use, on improving the efficiency of fuel use (and reducing emissions per mile) in personal vehicles, or on encouraging other modes of transportation that are less polluting when measured on a per-person-mile basis. Alternatively, one may eliminate the need to travel an extended distance by providing most of life’s necessities in close proximity to or within the new development.

According to the ETA, traffic has reached congestion when a car cannot pass a traffic signal in one rotation. This will be a growing issue in Cambridge if not addressed. Improving transport in the area before the North West development is inhabited will be vital to the success of any new transportation scheme. The longer cars are running but forced to sit idling, the more fuel they consume and thus the more pollutants they will emit. The following is a discussion of policy options.

- **Increase bus patronage:** Policies must be implemented if the city wants to increase bus patronage. Increased utilization of public transportation results in fewer cars to emit pollutants as well as fewer cars to create congestion. Chapel Hill, North Carolina implemented a program providing free buses and saw an increase in bus patronage of 42 percent the following year. Additionally, buses using alternative fuel sources can aid in pollution reduction even further. New York City plans to have 385 hybrid electric buses by 2006.

---


proposal for the North West site states an intention to implement buses with photovoltaic (PV) panels as well as potentially hydrogen fuel cells. While these plans may not be realized in the immediate future, research and development of programs such as these could greatly aid in provided sustainable transport. However, according to the Retail Motor Industry Federation (RMIF), 75 percent of motorists would still not travel by public transportation even if travel to work costs were reduced by 50 percent.  

Regardless of how much the city reduces public transit costs, this statistic demonstrates the resistance to public transit. Overcoming this resistance through a combination of social awareness and incentives is imperative.

- **Encourage walking and cycling:** When provided with a safe, direct path, people are much more likely to consider walking and cycling as viable methods of transportation. Cambridgeshire County Council is working with city and district councils to promote the development of cycle paths. Proper bicycle paths leading from the North West development into the city centre would greatly facilitate cycling for the residents of the area. One prime example of such a program is the Jane Coston Cycle Bridge, which leads from Milton to the Cambridge city centre. This dedicated cycle path not only aids in emissions, but also reduces traffic with fewer people driving into the congested city centre (www.camcnty.gov.U.K./sub/eandt/highways/a14cycbridge.pdf).

- **Increase the use of hybrid vehicles:** Hybrid electric vehicles (HEVs) are a legitimate option for reducing carbon emissions. By greatly increasing fuel efficiency, these cars emit pollutants at a lower rate per mile. Additionally, their fuel efficiency is often higher in the city than on the highway. To directly compare hybrid fuel efficiency with conventional efficiency, one may examine the Honda Civic. The hybrid version of this car gets 40 percent better gas mileage than the conventional version. One effective method for encouraging HEVs is the use of tax incentives. The state of Colorado has a progressive tax incentive program, providing breaks of between $2411 and $4310 for the purchase of a hybrid electric vehicle.

- **Provide local housing for employees:** An estimated 1300 homes are to be built in the North West development. As reported by Lindsay Dane and John Clark of Planning and Property for the University of Cambridge, 70 percent of these homes are reserved for university employees. A simple calculation reveals that 910 homes will belong to university employees. We estimate that 680 can be employed on location at the university buildings on the North West site. Therefore, assuming only one university employee per household, 680 * 2 or 1360 car trips can be removed from the total (representing the commute to and

---


from work) if all university employees living at the North West site no longer are forced to drive to work.

- **Consider mixed-use development**: Possibly the most effective tactic in reducing car travel is a mixed-use development. Mixed-use developments are a well-planned area that features more compact, pedestrian and transit-oriented communities with a mix of residential and commercial uses. By providing transportation choices and a proximity to a variety of commercial areas, it has been shown that these developments see a decrease in car usage, traffic congestion, and therefore carbon emissions. A 1994 study of 11 communities in California estimated that mixed-use developments show a 20-30% reduction in driving per family (http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/ADIM5GZQZG/$File/09_Der on_Lovaas.pdf). Residential density was shown to be a strong determinant of car ownership and vehicles miles travelled. A decrease in car trips of 20 percent is realistic if the appropriate businesses are located within or in close proximity to the North West site.\(^{75}\) Multiplying 20 percent by the total 7400 car trips yields a reduction of 1480 trips every day.

- **Implement a free bus system**: Next, we suggest that Cambridge analyze the potential benefits of a free bus system. A similar policy was implemented in Chapel Hill, North Carolina, resulting in a 42% increase in bus patronage the following year.\(^{76}\) If we take into account that bus patronage will improve over time and combine this with an education program on the benefits of public transportation, a goal of 50 percent increase in bus patronage in the Cambridge area is realistic. Nine percent of employees in Cambridge take public transportation to work.\(^{77}\) One can assume that the majority of these people are using the bus system. Applying that figure to the residents of the North West site not employed there, the result is a reduction of 35 trips per day (2520 people estimated to be at the North West site; 42.3% of whom are employed; with 680 being employed on the site; and 9% of the remainder commuting by bus). With a 50 percent increase in bus patronage, the total of saved car trips rises by 18. Considering the commute to and from work, that is another 36 car trips not taken.

- **Revamp the cycle system**: We also suggest that the benefits of a revamped cycle system be analyzed. If a safe, direct bike path is provided, it is realistic to expect a significant increase in cycling. According to the Local Transport Plan, 9 percent of Cambridge employees cycle to work.\(^{78}\) Using similar math as above, with a 50 percent increase in cycling another 36 car trips can be avoided.

- **Utilize cleaner vehicles**: The implementation of cleaner vehicles is an issue of growing importance. The EU CO\(_2\) from Cars Strategy calls for a reduction of

---


CO\(_2\) emissions to 120 g/km by 2010. This is a reduction of about 33% from current levels. Because we are planning for the entire century, we feel it is appropriate to use this level (120 g/km) as a realistic figure for the North West site. The residents can be greatly encouraged with tax incentives and other charges associated with owning a “dirtier” vehicle in the North West site. If all remaining car trips are undertaken with vehicles meeting this 2010 standard, it will contribute significantly (33%) to the reduction of overall CO\(_2\) emissions from the transportation sector.

- **Stagger work schedules:** An option to decrease traffic congestion, and therefore CO\(_2\) emissions, is to stagger work schedules. This strategy seeks to avoid the peak hours of 7:30-9:30 and 16:30-18:30. Using employee incentives, such as preferential parking, free lunches, and raffles, the magnitude of peak time traffic is lessened. This leads to a decrease in stop-and-go traffic, which wastes time and fuel and results in greater emissions. It has the added benefit of reducing emissions of other pollutants such as particulates, reduces ozone concentrations, and reduces lost productivity of workers who are mired in traffic. A successful program in Denver included 9,000 employees who arrived one hour earlier and departed one hour later, in addition to a four day workweek. The maximum percentage of total arrivals in any half hour period was reduced from 56 percent to 42 percent. The maximum percentage of total departures in any half hour period was reduced from 47 percent to 34 percent. It is estimated that the average carbon monoxide and hydrocarbon emissions were reduced 16.4 percent due to a reduction in traffic congestion and idling, with similar reductions expected in CO\(_2\) (http://yosemite.epa.gov/aa/tcmsiteinsf/0/cc28801da5d24468852565da006518b7?OpenDocument).

- **Encourage working from home:** Tele-working is an option that allows for employees to work from home. It is a method to decrease traffic congestion and carbon emissions by decreasing travel to work. According to AT&T in the US, their successful program resulted in 5.1 million gallons of gas and 110 million miles of driving being avoided by having their workers tele-work [www.att.com/telework]. This equates to a reduction of 50,000 tons of CO\(_2\) a year being emitted into the air, a reduction of more than 15% in this example.

- **Facilitate carpooling:** Carpooling is another strategy that can effectively decrease traffic congestion. A carpool is two or more people who commute to work together in a vehicle. Encouraging carpooling with employee incentives, such as free lunches or free tune-ups and oil changes can decrease congestion, especially at peak time; in addition, carbon emissions into the atmosphere will decrease as a result of a decrease in vehicles on the road. According to the US EPA, a pool of 1,000 people participating in carpools would reduce travel by 10,000 vehicle miles per year, leading to a reduction of 9,900 pounds of CO\(_2\) over a year (www.epa.gov/rtp/transportation/carpooling/emissions.htm).

- **Implement road charging:** Road charging is a policy that imposes monetary fines on drivers for use of key roads. Motorists pay to use those roads during peak travel times in order to decrease traffic congestion. This type of policy encourages motorists to vary their travel times, use alternate routes, carpool, use public transit, and avoid trips altogether. A successful congestion-charging
program started in London in 2003. By installing cameras at congested areas, motorists are compelled to pay in order to use the busy roads of central London. At the end of the first month, congestion decreased 30 percent and the volume of traffic decreased 15 percent. Traffic entering the zone decreased 18% and traffic circulating within the zone decreased 15 percent. The bus system saw a 38 percent increase in patronage and a 60 percent decrease in disruptions due to traffic delays (www.tfl.gov.U.K./tfl/press-releases/2004/april/press-1009.shtml). This correlates to a reduction in carbon emissions due to a reduction in congestion and vehicle usage.

7.4. Overall CO₂ Reductions with Implemented Policies

Taking all of the policies listed above together, the carbon dioxide emissions from cars in the North West site would be at least 60 percent lower than would be the case using current modes of transport typical of Cambridge. This is precisely the reduction that the U.K. seeks overall. However, it must be noted that these reductions apply only to individuals living in the development who adopt the measures as compared to individuals in the same development who do not adopt such measures. There is a possibility that the net effect of the development will be to reduce overall carbon dioxide emissions from Cambridge. The reason lies in the fact that many employees of the university currently live in areas outside Cambridge, forced there (as discussed elsewhere in this report) by high housing prices in the City. If these individuals currently drive into the City for work, it is possible that their relocation to the proposed development would place them sufficiently close to allow use of buses, bikes, etc. If that were to occur, the carbon dioxide emissions from those individuals would be decreased even if transportation measures were not instituted.

7.5. Other Hazardous Emissions from Transportation

Transportation significantly contributes to the atmospheric emissions of a range of pollutants in the U.K. and in Cambridge. In 2001, the transportation sector emitted approximately 25 percent of the total CO₂ and 32 percent of the total nitrogen oxide (NOₓ) in the U.K. Along with CO₂ and NOₓ, other pollutants are emitted during the combustion of fuel in the engines of vehicles, each of which can be detrimental to human health. A case study by the Parliament lists eight key harmful air pollutants from road transport as being especially significant with respect to health, including benzene, 1,3-butadiene, carbon monoxide (CO), lead, nitrogen dioxide (NO₂), ozone, particulate matter (PM₁₀), and sulphur dioxide (SO₂).

The National Atmospheric Emissions Inventory (NAEI), funded by the Department for Environmental Food and Rural Affairs (DEFRA), provides estimates of key atmospheric emissions from U.K. sources. The NAEI monitors six of the eight key pollutants likely to influence air quality. The table below shows the emissions of each pollutant in Cambridge from the transportation sector and their contributions to the

overall emissions. The % Total Emissions figures are for the entire Cambridge area, averaged over all parts of the city. The percent will be higher around high-traffic areas and roadways. It is clear that emissions from the transport sector should be a major focus of policies aimed at improving sustainability through improvements in public health.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Transportation Emissions(^a)</th>
<th>% Total Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,3-butadiene</td>
<td>0.18</td>
<td>64</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.5</td>
<td>66</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>211</td>
<td>93</td>
</tr>
<tr>
<td>Lead</td>
<td>0.4</td>
<td>58</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>21</td>
<td>34</td>
</tr>
<tr>
<td>PM-10</td>
<td>1.5</td>
<td>26</td>
</tr>
</tbody>
</table>

\(^a\)Average emissions around University of Cambridge in tons/year/km

The Air Quality Strategy assesses the effects of these pollutants on public health and identifies measurable targets to improve air quality. The standards for these pollutants are based on recommendations by the Expert Panel on Air Quality Standards, standards used by the European Council (EC), and the World Health Organization’s (WHO) guidelines. The following is a brief description of these pollutants and their possible health implications.

- **Benzene**: The main source of benzene in the atmosphere is from road transport. Acute health effects include drowsiness, dizziness, headaches, and eye/skin/respiratory tract irritation in low doses. At high doses, loss of consciousness may result. Chronic health effects include reduced red blood cell count, aplastic anemia, as well as adverse reproductive effects. A connection has been established between benzene and leukaemia, categorizing benzene as a carcinogen.

- **1,3-Butadiene**: Emissions of 1,3-butadiene result primarily from incomplete combustion in motor vehicle exhaust. It is categorized as a carcinogen, although the specific mechanisms are as yet unknown. Reproductive effects have been observed in laboratory mice. Areas of high traffic are associated with the highest concentrations.

- **Carbon monoxide**: A result of incomplete combustion, approximately 60 percent of carbon monoxide in England is emitted from road transport. It reduces oxygen delivery into the bloodstream resulting in visual impairment, reduced work capacity, reduced manual dexterity, and poor learning ability. At low levels it is primarily a threat to those with cardiovascular disease, but at high levels it is a threat to everyone. The highest concentrations in England are found in those areas with high traffic.

- **Lead**: Proven to damage children’s intelligence, England has banned the use of leaded petrol, dramatically decreasing blood lead concentrations. The Environment Agency expects all urban and roadside sites to meet 2008 objectives set by the Air Quality Strategy for England, Scotland, Wales, and Northern Ireland.

---

- **Nitrogen dioxide**: Originating mainly from road transport, nitrogen dioxide is a contributor to acid rain and tropospheric ozone. Concentrations are highest over road networks and urban areas. It is the opinion of the Environment Agency that current measures to reduce transport emissions of nitrogen dioxide may not be enough to meet goals. Emissions from other sectors have dropped, but levels from road transport have risen.

- **Ozone**: Tropospheric ozone is the only pollutant on the list that is not directly emitted by an anthropogenic sources in any significant quantity. It is created by a reaction in the atmosphere between volatile organic chemicals (VOCs) and nitrogen oxides (NOx). This reaction creates enough ozone to affect both crops and people. In England, the highest levels of tropospheric ozone are in the south where higher temperatures and levels of sunlight promote the photochemical reaction that creates it.

- **Particulate matter (PM\textsubscript{10})**: Particulate matter having a diameter of less than or equal to 10 micrometers is categorized as PM\textsubscript{10}. As described by Jo Dicks (of the Cambridge City Council office of Environmental Health and Waste Strategy), particulates are of growing concern in England, especially in urban areas. The primary source of particulates is road transport, especially diesel vehicles.

- **Sulphur dioxide**: The main source of sulphur dioxide is the fuel and power sector, but road transport makes a significant contribution. Sulphur dioxide worsens lung diseases, has a direct effect on crops, and is a contributor to acid deposition. Small sources of sulphur dioxide are not regulated. The recent implementation of low sulphur fuels has made a significant reduction in the emissions of sulphur dioxide in the transportation sector.\textsuperscript{84}

Further research on these pollutants and their effects on air quality and human health will be done in future reports in this series. This report will focus on ground-level ozone and particulates.

### 7.6. Health Risk Implications of Particulates and Ozone

DEFRA identifies particulates and ground-level ozone as two of eight main health-threatening air pollutants in the U.K.. A study by the Department for Transport estimates that between 12,000 and 14,000 vulnerable people die each year from detrimental effects from road vehicles in the U.K.. Additionally, the Department of Health estimates that 14,000 to 24,000 hospital admissions and readmissions could be associated with poor air quality. The majority of these health effects are attributed to three pollutants: sulphur dioxide, ozone, and particulate matter. An estimated 3,500 deaths each year are associated with sulphur dioxide, 700 to 12,500 with ozone, and 8,100 deaths each year with particulates.\textsuperscript{85}

The Air Quality Strategy assesses the effects of these pollutants on public health and identifies measurable targets to improve air quality. The standards for these pollutants are based on recommendations by the Expert Panel on Air Quality Standards,\textsuperscript{84} Environment Agency, Hazardous Emissions, <www.environment-agency.gov.uk>\textsuperscript{85} Department for Transport, *The environmental impacts of road vehicles in use*, 13 August 1999, <www.dft.gov.uk>
standards used by the European Council (EC), and the World Health Organization’s (WHO) guidelines.\[86\]

\textit{Particulate Matter}

The Cambridge City Council places particular emphasis on health impacts related to PM\(_{10}\) concentrations. Jo Dicks, Principal Scientific Officer of the Environmental Health & Waste Strategy, describes particulates as a growing concern in England, especially in urban areas; these are often a key indicator of air pollution from road vehicles. The human health implications from an increase in particulate concentration are significant. In 1998, the total PM emissions in the U.K. were 163,000 tons. Some estimates show exposure to these particulates is responsible for up to 10,000 premature deaths a year in the U.K..

Road transport accounts for 25 percent of total PM\(_{10}\) emissions. Within this category of road transport, diesel accounts for 19 percent of PM\(_{10}\) emissions, a disproportionately large amount. However, in London, road traffic accounts for 82 percent of PM\(_{10}\).\[87\] This is especially disturbing as Cambridge is an increasingly urban setting, indicating that the contribution of transport to particulate emissions and concentrations may similarly increase.

The level of severity of health effects is determined by the composition of the particulates. Particulates consist of a mixture of organic and inorganic substances present in the atmosphere as both liquids and solids. Particulates with a diameter greater than 2.5 micrometers are considered coarse and usually contain earth crustal materials and dust from road vehicles and industries. Fine particles are those with diameter less than 2.5 micrometers and contain secondarily formed aerosols, combustion particles and re-condensed organic and metallic vapours. Fine particles usually contain the acid component of particulates.\[88\] While it is established that the fine particulates probably are a more significant cause of health effects than coarse particulates, regulatory standards in the U.K. focus on particles below 10 microns in diameter, and so those are the particles considered here.

PM is associated with several adverse human health and environmental effects. Scientific studies have linked the breathing of PM to several significant health problems, including increases in respiratory symptoms like coughing, difficulty in breathing, chronic bronchitis, decreased lung function, aggravated asthma, and premature death. People with heart and lung disease experience increased hospital admissions and emergency room visits due to exposure to PM. It is a major cause of reduced visibility, or haze, irritating eyes and aggravating contact lens wearers. Sensitive individuals can experience worsened health problems if exposed to high

\[86\] Encyclopedia of the Atmospheric Environment, \textit{Transportation Pollutants}, \texttt{<http://www.ace.mmu.ac.uk/eae/english.html>}


\[88\] Encyclopedia of the Atmospheric Environment, \textit{Particulate Matter}, \texttt{<http://www.ace.mmu.ac.uk/eae/english.html>}
levels of PM for several days. In the U.K., a 10 μg/m³ increase in PM$_{10}$ concentration coincides with a 1.1 percent increase in mortality and a 2.4 percent increase in hospital admissions for all respiratory conditions. Specifically, a 10 μg/m³ increase in PM$_{10}$ concentration leads to a 3.3 percent increase in hospital admissions for asthmatics (For more information on asthma, see Appendix A).

Currently, the DEFRA regulations for PM$_{10}$ are that the 24 hour mean concentration cannot exceed 50 μg/m³ more than 35 times in a year, and the annual mean concentration must remain below 40 μg/m³. According to Jo Dicks, in 2010 the annual mean concentration limit will be reduced to 20 μg/m³. Due to high levels of background particulate concentrations, this is a stringent goal that demands immediate attention; in fact, given background levels, it is unlikely this goal can be met, suggesting it may be revised at some point or perhaps applied only to the anthropogenic sources of particulates.

Recent health studies have found adverse health effects associated with exposure to PM$_{2.5}$ greater than the risks posed by PM$_{10}$. Exposure to fine particles (PM$_{2.5}$) shows a significant association with premature mortality. Exposure is also associated with aggravated respiratory and cardiovascular disease, shown by increased emergency room visits, hospital admissions, absences from school or work, and restricted activity days for school children. Other health affects include lung disease, decreased lung function, asthma attacks, heart attacks, cardiac arrhythmia, and other cardiovascular problems. Populations at higher risk include children, people with heart and lung disease, and older adults.

The U.S. EPA estimated the new 1997 standards for PM$_{2.5}$ (15 μg/m³) would save about 15,000 lives each year in the U.S. They also estimated that each year the new standard would reduce hospital admissions by thousands, reduce risk of symptoms associated with chronic bronchitis by tens of thousands, and avoid hundreds of thousands of cases of asthma. DEFRA may want to consider implementing stricter regulations on particulate emissions after researching the health benefits of stricter regulations on PM$_{2.5}$ versus PM$_{10}$.

There are a limited number of means by which PM$_{10}$ emissions may be reduced. There are particulate traps that can reduce PM$_{10}$ emissions by up to 90 percent. We feel most vehicles, especially diesel vehicles, should be fitted with some sort of particulate trap. Additionally, alternative fuels such as biodiesel can be implemented and are far cleaner than conventional diesel fuel. The EPA confirms that particulate emissions are reduced by 48% from the levels released by burning of petrodiesel. One major advantage to biodiesel, which is often used as a 20 percent mixture in petrodiesel, is that it requires no alteration of the diesel engine (www.biofuels.fsnet.co.U.K./basics.htm).

---

90 United States Environmental Protection Agency, PM2.5 National Ambient Air Quality Standards (NAAQS) Implementation, <http://www.epa.gov/ttn/naaqs/pm/pm25_index.html>
Policies to reduce emissions of particulates, and therefore the risk posed to human health, will be considered in future reports in this series. Consider, however, the current state of affairs in Cambridge. Transportation is producing on the order of 30 to 40 \( \mu g/ m^3 \) of particulates in the vicinity of roadways. Each unit increase in transportation of 10% along the major roadways into Cambridge from the North West site, assuming current transport modes, would increase the particulate concentration by 3 or 4 \( \mu g/ m^3 \). If the mortality and morbidity figures described previously are applied, a 0.3% increase in mortality and 1% increase in respiratory effects requiring hospitalization might be expected in the population living along those roadways. This is a significant increase that can be avoided by progressive transportation plans such as those described previously in this section.

**Ground-level Ozone**

The NAEI does not monitor ground-level ozone, but instead monitors the precursor pollutants. Ground-level ozone, a main ingredient of smog, is formed when emissions of NO\(_x\) and VOCs from motor vehicles or industry react with heat and sunlight.\(^93\) Consequently, ground-level ozone primarily affects urban and high traffic areas during warmer periods. However, prevailing winds transport ozone into surrounding areas.

Ground-level ozone has been shown to cause several adverse health effects. At low levels, it can cause a number of respiratory effects such as coughing, irritation in the throat, and uncomfortable sensations in the chest. Exposure reduces the lung function, making it more difficult to breathe deeply and vigorously. This results in more rapid and shallow breaths than normal and creates uncomfortable breathing.

Several populations are at greater risk from exposure to ozone. During the warmer months, people engaged in physical activities outdoors are sensitive to lower levels due to fast and deep breathing. Active children spending long hours playing outdoors in the summer are at the highest risk. People with asthma or other respiratory diseases usually experience health effects at lower ozone levels than less sensitive individuals due to the reduced lung function and sensitivity to irritation. At high levels, more asthmatics have attacks, requiring doctor’s visits or additional medicine. Ozone also causes a greater sensitivity to allergens, the most common triggers for asthma attacks (For more information on asthma, see Appendix A).

Exposure to ozone also aggravates chronic lung diseases such as bronchitis and emphysema. Reduced immune systems lose the ability to fight bacterial infections in the respiratory system. Children are susceptible to permanent lung damage from repeated short-term ozone damage to developing lungs. In adulthood, these children experience reduced lung function.

As concentrations of ground-level ozone increase, a larger fraction of the population is affected, the effects become more serious, and hospital visits due to respiratory problems become more frequent. Although the Cambridge City Council is not as concerned with ground-level ozone as particulate emissions, consideration of this pollutant in the future may be important for protection of human health, especially as

the concentrations in the atmosphere continue to rise and the health effects are given greater scientific scrutiny. Transportation policies will therefore be increasingly important since transport accounts for most of the ozone in urban areas such as Cambridge, and since the North West site development will further increase these levels if the traditional mix of transport modes is adopted to serve the needs of that community. In order to assess air quality and human health risks, further research needs to address how the emissions of the precursors can be reduced. In the near future, research will be done to detail the costs and benefits of regulating particulate emissions and ground-level ozone to reduce the overall risk to human health (the subject of future reports in this series). In order for Cambridge to be considered a “Sustainable City,” these pollutants must be regulated and decreased to promote a healthy living and working environment for all individuals. Improving air quality by implementing transportation policies and regulating emissions will help Cambridge establish a sustainable environment.
Section 8: Renewable Energy

This section of the report provides an examination of renewable energy, both within the framework of sustainability in general, but more specifically within the framework of the development at the North West site in Cambridge. It aims to address the following questions:

- How does the use of renewable energy come within the framework of sustainability, and how are the two terms defined?
- What types of renewable energy are available at present and which of them can be implemented within a development such as that of the North West site?
- What government legislation and targets exist and how might energy policy be changed or adapted to ensure compliance with aforementioned targets?

In addressing the above questions the report aims to deliver a framework for the implementation of renewable technologies within the new development in Cambridge; it also aims to be applicable to other new developments occurring in Cambridge or elsewhere, along with providing the impetus for the city to move more generally towards a renewable energy base through the phasing out of fossil fuel technologies and their replacement with technologies that allow for Cambridge to fully deserve its “Sustainable City” title.

8.1. Explanation of Terms

The U.K. government describes sustainable development as “ensuring a better quality of life for everyone, now and for generations to come.” The most widely used definition is however, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”, a definition coined in the Brundtland Commission. As mentioned in the Preface, the tripartite goals of sustainable development are: environmental quality, social justice and economic vitality. The utilisation of renewable energy is a vital focus pertaining to the achievement of the sustainable development of a city, with major benefits in all three areas. Therefore, an assessment of the potential of an area, whether new or existing, to implement renewable energy is imperative, especially in helping to conform to national targets relating to the Kyoto Protocol and the U.K.’s own Climate Change programme.

Climate change as a result of greenhouse gas emissions is one of the most topical debates in global politics, requiring national governments from both the developed and the developing world to start working together to bring about the necessary changes for the reduction in greenhouse gases that is needed, especially that of carbon dioxide. With the current world population growth rates and the economic growth of developing countries, an increasing demand is being placed on energy supply, with the result that projections show an overshoot of the world’s capacity to accommodate this growth without seriously putting the security of future generations at risk. This pessimistic forecast has been a strong factor in the development of renewable energy technologies, which only utilise resources that can be replenished, thus reducing the

---

94 Climate Change - UK Programme: Department for Environment, Food and Rural Affairs
95 Our Common Future: World Commission on Environment and Development (Brundtland Commission, 1987)
amount of carbon dioxide that is released into the atmosphere through the burning of fossil fuels. As it relies solely upon natural energy flows and sources in the environment, supplies are able to replenish themselves constantly, providing unlimited sources of energy that produce carbon dioxide and other pollutants only during the manufacturing and perhaps decommissioning/disposal of the technologies.

8.2. Government Legislation and Targets on Renewable Energy:

There are three primary targets to consider in development of renewable energy as it relates to climate change:

*The Kyoto Protocol:* The Kyoto Protocol Convention, held in December 1997, was established to limit emissions of six greenhouse gases currently known to be accelerating climate change. The six gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. Under the Protocol, industrialised countries and those in the transition to a market economy are known as the Annex 1 countries, and this group has agreed to either limit, or reduce, their greenhouse gas emissions. The U.K.’s domestic target is a 12.5% reduction in greenhouse gases from 1990 levels by 2008-2012. Currently however, the Kyoto Protocol has not yet come into force, as the conditions needed for ratification have not yet been met. The conditions are that at least 55 countries have to ratify the treaty, with Annex 1 countries accounting for at least 55% of this industrialised group’s emissions in 1990.

*The U.K. Policy on Climate Change:* The U.K. Programme for Climate Change is a programme within DEFRA (Department for Environment, Food, and Rural Affairs), which aims to tackle the problem of climate change through a number of campaigns. These include energy efficiency objectives, ‘Going for Green’ policies including education and energy saving incentives at a local and individual level, and targets to help the government comply with the Kyoto Protocol. The Royal Commission on Environmental Pollution (RCEP) recommended that the Government adopt a strategy that puts the U.K. on the path to a 60% reduction in greenhouse gas emissions by 2050, a figure that is recognised as the amount by which industrialised countries need to reduce their emissions in order to avoid a doubling of the pre-industrial level of atmospheric carbon dioxide (see Section 3 of the present report). Furthermore, with regards to renewable energy and the part that this can play in a reduction of emissions and the move to a sustainable future, the Government has set a target that 10% of energy must be sourced from renewable means by 2010. Currently it seems that the Government is in danger of missing this target, making it all the more important that every new development consider adoption of renewable options.

*The Renewables Obligation:* This is piece of domestic legislation, introduced in April 2002, “calls on all licensed electricity suppliers in England & Wales to supply a specified and growing proportion of their electricity sales from a choice of eligible renewable sources” and “is the key policy mechanism by which the Government is encouraging the growth necessary to reach the U.K.’s renewable energy targets”.

---

96 Energy – The Changing Climate: The Royal Commission on Environmental Pollution (RCEP, 2000)
97 The Renewables Obligation, 2002
8.3. Renewable Energy Challenges

Renewable energy offers a number of benefits that are significant here:

- Renewable energy provides cleaner alternatives to the provision of energy which currently favours fossil fuels and nuclear. This contributes far less to atmospheric and associated pollution and waste problems, and doesn’t carry the same risks associated with nuclear sources;
- There is currently a large imbalance between the developed and developing worlds regarding energy consumption and the ratios of population to energy consumption. This inequity could be significantly reduced through the use of less polluting renewable sources. The imbalance is shown in Figure 8.1, illustrating the need for renewable energy to be exploited in all areas of development:

![Figure 8.1: A comparison of populations and energy consumption in different countries.](image)

<table>
<thead>
<tr>
<th>United States</th>
<th>China</th>
<th>Russia</th>
<th>Japan</th>
<th>Germany</th>
<th>India</th>
<th>France</th>
<th>U.K.</th>
<th>Canada</th>
<th>Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Energy Consumed</td>
<td>25</td>
<td>9.9</td>
<td>7</td>
<td>5.8</td>
<td>3.9</td>
<td>3.1</td>
<td>2.9</td>
<td>2.6</td>
<td>2.5</td>
</tr>
<tr>
<td>% of World Population</td>
<td>4.6</td>
<td>21.2</td>
<td>2.5</td>
<td>2.1</td>
<td>1.3</td>
<td>16.6</td>
<td>0.9</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

- Renewable energy technologies are unlimited. This means that technologies can be built to longer lifetime specifications and that problems of limited or diminishing resources do not affect it;
- The current phenomenon of global warming and the associated energy increase with regards to weather conditions and large-scale climatic events means that the potential for large quantities of energy to be supplied this way increases;
- As investment in R&D increases, efficiency will improve rapidly, allowing for schemes to become cheaper to implement, smaller and more cost-efficient;
- Consumers in all sectors of the economy (residential, commercial, industrial) can benefit economically as energy provision becomes more efficient, especially with the introduction of CHP (Combined Heat and Power schemes), which increase efficiency to up to 85% in comparison to 30% from traditional electricity generation methods that don’t reuse heat.98

Expenditure is currently increasing in areas of research into green technologies and improving the efficiency of renewable energy technologies.

Drawbacks to renewable energy include:

- The construction of renewable energy technologies will produce emissions – these should be offset against the savings that can be made by long-term utilisation of such technologies;
- Many technologies are at an early stage of development, and until further resources have been invested in R&D they will not be as efficient or cost-effective as possible;
- Public opposition to the location of technologies in areas of natural beauty and near homes can limit the success of implementation; further research needs to go into more aesthetically pleasing, less intrusive designs and community awareness of the benefits of such schemes.

8.4. Renewable Energy Technologies Available, Efficiencies and R&D Needs:

**Solar Power:** The use of solar power is one area that needs a lot of consideration, as it is an almost unlimited source of energy. In 30 minutes, the amount of energy hitting the earth from the sun is equivalent to the total amount consumed by people over an entire year. This energy is ideal for use in the heating of domestic water or for leisure facilities such as swimming pools. One recent technological development is ground source heat pump systems, which provide the means for individual households to supply enough energy for their household use from the solar energy stored in the earth’s surface (due to the thermal mass of that surface. The information is being promoted by the National Energy Foundation who state, without providing exact figures on how much energy could be used in this way, that “if 10% of homes in the U.K. were to install Ground Source Heat Pump systems between now and 2020…it could deliver over one million tonnes of carbon savings. This would make a significant contribution towards the Government's CO$_2$ reduction targets, which we are currently in danger of missing.”

**Wind Power:** This is one of the highest potential renewable energy sources, as well as the fastest growing and (perhaps) most controversial. Costs are relatively low, and the new generation of wind turbines is expected to cut the cost even further. Europe’s installed capacity has already exceeded that of the United States, with the potential for this to grow even further. The U.K. is thought to have the highest wind power potential in Europe, already providing energy for over 390,000 households (940,000 people), preventing the annual emission of more than 1.46 million tonnes of carbon dioxide. As wind farms can be situated offshore the possibilities are increased manifold, as public effects will be substantially lessened. Wind turbines sited in windy parts of the countryside could in principle generate perhaps 20% of the U.K.’s electricity, while the potential for wind turbines mounted in shallow water off-shore is even larger - perhaps up to 50% of U.K. electricity requirements, although the cost would be higher than for on-land machines. Typical large modern wind turbines have

99 http://www.galeforce.uk.com/solar/index.htm
101 http://www.dti.gov.uk/renewable/wind.html
a rated output at full power of 1000 to 2000 kilowatts (1 to 2 megawatts or MW). They are usually grouped together in wind farms 102.

Hydro Power: Hydroelectric power is the energy derived from flowing water in rivers or from man-made installations where water flows from a high reservoir down through a tunnel. Electrical energy is the main form of energy derived from hydroelectric power. Although the energy potential from hydropower is relatively limited in the U.K., it is an area worth considering, as with their construction costs paid off, larger hydroelectric dams produce the cheapest electricity in the U.K. In 2003 the total new capacity of energy planned from the 1st January 2003, was 1385 MW from large-scale hydroelectric plants, and 194 MW from small-scale plants. The three categories used to define the output from hydroelectric power, according to the Department of Trade and the Environment, are (i) large-scale hydroelectric producers generating more than 5MW; (ii) small-scale hydroelectric producers generating less than 5MW; (iii) systems of a few tens of kilowatts, referred to as micro hydroelectric. The first two generally feed their power into a grid, while the third usually provides power for a small community or rural industry in remote areas away from the grid 103. The U.K. currently generates ~ 1.8% of its electricity from large-scale schemes, mostly in the Scottish Highlands. As it is a very efficient technology, with efficiency rates of up to 90% in the most modern plants, it is a good technology to try to exploit in areas that are environmentally suited. Due to the small nature of the River Cam in Cambridge, it is unlikely that enough energy could be generated from this source for it to be viable.

Wave Power: Wind moving over water creates waves, and the U.K. wave energy potential could be up to 20% or more of U.K. electricity requirements if suitable floating devices could be located in deep water out to sea in what is known as ‘deep-sea’ systems. Smaller amounts of power, at possibly less cost, could be obtained from devices operated nearer to the shore- in-shore or coastal systems- and from shore mounted units such as those sited in gullies- on-shore systems 104.

Tidal Power: The gravitational pull of the moon on the seas produces two tides per day as the earth rotates. The high tides can be trapped behind a barrier on suitable estuaries, creating a head of water which, when released, can be used to drive turbines, as with low head hydroelectric plants. Like some existing hydro schemes, some tidal barriers might be large. For example, the scheme proposed for the Severn Estuary would have around 8000 MW of installed generating capacity and could supply 6% of U.K. electricity requirements. The total U.K. tidal barrier potential is around 20% of U.K. electricity requirements 105. Additionally, fast moving tidal streams such as around Scotland and the Channel Islands can be used as a source of energy through the use of propeller-type devices located in the flow. The total generating capacity from all possible streams could provide up to 19% of the U.K.’s total energy requirements.

A consideration to bear in mind with regards to wave and tidal power is that of its effect on the coastline. A by-product of the generation of this type of energy is the

102 http://www-tec.open.ac.uk/eeru/natta/natta-guide.html
103 http://www.dti.gov.uk/renewable/hydroelectric_currentuptake.html
104 http://www-tec.open.ac.uk/eeru/natta/natta-guide.html
105 http://www-tec.open.ac.uk/eeru/natta/natta-guide.html
necessary slowing of water approaching the coastline. This will have impacts upon the processes of sedimentation, transport and erosion in coastal and estuarine environments. None of these effects has been researched to date, so the environmental and ecological impacts are unknown. This has to be considered, with individual area assessments before such schemes are implemented, especially in areas where coastal management schemes are already an issue.

**Biomass Energy:** Large resources of organic material in the form of wood, grasses, crops and crop residues can be convertible to usable energy in a number of ways. Burning it is one method, and whilst this is known to be carbon neutral, it is associated with the well-documented problems of deforestation, soil erosion and increased risk of seasonal flooding, along with a lag in grow-back time. Gasification therefore is thought to be the best current method of converting the energy for use as fuel for high efficiency combustion turbines, or as synthesis material for producing liquid fuels. Biomass materials can also serve as a feedstock to produce ethanol, which can be used as a transportation fuel and as an industrial chemical, thus reducing dependence on petroleum.\(^{106}\) Currently biomass accounts for over a third of all energy used in developing countries, although existing biomass-using technologies are relatively inefficient, and the way in which it is sources in developing countries is not managed in a sustainable way. R&D can provide modern and much more efficient ways of using biomass, and a recent assessment of the potential for renewable energy, prepared as input for the U.N. Conference on Environment and Development (UNCED), found that sustainable biomass energy systems could be the largest single contributor to global energy supply; the study found that under a "Renewables-Intensive Global Energy Scenario" (RIGES), biomass could provide as much as 35 per cent of the total demand for primary energy in 2050 (see graph below)\(^{107}\)

---

\(^{106}\) [http://www.arch.hku.hk/research/BEER/renew01.htm](http://www.arch.hku.hk/research/BEER/renew01.htm)

**Hydrogen:** Energy can be produced from a hydrogen fuel cell, which works like a conventional battery. Energy in the form of heat and fuel can be produced. Through the use of a fuel cell containing an anode, a cathode and an electrolyte, hydrogen can be used to create a chemical reaction generating electrical and thermal energy, with the production of 100% water as a by-product. Emissions from this type of energy formation can be lower than the cleanest method of fuel combustion, as only hydrogen from any hydrocarbon fuel (from natural gas to methanol) is utilised. As the hydrogen supply can also be based on other renewable resources such as hydropower, biomass or wind, the greenhouse gas emissions can be zero for the energy system, or very close to zero given the need to manufacture parts. However, due to this being a very immature technology, with barriers to use being cost and the challenge of improving on existing technologies, implementation has not yet been successful on an industrial scale. The potential exists for the use of hydrogen as a fuel for larger scale static power generation power plants, although significant investment in terms of R&D is necessary for this to become an option. All the major car manufacturers are also working to commercialise a fuel cell car, and one current use of the technology is in waste-water treatment plants and landfills, which are using fuel cells to convert the methane gas produced into electricity. This is one possible use for this technology with regards to the North West site, if such a plant is to be placed on or around it.

**8.5. Comparison of Renewable Energy Technologies and Fossil Fuel Technologies with Respect to Lifecycle**

A question that is asked in energy debates is whether or not the manufacture of a particular technology will consume more energy than it will produce in its lifetime. This issue has been addressed in a recent paper by Peter Jolly and Richard O’Sullivan, with specific reference to renewable energy technologies. The paper is entitled “The Energy Required to Manufacture Renewable Energy Technologies” and the reader is referenced to it. The conclusions are that, for the renewable energy technologies concerned, a solar hot water system and a RAPS System, “renewable energy devices consume much less energy over their lifetime compared to fossil fuel powered systems performing the same task”. This leads the authors to suggest that “if the minimisation of energy consumption and pollution were a societal goal then we should be actively promoting the use of renewables”. One thing that must be borne in mind when referencing this paper is that it was based in Australia, where the amount of solar energy received is substantially larger than in the U.K., where, at best, the mean daily insolation is ~5kWh/m²/day and at worst is ~1kWh/m²/day. This doesn’t mean the results obtained do not apply to the U.K., but it does suggest that the same assessments must be carried out on such technologies in the U.K.

**8.6. Estimation of Contribution of Renewable Energy to the Needs of the Site**

It is of interest to ask whether the total energy available in the environment of Cambridge is sufficient to power the energy needs of this City; if that is the case, the same may be said of the North West site. This report examines two ways of providing that energy: from solar radiation and from wind energy. Future reports in the series will examine other sources in the area. For both solar and wind, the land area of the U.K. attributed to Cambridge, based on the fraction of the population of the U.K.

---

Solar Power: The figures available only show the mean solar insolation for the U.K. rather than just for Cambridge. As these were the best available estimates, they are the ones used for the calculations here. At best, the mean daily insolation is ~5kW-h/m²/day and at worst the mean daily insolation is ~1kW-h/m²/day. This translates to 208 watts/m² and 41 watts/m², respectively. If the assigned land area is 450 km² (which translates to 2.1E11 m²), the total solar insolation striking the surface is between 4.2E13 watts (208 x 2.1E11) and 8.3E12 watts (41 x 2.1E11). Assuming that the efficiency from solar powered technologies is currently ~6%, the total amount of energy that can be utilised with the highest estimate is 2.5E12 watts or 2.5E9 kW; with the lowest estimate it is 4.8E11 watts or 4.8E8 kW. Each of these values is several orders of magnitude above the energy of Cambridge as a whole, which is on the order of 5E4 kW for residences (50,000 residences at 1kW per residence) and somewhat less than 2E5 kW for all uses of energy combined (assuming energy use in a residence is 25% of overall energy use from residential, commercial, industrial and transportation sectors). As efficiencies of solar panels are improved (as they surely will), the values will rise to the theoretical upper limits of between 8.3E12 and 4.2 E13 watts (8.3E8 and 4.2E10 kW). The conclusion: Cambridge could power all of its energy needs by devoting a fraction of total land area equal to somewhere between approximately 2E-5 (5E4/2.5E9) and 1E-4 (5E4/4.8E8). Expressing these as percentages of land area, this is 0.002% to 0.01%.

If we translate this into the size of solar panel needed to power a home (assuming that home utilises approximately 1 kW), we need ~80 m² with the best insolation estimates assuming 6% efficiency, and ~406 m² with the worst insolation estimates at this same efficiency. This calculation assumes the panels are oriented at right angles to the radiation. The areas would need to be quadrupled if the panels were to supply energy needs from all sectors.

Wind Power: For this calculation, we ask about the total kinetic energy that might be extracted from the air moving over Cambridge, assuming that air passes through a “wall” equal in height to the height of a large wind turbine. We will assume here that this height is 200 m. The width of this “wall” is taken from the assumption that the approximate area assigned to Cambridge is 450 km² as in the discussion of solar energy. If this is a square, the length of any one side is approximately 21 km, or 21,000 m (if a circle is assumed, the diameter would be 23 km). The rate of energy flowing through this surface, assuming a mean wind velocity of 5 m/s above the area of turbulence near the surface of the earth, may be found by multiplying the area of the wall (21,000 x 200 = 4.2E6 m²) by the density of air (1.3 kg/m³) by the velocity cubed (53 or 125 m³/s³) by 0.5. The reader will note that this calculation is simply the equation for kinetic energy, 0.5mv², with m (mass) replaced by the RATE of mass flowing through the wall surface to calculate power rather than kinetic energy. The result of this calculation is 3.4E8 watts or 3.4E5 kW, again slightly higher than the 2E5 kW needed to power all of Cambridge (see the discussion of solar energy above). If a single row of wind turbines placed along this “wall” were to extract this energy with 10% efficiency (a typical value), this would yield approximately 35,000 kW, enough energy for on the order of 35,000 homes. Six rows of such turbines would provide approximately the total energy needs from all sectors of Cambridge (2E5
kW). If the turbine rotor blades have a radius of 100 m (as assumed above), the area of a single turbine is 31,400 m². Six “walls” of 4.2E6 m² each equals a total of 2.5E7 m². This represents approximately 800 of these wind turbines (2.5E7/3.14E3).

As in the discussion of solar energy, it is interesting to consider the size of a wind turbine needed to power a single home requiring 1 kW. With a wind speed of 5 m/s and 10% efficiency, this would require a blade radius of 6.5 m (diameter of 13 m). If the energy needs of all sectors associated with this residence (approximately 4 kW) were to be supplied, the required rotor blade radius would be 12.5 m (diameter of 25 m).

The above calculations are designed to be a rough estimation of how much energy could potentially be generated from the two main sources evaluated in detail, and to show that Cambridge does have the potential for large amounts of renewable energy, if technology is developed and utilised in the most efficient way. We caution that this initial report does not discuss the desirability of such technologies. Wind in particular may come with an unacceptably large aesthetic impact on the landscape, as is evident from recent controversies over the government’s ambitious plans for wind power.

8.7. Additional Considerations

The information provided earlier in this section is based on estimates of the total energy potential of the site and its relationship to actual energy use. Conclusions will not be accurate until the site is completed, people are living there, and experience has shown actual energy use. Also, any estimates assume people behave according to the assumptions adopted in this section. People still have to make an effort to be energy efficient and sustainable, including adopting energy sources rooted in renewables. A significant educational effort will be needed to establish this behaviour. Furthermore, the recommendations produced from this Renewable Energy Report cannot stand alone. In order to be effective within the framework of the North West development, they need to be implemented alongside other measures-discussed in other sections-which aid the ultimate goal of sustainability and energy efficiency. For example, infrastructure networks must ensure that the use of renewable energy makes it efficient and attractive, and the correct type of renewable energy must be chosen for the specific site. CHP for example may be a very good choice for such a development as numerous buildings of different uses are going to be situated relatively close to one another, making the transmission of energy from this source easier and more efficient than in other areas. Even a CHP, however, is not an example of renewable energy use if it simply burns coal or oil or natural gas. An option is to move towards a CHP operating on biomass produced in the surrounding countryside. The burning of biomass is largely (although not completely) a carbon neutral source of energy.
Section 9. Construction and Demolition Waste Management at the North West Development

The ideal of sustainable development is to move towards a closed system of material and energy flow, in which as little material or energy as possible goes into the waste stream. This section considers construction and demolition waste management (C&DW) as an opportunity to employ this principle at the North West site. Having a strong environmental ethic from the beginning of the development of the North West site starts the process of site development towards sustainability. According to the Department of Trade and Industry, “the construction industry produces around 92 million tonnes of waste, including an estimated 13 million tonnes of unused material”\(^{109}\). Around 55% of that waste entered the landfill by 1999 numbers, and 70% of the waste that enters the landfill can be reused or recycled\(^{110}\). Reusing or recycling those materials can save companies money, decrease landfill waste, and also save energy. The following section considers a number of strategies that might be adopted at the North West site to ensure that the material use is as near to a closed system as possible.

9.1. Defining C&D Waste

*Construction and Demolition Waste* can be defined in four ways (Symonds Consultancy et al 1999):

- Waste arising from total or partial demolition of buildings and/or civil infrastructure
- Waste arising from total and partial construction of buildings and/or civil infrastructure
- Soil, rocks and vegetation arising from land leveling, civil works and general foundations
- Road planning and material from maintenance

9.2. Types of C&D Waste

Some of the major types of Construction and Demolition Waste are asphalt, tar and tarred products\(^{111}\), concrete, bricks, tiles, ceramics, and gypsum glass, insulation materials, metals, plastics, rocks, soil, steel, vegetation and wood.

\(^{109}\) DTI, Thursday 8 July 2004, Construction Industry to Get its Green House in Order
http://www.wasteonline.org.uk/resources/Wasteguide/mn_wastetypes_constructiondemolition.html
\(^{111}\) http://www.wasteonline.org.uk/resources/Wasteguide/mn_wastetypes_constructiondemolition.html
9.3. Relation to Energy and Sustainable Development

Construction Waste Management is linked to energy and sustainable development. When one manages construction and demolition waste sustainably, less energy is used in the manufacture and transport of construction materials, which reduces the emissions of carbon dioxide and hazardous air pollutants. Other links with sustainable development are illustrated below.

Figure 9.2. Relationship of CDW Issues to Energy and Sustainability

Many laws currently influence C&DW management on a variety of levels. Below are some of the major environmental policies and documents that are relevant to this industry and should be reviewed in future reports in this series; any of these may provide both insights into best practices as well as policy tools to ensure those practices are adopted:

At the National Level 112

- Environmental Protection Act 1990
- Environment Act 1995
- Directive on the Landfill of Waste 1999
- Directive on Integrated Pollution Prevention and Control 1996
- Directive on Waste Electrical and Electronic Equipment 2002
- The Producer Responsibility Obligations (Packaging Waste) Regulations 1997
- The Finance Act and Landfill Tax Regulations 1996
- Waste Minimisation Act 1998
- The Local Government (Best Value) Performance Indicators and Performance Standards Order 2001
- Anti-Social Behaviour Act 2003 (relates to Fly-tipping)

At the County Level 113

- Structure Plan 2003
- Cambridgeshire and Peterborough Waste Strategy 2002

At the City Level 114

- Waste Strategy Policy
- Environment Plan 2004

At the University of Cambridge Level

- Guidance on Environmental Aspects of Building Design 2000
- (Estate and Building Management Services)
- Guidance on Environmental Aspects of Construction 2000 (EMBS)
- Policy on Environmental Issues 1996 (EMBS)

9.5. Overview of Waste Management Options

There are a variety of methods for managing construction waste. The goal for managing waste is to limit the amount that enters the landfill. Thus, if a material can

113 Structure Plan and Waste Strategy
114 http://www.cambridge.gov.uk/env/Wastestrat_homepage.htm
be reused, the process is more sustainable than if material were to be recycled, which is better in turn than a cycle in which material is landfilled. By far, the best option is to reduce the amount of waste from the very beginning. These options are discussed in more detail below.

| Reduction | → | Reuse | → | Recycling | → | Landfill |

**Figure 9.3.** Waste Stream Diagram showing the four options available for waste, proceeding from best (left) to worst (right)

*Landfilling:* The most common method used is simply to landfill the waste. However, due to limited landfill space, environmental policies—such as the Landfill Directive—and economic costs, landfilling inert waste will decrease as a primary management strategy.

*Recycling:* Currently, some of the waste from construction sites is recycled. This process requires some energy to transport materials to the recycling facility, to operate that facility, and to transport the sorted materials to manufacturers. While this process uses less energy and materials than using virgin materials, and closes the cycle better than materials being placed into the landfill, this process is not preferred to reuse of materials, which requires little to no energy.

*On-site reuse:* The University can also reuse materials on-site. One example is using wood from one area of construction (e.g., forms for concrete) in another part of the building. A common qualm with this is that the wood is often less desirable due to paint, varnish, nails, etc., from this previous use. Still, reusing materials is preferred to recycling, and much better than landfiling.

*Exchange programs:* If the construction and demolition materials cannot be reused on-site by the construction company, one solution may be to locate someone else who may be able to reuse them. Such exchange programs help to reduce the amount of waste that enters landfills. Making use of Internet technology, exchanges provide a medium for companies to declare they have waste that can be used for other products. Examples of previous exchanges are available on the Materials Exchange Website or by contacting the exchanges[^115].

[^115]: Contact information for the exchanges are given on page 14 of this section.

There are many benefits to managing construction waste on many different scales, from the company level to the scale of an entire ecosystem. Below is an illustration of the benefits wise C&D Waste Management can bring.

Financial Benefits: Managing the waste wisely can save companies large amounts of money. The Department of Trade and Industry (DTI) estimates that £100 million a year will be saved after signing up the top 2000 contractors in the U.K. (July 8, 2004 article). By reusing the materials on-site or even exchanging them, less will have to be landfilled at a rate of £2 per tonne for inert waste, such as stones, bricks, sand, and £15 for other types of waste. By reusing waste you are also dodging the cost of hiring a skip. One can save money additionally if waste is sorted, as it costs £157.45 for normal rubbish and £94 for hard-core materials (figures from Donarbon). Though Donarbon’s 8-yard skip for normal rubbish is more expensive than those of A10 and Warton and Clark, one should note that Donarbon’s attempts to recycle construction waste, while the other agencies collect the waste for landfill disposal.

Money can also be made from construction waste. Through exchange programs, companies can sell their waste to other organizations. This money can then be used for future development projects.

By managing waste properly through the DTI Site Waste Management Plan Guidance for Construction Contractors and Clients, around 20% of materials could be saved for later use. Furthermore, if materials were recycled, less virgin materials would have

---

116 The landfill costs are taxed to encourage creative recycling. Nationally, the United Kingdom’s goal is to recycle 25% of waste by 2005/2006. (http://www.greentaxes.org/country/uk/land.asp). Wastewatch states that that the “landfill tax will be increased by £3 per tonne in 2005/06 and by at least £3 per tonne in the years thereafter, on the way to a medium to long term rate of £35 per tonne”.

117 “inert waste” means waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the ecotoxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater (Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste).

118 DTI Site Waste Management Plan Guidance for Construction Contractors and Clients
to be used. Managing the waste wisely will help to create wise use of resources, again by closing the cycle of energy and material use.

Saving Landfill Space: By managing waste wisely, less waste will enter the landfill. This will result in fewer materials taking up valuable landfill space, freeing land for economic development.

Energy Savings: Energy can be saved by reusing and recycling construction and demolition waste. When creating new materials, energy is spent gathering the source materials, manufacturing the product, transporting the product, and operating commercial spaces for the product. An example is provided by the Cambridge City Council:\(^{119}\): “Every tonne of glass recycled saves 1.2 tonnes of raw materials and the equivalent of 30 gallons of oil energy”. Additionally, “using ferrous scrap instead of iron ore requires 74% less energy”. An exchange program would also result in energy savings, perhaps operated through the recycling facility at Donarbon. That facility is located 6 miles from the North-West Development site, about a 15-minute drive, which is an appreciable savings in energy use for transport from other facilities at which virgin products might be sold. All of these options would be better than the creation of the new materials.

Social Benefits: By sharing materials with others communities, relations can be strengthened. One example of demolition waste being shared can be found in the case of the demolition of Murphy Hall at the University of North Carolina, where 250 desks were given to the Boys and Girls Club of Nash/Edgecombe County\(^{120}\). This not only resulted in a significant reduction in waste, it built ties between the university and public organizations, meeting the university’s goal of becoming a partner in strengthening the social network of the surrounding community. Some of the materials currently found in the buildings at the North West site, if these buildings are demolished, could be donated to local charities and organizations. These donations can help to enhance the Cambridge community. Information about local charities can be found in Finding Your Way Around the Environment in Cambridge.

Reduction of Environmental Degradation: By managing waste properly, less energy will be used in production of materials, resulting in lowered emissions into the atmosphere. Less waste will enter landfills, resulting in less pollution to water resources. Furthermore, fewer resources will be needed to provide energy to produce new materials for construction, which will result in less destruction of wildlife habitats.

Human Health Risk Reduction: By reducing the amount of emissions, there will be less risk to human health. Emissions to the air and water decrease as a result of reuse and recycling of construction materials, decreasing the associated adverse effects.

Job Creation: By managing waste wisely, jobs can be created. For example a construction waste specialist position focusing on managing waste sustainably could be created. One example of such a position can be found at the University of North

\(^{119}\) [http://www.cambridge.gov.uk/sustainablecity/](http://www.cambridge.gov.uk/sustainablecity/)

\(^{120}\) C&D Waste Presentation, Office of Waste Reduction and Recycling, University of North Carolina at Chapel Hill (UNC)
Carolina at Chapel Hill, where Sarah Myers holds the position of Construction Waste Specialist. Consultants at companies also specialize in demolition and construction waste management.

Avoidance of Law Suit/Fines: Lawsuits are a major problem when it comes to disposal of construction, demolition and earthworks waste. Ralph Crouch of the Environment Agency stated in Daniel Wilkinson’s article\textsuperscript{121} that, “Only 13 percent of construction companies are aware of their responsibility to check that the company they use to dispose of their waste is authorized to do so.” According to the Environment Agency, 30\% of all flytipping\textsuperscript{122} cases come from this sector. According to Wilkinson’s article, “In 2002 there were 35 court cases involving the construction ples for breaching waste legislation”. Flytipping can result in hefty fines. A fly tipping incident can face a maximum of £20,000 and/or a six-month custodial sentence in a magistrate court and unlimited fine and/or two-year custodial sentence in Crown Court\textsuperscript{123}.

9.7. Best Management Practices

As stated earlier in this document, there are many ways to manage waste. Below are some best management practices that can help a community better manage construction waste.

Pre-planning Practices: The pre-planning practices are methodologies that can be done before demolition procedures have started.

Bid Alternatives\textsuperscript{124}: Conduct a feasibility study to see if waste management options other than landfilling are financially viable. Through this study the municipality can illustrate the costs of recycling and other methods of management.

Require a Waste Management Plan\textsuperscript{125}: When companies are bidding for construction of buildings, require a waste management plan. The Department of Trade and Industry provides a document Site Waste Management Plans Guidance for Construction Contractors and Clients that can be used to better manage waste. If resources are not available to manage the waste in this comprehensive fashion, a simplified plan could be developed to select some types of materials and determine how they will be managed. For example, all wood might be recycled to the greatest extent possible. It is also advisable to specify the types of wastes to reuse and recycle during the construction process so that contractors will be given a starting point for waste management.

\textsuperscript{121} Daniel Wilkinson Article May 17 2004; Flytipping is disposing of waste improperly. Environment Agency Article, “Constructive Conversation on Illegal Building Waste”.
\textsuperscript{122} Daniel Wilkinson Article May 17 2004; Flytipping is disposing of waste improperly. Environment Agency Article, “Constructive Conversation on Illegal Building Waste”.
\textsuperscript{123} Chris Mitchell May 21 2004; Environment Agency Article “Hertfordshire builder pays £7,000 fore careless waste”
\textsuperscript{124} Triangle J Council of Governments—Using Specifications to Reduce Construction Waste Handout
\textsuperscript{125} C&D Waste Presentation, Office of Waste Reduction and Recycling, University of North Carolina at Chapel Hill (UNC)
Talk to Contractors during Preconstruction meetings: By discussing construction waste with the contractors early in the process, it is more likely that waste will be managed in a sustainable fashion.

Walk-Through for Waste: Early in the process is a good time to have charity shops, subcontractors, and recycling officers do a walk-through of the buildings that will be demolished, determining how to dispose of all the waste properly. By walking-through early, more waste can be noted and reused or recycled, thereby resulting in less waste entering landfills, less energy being used, and more money saved.

Establish Responsibility: Before the construction breaks ground, it is important to determine who is going to be responsible for managing the waste, both on-site and off, in addition to completing the paperwork and logistics that goes along with the process.

Review Building Plans After Every Part: Sarah Myers, Construction Waste Specialist for the University of North Carolina at Chapel Hill, states that one should “review building plans at each step, verifying exactly what will be removed”. This can enable more waste to be reused and recycled.

Demolition / Construction Practices

Exchanges: Exchanges are one method of reducing construction and demolition waste. Each of the exchanges makes use of the Internet as a medium for communication. Organizations can post waste to exchange with other organizations. Some companies sell their waste, while at other times they are simply getting rid of the waste by donating it to organizations that are in need. The services for the exchanges are free and yield great financial benefits, as money can be saved and earned, resources can be saved and less environmental degradation will occur. Two of the major exchanges are The Materials Exchange and Salvo!

- The Materials Exchange started in November 2002 and has had 3,839 visitors to its website. 238 organizations are registered. Everyday, there are about 7 new visitors to the website. This organization is a local exchange for Cambridge.

- Salvo! started in 1991. This exchange has markets all over the United Kingdom.

Hire a Waste Management Subcontractor: One can hire a construction waste specialist or consultant to manage the waste sustainably. Salvo! has subcontractors

---

126 C&D Waste Presentation, Office of Waste Reduction and Recycling, UNC
127 C&D Waste Presentation, Office of Waste Reduction and Recycling, UNC
128 For a list of charity shops refer to the recycling directory for Cambridge produced by the Cambridge City Council
129 Office of Waste Reduction and Recycling, UNC
130 C&D Waste Presentation, Office of Waste Reduction and Recycling, UNC
131 http://www.materials-exchange.org.uk/
132 http://www.salvo.co.uk/
available to provide such services. Their agency stresses reuse and reclaiming the waste for reuse, as opposed to recycling and landfilling. Donarbon stresses wise management of construction waste. Donarbon sorts rubbish skips off-site for recycling. This service costs £157.45 per skip. A skip hire for hard-core materials the skip hire is £94; therefore, by separating those materials, the company can save £63.45. About 55-60% of the waste entering the site is recovered or recycled. Donarbon provides hard-core materials and soil for sale.

Construction Practices

On-site management: Materials from the construction site can be sorted and reused on-site if at all possible. Some examples of reuse include using crushed bricks for filling holes. Another example of reuse can be the crushing of bricks for landscaping. Lumber can also be reused on-site to reduce the need for new materials.133

Preventative Measures

Surplus Materials Management: The University of North Carolina at Chapel Hill has a surplus134 facility to house surplus furniture, electronic equipment and other materials. Nothing in surplus is over $100. This facility provides a great opportunity to reuse materials. The University of Cambridge could adopt this same practice and reduce the amount of waste that enters landfills. Schools could buy the surplus materials at greatly reduced cost to improve the educational system. Community members could also purchase furniture and other items. Money from sales could go to further sustainable development of the University.

Currently the University of Cambridge uses an online message board system135 to post available goods to other departments. This system does not support the ability to post images of the goods and does not allow faculty and staff to “touch” the goods. Also, this system requires that staff advertise the goods and set up a time to transfer those goods to another party, all of which requires time. A surplus building system would simplify the process by having all the goods in a central location where departments could come by and purchase goods that are available. Staff members of the surplus building would keep track of inventory and bookkeeping.

Donation Stations: Bins can be used for donations to charities during the process of moving in and out of colleges during the beginning and end of term time.136 Charities may receive many materials from this process. The University of North Carolina at Chapel Hill uses bins to collect clothing, school supplies, and food for local charities. Colored bins can be purchased for £4.99 from Warehouse Clearance on St. Andrews Street. Prices may vary with shop and bulk rates. One should try contacting other

133 Wasteguide
134 http://www.unc.edu/mds/sp/
agencies, such as ASDA or environmental product companies for quotes. The bins that are purchased can be reused in future years. The cost of implementing such a program would be around £775 if there were 5 of those bins in each of the 31 colleges.

Train for Waste Reduction: Train employees who are working on the development to conduct sustainable practices. By keeping waste reduction in mind when developing the site, less waste will have to be managed.

Green Purchasing: Buying materials that have previously been used and products that have been recycled helps to close the loop of pollution. By buying products manufactured and transported sustainably, society is reducing the amount of energy used to create new products, thus reducing the amount of environmental degradation that occurs. Donarbon and Salvo! both are vendors of sustainable construction materials. One should seek out used materials and environmentally sound materials for construction of the North West Development site.

9.8. Relevant Legislation

To make the greatest change in regards to construction and demolition waste practice, there needs to be a change in the legislation that would provide “legal hammers” to implement wise waste management practices. The most likely place at which to introduce this would be in the issuing of construction permits. It is crucial to strengthen existing policies, such as those listed in the box to the right, to reduce the amount of waste that enters landfill, reducing energy consumption and environmental degradation.

In order for current legislation to be effective for waste management, the language must be changed. The guidance on Environmental Aspects of Construction reads:

“The tender shall include a description of the wastes likely to arise during construction and the disposal routes for those wastes”

Such a policy does not mention reusing materials or recycling materials, and it calls only for describing wastes, not for managing those wastes sustainably. Stronger language should be used to stress sustainability. One statement that could be used is: “On all University Development Projects the tender shall require waste reduction, reuse, and recycling to the extent possible”. Another possibility is to issue a goals statement focused on a percent reuse/recycling for a development project. University
administrators should look at a variety of examples of language that is most appropriate for The University of Cambridge.

9.9. Outreach and Education Campaigns

An outreach and education effort would be very helpful in creating greater awareness regarding CDW. Some methods for creating such a campaign may include, but are not limited to:

- **Workshops**- Conduct workshops specifically for contractors to learn how to manage waste sustainably.
- **Presentations**- Go to different agencies and conduct presentations on site-specific or waste-specific procedures.
- **Printed Materials**- Create brochures, posters and flyers to increase general awareness.
- **Website**- Create an easily referenced website regarding construction waste management in the Cambridge area.
- **EZ Reference Waste Chart**- Create a one page easily referenced chart with different materials that can be recycled, and contacts for more information.
- **Seminars**- Offer seminars regarding construction waste related topics.
- **City and County Promotions**- Mention and promote Construction Waste as an issue in recycling campaigns.
- **Require Training**- Create a policy that requires training on wise construction waste management for all contractors.
- **Promote the Considerate Contractor Program**- Promoting this program will stress sustainable practice. Encourage and stress wise construction and demolition waste management.
- **Create a Construction Waste Plan Rewards System**- Creating an incentive program will help encourage sustainable practice.
- **Publicize Demonstrations**- Publicize demonstrations of wise sustainable practice so that companies can see first-hand examples of “good practice”.
- **Public Relations Campaign**- Publicize excellent CDW practice in local media/publications, trade organizations, and conferences.
- **Define Terms**- Terms such as sustainable development and inert waste should be defined on documents to increase consensus on their use.
- **Mediation**- If conflicts arise, use mediation to resolve disputes, such as through the Cambridge Mediation Service.
- **Celebration**- It is very important to celebrate the accomplishment of waste management, especially after goals are met. Save money in the budget for a sustainable celebration to enhance group relations and reinforce the theme of sustainability for the North West Development.\(^{137}\)
- **Working as a Team**- One needs to remember that managing construction can be a team process and that there are many different interests that should be addressed when managing the waste. All of the interests should keep the overarching theme of sustainability- economic vitality, social equity, and environmental quality- in mind while managing the waste.

9.10. Conclusions

Construction and demolition waste management must be a relatively easy process to get the greatest involvement from the construction and demolition communities. Some of the key things to remember when discussing construction and demolition waste management are:

- **Sustainability and sustainable development:** Stress these when discussing waste management.
- **Energy savings:** Large amounts of energy can be saved from wise management, reducing cost and the amount of carbon that is emitted into the atmosphere.
- **Social Benefits:** Educational systems and other institutions can be enriched from the reuse of construction and demolition waste.
- **Human Health:** Because there will be less groundwater pollution and less air pollution through wise management of construction materials, human health is protected.
- **Waste Stream:** Keep in mind the waste stream and that the order of preference (from best to worst) is: to reduce the amount of waste produced, to reuse the waste produced, to recycle the waste, and to landfill the waste

*Environmental Landscape:* By managing construction and demolition waste wisely, less of the English countryside will be degraded.

By keeping these core concepts in mind, one’s discussion of construction and demolition waste can be more effective and will help to manage the North West Site sustainably.
Section 10: Policy Tools and Political Feasibility

Previous sections have focused on the effects of the North West development on key measures of sustainability, and potential design features that might improve sustainability. While many of these features may be introduced purely voluntarily and without government assistance, it is of interest to ask whether there might not be specific organizations with a vested interest in supporting development of sustainable practices at the site, and/or specific policy tools that can be applied by those organizations. No attempt is made in this initial report to fully describe these policy tools; instead, we focus here on providing insights into some of the more evident organizations and their powers. Future reports in this series will provide a more complete analysis of this issue and identify more specific policy approaches that might be adopted.

The goals of this section are to:

- Explain the set of tools that might be applied to aid the development in moving towards sustainability
- List and describe the organizations that might participate in putting these tools to use
- List and describe the tools that these organizations possess
- Show which of these tools have worked elsewhere and which have failed, and explain the reasons of their successes or failures
- Analyze whether or not Cambridge is different from these examples, and what this means in terms of the likely success or failure of Cambridge’s attempt to build sustainability into the site design
- Provide a hierarchical decision matrix of the U.K. government leading to down Cambridge City Council members

10.1. Tools available for policy makers to promote sustainability

The following tools are found commonly in the area of sustainability, and might be considered for improving the sustainability of developments in Cambridge:

- **Emissions/carbon/energy taxes**: In this tool, the government would place a tax on a unit of a certain pollutant; for example a tax of £0.02 per cubic metre of carbon dioxide emitted by an operation. A similar tool is to place a tax on a unit of energy used by an operation, which would drive up the costs, giving the operation an incentive to invest in sustainable energy.

- ** Tradable or non-tradable permits**: Tradable permits are often referred to as emissions trading. In this scheme, operations that use a certain amount of energy, or emit a certain amount of pollution, would be required to apply for a permit (such permits would be approved and given out by the EA) which would allow them to emit a set level of carbon dioxide. If the operation emits less than this set amount, then they are free to sell their remaining emissions allotment to other operations. The idea behind this is to use market forces to drive down emissions or energy use. Non-tradable permits allow an operation to emit a certain amount, but not to trade any unused emissions.
• **Provision and/or removal of subsidies:** The government might provide subsidies for the use of “green” energy (wind, solar) to encourage sustainability. For example, the government might pay a percentage of the cost for a homeowner to install a solar panel on their roof. Another example would be a tax cut to operations that use renewable energy for a portion, or the whole of their energy source. The government might also remove certain subsidies, for example subsidies on gasoline, to discourage consumption of non-renewable energy sources.

• **Deposit/refund systems:** This is a dual system comprised of a tax on a product (the deposit), which may be partially or completely refunded when the user returns the product to a specified location, either for recycling or proper disposal. A common example of this is the recycling of bottles or cans. The objective behind this scheme is to reuse resources, or to prevent them from becoming litter or being otherwise improperly disposed of. For certain materials, however, recycling does not always save energy or money, so this may not always work towards the goal of sustainability.

• **Technology or performance standards:** Technology standards would be used to promote sustainable energy use by requiring operations to use a specific energy efficient technology, or a certain technology that limits emissions of greenhouse gases. A performance standard would, instead of requiring a specific technology, require an operation to stay within a set operational criterion such as efficiency, but leaves the decisions as to how to do this up to the operator.

• **Energy mix requirements:** This tool requires operations to obtain a certain percent of their total energy from renewable sources. This may be used to phase in the use of renewable energy sources, leading eventually to a system based completely on renewable energy.

• **Product bans:** A fairly straightforward tool, this would be used to ban products which do not promote sustainability. These may be products for which the manufacturing process is an unsustainable practice, products that cannot be recycled or reused, or products that contribute disproportionately to pollution levels.

• **Voluntary agreements:** Voluntary agreements would be programmes or strategies promoted, but not actually enforced, by the government, NGOs, or other organizations. Operations may choose to participate in these perhaps by pledging to use a certain amount of renewable energy. Incentives for participation might be to improve their public appearance as a “green” operation, which may drive up demand, to reduce long-term costs (perhaps by investing in energy efficient technologies), or to avoid actual regulation by the government. The latter is often a strong incentive for operations to participate, as regulation by the government may force the operation into stricter, more costly requirements. An example is the “green pledge” associated with the CRed project at the University of East Anglia.

• **Government spending and investment:** This is another fairly straightforward tool in which the government spends directly on projects to promote sustainability and boost the market. These projects vary greatly, but may include funds for DEFRA or local governments.

• **Support for research and development:** The government may use spending as a way to advance the development of sustainable technologies. This tool,
however, is often used not for the genuine advancement of technology or information, but rather as a way to stall the adoption of regulations. In the face of uncertainty, governments often claim that more research is required before any action is taken. This may not be as much of a problem in the U.K. as it is in the US, as both the U.K. and EU require the use of the precautionary principle, but it is worth noting that this sometimes occurs and must be guarded against.\textsuperscript{138}

10.2. Organizations that Might Participate

To analyze the feasibility of the proposed policies for the North West site, one must first examine the groups that may have a stake in the development and/or the sustainability issues it raises. These groups are the authorities or organizations that will help bring policy tools to bear. They can be divided into two categories: organizations directly involved with the development of the North West site, and organizations that may participate because the activities of the site fall under the domain of the organization’s programs or regulations. Following is a list of organizations that fall under these categories, and a brief description of their purposes. Future reports in this series will focus more completely on the authority and the power of these organizations with respect to guiding development of the North West site.

Those with direct authority

\textit{Cambridge City Council:} “Cambridge City Council is responsible for providing a wide range of services to people who live in the City, to people who visit the City and to businesses and other organizations here.”\textsuperscript{139} In general, “districts are responsible for leisure, environmental health, housing, rubbish collection, and local roads” and “have a general power to 'promote economic, social and environmental well-being' of their area.”\textsuperscript{140} This power, however, is subject to acts of parliament, as authorities may only exercise powers that are specifically given to them in an act. Councils are funded by both central grants and local taxes.\textsuperscript{141}

\textit{The University of Cambridge:} The University of Cambridge, specifically the Estate Management and Building Service, makes contracts with developers for the North West site, and oversees the plans for and the development of the site. As the plans for the site are at a very early stage, these developers have not yet been selected. When they are selected, these developers will be key players in the goal of building sustainably.

\textsuperscript{138} The headings for section 10.1 are from “Summary for Policy Makers - Climate Change 2001: Mitigation”\textsuperscript{139} From “Cambridge City Council Constitution” http://www.cambridge.gov.uk/councillors/constitution.pdf\textsuperscript{140} From “Local Government in the United Kingdom” at http://www.wordiq.com/definition/Local_government_in_England\textsuperscript{141} From “Local Government in the United Kingdom” at http://www.wordiq.com/definition/Local_government_in_England
Those with indirect authority and/or interest

*The European Union (EU):* The European Union is the governing body for the democratic European countries that have signed treaties and have given some of their sovereignty to the Union (this is called “European integration”). The Union does not interfere with Member States’ abilities to govern themselves, but rather acts as a unifying force for the 25 countries participating. The EU is governed by 5 institutions, listed here as appearing on the Europa website:

- European Parliament (elected by the peoples of the Member States);
- Council of the European Union (representing the governments of the Member States);
- European Commission (driving force and executive body);
- Court of Justice (ensuring compliance with the law);
- Court of Auditors (controlling sound and lawful management of the EU budget),

These are flanked by five other important bodies:

- European Economic and Social Committee (expresses the opinions of organised civil society on economic and social issues);
- Committee of the Regions (expresses the opinions of regional and local authorities);
- European Central Bank (responsible for monetary policy and managing the euro);
- European Ombudsman (deals with citizens’ complaints about maladministration by any EU institution or body);
- European Investment Bank (helps achieve EU objectives by financing investment projects)”

The EU is concerned with trade and the economy, and also with “citizens rights, ensuring freedom, security and justice, job creation, regional development, environmental protection, and making globalisation work for everyone.”142 The most relevant office within the EU is the Environment Directorate of the European Commission, which has a number of programs and directives relevant to the issues of sustainability at the North West site.

*The Department for Environment, Food, and Rural Affairs (Defra):* “Defra was created in June 2001 to drive forward the Government’s programmes on the environment, food and rural affairs.”143 Their objectives are listed below:

- “To protect and improve the rural, urban, marine and global environment and to lead integration of these with other policies across Government and internationally.
- To enhance opportunity and tackle social exclusion in rural areas.
- To promote a sustainable, competitive and safe food supply chain which meets consumers’ requirements.

---

142 Section 10.2, II, a, is entirely taken from “The European Union at a glance” at http://europa.eu.int/abc/index_en.htm
143 From “About Defra” at http://www.defra.gov.uk/corporate/index.asp
To promote sustainable, diverse, modern and adaptable farming through domestic and international actions.
To promote sustainable management and prudent use of natural resources domestically and internationally
To protect the public’s interest in relation to environmental impacts and health, and ensure high standards of animal health and welfare.”

The Environment Agency (EA): The EA’s responsibilities range from “influencing government policy and regulating major industries nationally…to day-to-day monitoring and clean up operations at a local level.” Their vision includes the goals of:

- A better quality of life;
- An enhanced environment for wildlife;
- Cleaner air for everyone;
- Improved and protected inland and coastal waters;
- Restored, protected land with healthier soil;
- A greener business world;
- Wiser, sustainable use of natural resources;
- Limiting and adapting to climate change;
- Reducing flood risk

The Office of Gas and Electricity Markets (Ofgem): Ofgem is responsible for the regulation of the gas and electricity markets of the U.K. They “protect and advance the interests of consumer by promoting competition where possible, and through regulation only where necessary.” Their goals are as follows:

- making gas and electricity markets work effectively
- regulating monopoly businesses intelligently
- securing Britain’s gas and electricity supplies
- meeting its increased social and environmental responsibilities.

Ofgem is governed by the Gas and Electricity Markets Authority, which “makes all major decisions and sets policy priorities for Ofgem.”

The Department for Transport (DfT): The purpose of the Department for Transport is to “provide a stronger focus on delivering the Government’s transport strategy…to set strategy and policy context, and to establish and manage relationships with the organisations that are responsible for delivery.” In addition, part of the DfT’s focus is on sustainable transport, which includes providing information, or researching strategies for the following:

---

144 From “Defra’s aim and objectives” at http://www.defra.gov.uk/corporate/aims/aim.htm
145 From “About Us” at http://www.environment-agency.gov.uk/aboutus/275155/?version=1&lang=_e
146 Bullets in section 10.2, II, c, are from “Our Vision” at http://www.environment-agency.gov.uk/aboutus/286233/289892/?version=1&lang=_e
147 Insert later
148 From “Organization of the Department of Transportation” at http://www.dft.gov.uk/stellent/groups/dft_about/documents/page/dft_about_022752.hcsp
- cycling
- road charging
- home zones
- school travel
- travel plans
- walking

**The Department of Trade and Industry (DTI):** The three main goals of the DTI are “supporting successful businesses, promoting science and innovation, and ensuring fair markets.” In line with these goals, the DTI strives towards “facilitating partnerships and promoting fresh thinking between government, businesses, employees, unions, consumers and the scientific community. We invest in world-class science and technology, and help ensure its successful exploitation. We promote a legal framework that encourages enterprise and innovation, ensuring consumers, companies and employees receive a fair deal. We ensure a successful economy is underpinned by secure, sustainable and affordable energy. And we champion British interests globally while promoting economic reform in Europe and free and fair world trade.”

### 10.3. Tools of these organizations

This section provides a brief overview of the existing tools used by these organizations to promote sustainability and the mitigation of climate change. The material is arranged by the organizations listed in the previous section. Future reports in this series will continue and expand this discussion, assessing the application of these tools to the North West development.

**Cambridge City Council**

*Local Government Act 2000:* The Local Government Act 2000 gives local authorities broad new powers. In it, the Local Government in England is defined as any of the following:

- A county council
- A district council
- A London borough council
- The Common Council of the City of London in its capacity as a local authority
- The Council of the Isles of Scilly

The Act gives local authorities the power to “do anything which they consider is likely to achieve…the promotion or improvement of the economic…social…(and) environmental well-being of their area.” This includes power for local authorities to:

---

149 Bullets in section 10.2, II, e, are from “Sustainable Travel” at http://www.dft.gov.uk/stellent/groups/dft_susttravel/documents/sectionhomepage/dft_susttravel_page.html

150 From “DTI vision and objectives” at http://www.dti.gov.uk/about_dti_objectives.html

151 From “Our challenges” at http://www.dti.gov.uk/about_dti_challenges.html
• Incur expenditure;
• Give financial assistance to any person;
• Enter into arrangements or agreements with any person;
• Co-operate with, or facilitate or co-ordinate the activities of, any person;
• Exercise on behalf of any person any functions of that person; and
• Provide staff, goods, services or accommodation to any person

These powers may also apply to persons situated outside their area if the authority considers “that it is likely to achieve any one or more of the objects in that subsection.” These powers do not allow local authorities to do anything prohibited “by virtue of any prohibition, restriction or limitation on their powers which is contained in any enactment.” These powers also do not allow a local authority to raise money “whether by precepts, borrowing or otherwise,” and the Secretary of State has the power to overturn any order passes by the local authorities. The Secretary of State also has the power to “amend, repeal, revoke or disapply” any enactment that “prevents or obstructs local authorities from exercising their power” or “requires a local authority to prepare, produce, or publish any plan or strategy relating to any particular matter.” The Act also requires every local authority to “prepare a strategy…for promoting or improving the economic, social and environmental well-being of their area and contributing to the achievement of sustainable development in the United Kingdom.”

Home Energy Conservation Act 1995: Also under the domain of local government in the U.K. is the Home Energy Conservation Act 1995. Definitions pertaining to this Act are:

• “energy conservation authority” means in England and Wales, a local housing authority within the meaning of the Housing Act 1985.
• “energy conservation measures” includes information, advice, education, promotion, making grants and loans and carrying out works.
• “residential accommodation” means premises occupied or intended to be occupied as a separate dwelling and forming the whole or part of a building, or a mobile home.

In short, the Act places the duty on every housing authority to draw up a report of energy conservation measures that “the authority considers practicable, cost-effective, and likely to result in significant improvement in the energy efficiency of residential accommodation in its area.” The report must include a cost assessment of the measures listed within, an assessment of the reduction of carbon dioxide emissions resulting from the measures, and a statement of the authority’s policy regarding the effects on any one person when deciding whether or not to exercise power. The report may also include an assessment of the reductions in nitrogen oxide and sulphur dioxide emissions, an assessment of the number of jobs created by the measures, an assessment of the reductions in the cost of energy and amount of energy used, as well as any other matters the authority deems important. The report must be published and

---

submitted to the Secretary of State, who will set a timeline for implementing the plan. The Secretary will also report on the progress made by energy conservation authorities or by his or her self. He or she may also give guidance to the energy conservation authority.

The Act does not give “any power to make grants or loans, any power of entry, or any power to carry out works, or require any person to carry out works.” It also does not require any inspection of premises, not does it require any individual to provide information to an energy conservation authority. The expenses incurred under this Act will be paid out of money provided by the Parliament.153

The University of Cambridge

*The Committee for Environmental Management:* The Committee for Environmental Management advises the Environmental Officer of the University “to deliver continuous improvement in conservation of natural resources and prevention of environmental pollution by the University.” It monitors and enhances the University’s environmental management system. Some of the committee’s main objectives are:

- Ensure compliance with environmental legislation;
- Contribute to the rigorous treatment of environmental issues in the development of the Estate Plan;
- Maintain a dialogue with Heads of Department about environmental impacts arising in their Departments;
- Advise on purchasing policies, including those for buildings, equipment, utilities, services and investment;
- Liaise with the Safety Office about the reduction of and safe disposal of hazardous waste and the avoidance of pollution;
- Pursue waste minimisation, re-use and recycling;
- Promote biodiversity within the University estate;
- Ensure that the University Transport Plan reflects environmental imperatives;
- Devise effective training for staff and students;
- Exploit the environmental expertise of the University and contribute to student learning through co-operation with the Committee for Interdisciplinary Environmental Studies.
- Consult relevant student bodies, namely the Students’ Union, Graduate Union and College Green Officers, and to recognise students' environmental concerns and aspirations;
- Engage with national and local agencies involved with the protection of the environment;
- Inform the Colleges on environmental matters where relevant;
- Identify and respond to environmental issues of concern to the local community.154

---


154 Section 10.3, 1, b, is taken entirely from “Environmental Management Committee” at http://www.admin.cam.ac.uk/cam-only/committee/environment/terms
The European Union

The SEA Directive: The 2001/42/EC Directive, commonly known as the Strategic Environmental Assessment Directive, has the objective to “provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment.”

Similar goals were previously found in Environmental Impact Statements, however this directive has several important differences. The new areas of importance are an emphasis on:

- “collecting and presenting baseline environmental information
- predicting the significant environmental effects of the plan and addressing them during its preparation
- identifying strategic alternatives and their effects
- consulting the public and authorities with environmental responsibilities as part of the assessment process,
- taking into account the environmental report and the results of consultation in decision-making,
- providing information when the plan is adopted and showing how the results of the SEA have been taken into account, and
- monitoring the actual environmental effects of the plan during its implementation.”

The significance of assessment during the preparation of a plan is that in the past, when the environmental effects were assessed after a plan had been approved, the assessments often had little impact on the plan. The new Directive is intended to address this issue by requiring that assessments be used to compare and contrast alternative development strategies.

Projects requiring such plans include those for “agriculture, forestry, fisheries, energy, industry, transport, waste management, water management, telecommunications, tourism, town and country planning or land use and...which, in view of the likely effect on sites, have been determined to require an assessment.” The North West site clearly falls under the domain of this directive; however, this plan was just recently passed, and may take some time to be implemented in the U.K.*. The Office of the Deputy Prime Minister (ODPM) has some suggestions as to how the U.K. should go about integrating this directive on their website (see footnotes). Fortunately, the plans for the site have not been finalized, and the City Council may still be able to benefit from an environmental assessment at the early stages of planning.

**Greenhouse Gas Emissions Trading Scheme:** Emissions trading is designed as a way to reduce the overall level of greenhouse gas emissions in the EU and to do so in a flexible, cost-effective manner. The general concept is that a set level of emission will be determined for an installation, and any installation not using all of its allotted emissions can sell them at the market price to other installations. The EU Trading Directive lists a number of installations that are covered by this trading scheme, including:

- Energy activities
- The production and processing of ferrous materials
- The production of cement clinker or lime
- The manufacture of glass and glass fibre
- The manufacture of ceramic bricks
- The production of pulp from timber or other fibrous materials
- The manufacture of paper and board

In order for these installations to emit carbon dioxide after 1 January 2005, they must apply for a permit by 30th September 2004 (installations emitting more than 500 kilotonnes of carbon dioxide annually must have submitted their plans by 30 June 2004). In England and Wales, the applications are submitted to the Environment Agency. These permits contain “conditions that have to be complied with in respect of emissions of carbon dioxide, including monitoring and reporting requirements. Once they receive their permit they will receive an allotment (set by Defra) of carbon dioxide emissions.”

**Large Combustion Plant Directive:** The Revised Large Combustion Plants Directive (2001/80/EC) “aims to reduce acidification, ground level ozone and particles throughout Europe by controlling emissions of sulphur dioxide, nitrogen oxides, and dust (particulate matter).” New plants are given set limits for these pollutants in the directive, while existing plants may either comply with these limits or comply with a national plan. Operations falling under the domain of this directive include “combustion plants with a thermal output of greater than 50 MW,” including “plants in power stations, petroleum refineries, steelworks and other industrial processes running on solid, liquid, or gaseous fuel.” The directive is set up to mitigate a wide array of negative effects caused by these pollutants, and many of these effects might apply to the North West site. This directive, however, is included in this report mainly because it applies to the section on human health, rather than carbon dioxide, as both ozone and particulates are known to cause adverse health effects.

**The Department for Environment, Food, and Rural Affairs**

**Climate Change Levy:** The Climate Change Levy, a part of the government’s overall Climate Change Programme, is “a tax on the use of energy in industry, commerce and the public sector, with offsetting cut in employers’ National Insurance Contributions –

---


NICs – and additional support for energy efficiency schemes and renewable sources of energy.” The levy is an incentive for industries to use energy more efficiently, yet it is designed so as not to interfere with the competitiveness of the industries. This is done by returning the revenues to the non-domestic sector, “principally through a cut in the rate of employers’ National Insurance Contributions of 0.3 percentage points.” Also, £50 million per year will be given to schemes aimed at promoting energy efficiency and the use of renewable sources of energy (wind and solar power).  

The Environment Agency

*Integrated Pollution Prevention and Control:* One of the main programs under the EA is the Integrated Pollution Prevention and Control system created to follow the EU Community Directive (96/61), which is an integrated approach to regulating emissions from industrial sources. This program is an improvement over the previous Integrated Pollution Control (IPC) program as it covers a wider range of environmental impacts and sets stricter limits on emissions. The program covers England and Wales, and regulates the following types of industry:

- Energy
- Production and processing of metals
- Minerals
- Chemicals
- Waste management, including landfill sites
- Intensive agriculture
- Other (including pulps and paper production, textiles treatment, tanning, food and drink production and the intensive rearing of poultry and pigs)

All industries regulated under IPPC must apply for an IPPC permit to operate. New industries, or industries undergoing significant changes, must apply for new permits starting from 31 October 1999. All existing industries will apply in phases, on a sectoral basis, by October 2007. When applying, industries must consider all of their environmental impacts. The permit is placed in a public register, which is free to the public for viewing. The application must go through a public consultation, in which the operator is required to advertise the application in at least one local paper and in the London Gazette and the public may make comments regarding the application. After this consultation, the EA will either accept or deny the application. If a permit is granted, the EA must ensure that the following general principles are adhered to (taken directly from the organization’s website):

- All appropriate preventative measures are taken against pollution, in particular through application of Best Available Techniques (BAT).
- No significant pollution is caused.
- Waste production is avoided and where waste is produced, it is recovered. Where that is not possible it is disposed of in a way producing the least impact on the environment, if any impact is produced at all.
- Energy is used efficiently.

---

160 Section 10.3, II, b is entirely taken from “Climate Change Agreements: The Climate Change Levy” at http://www.defra.gov.uk/environment/ccl/intro.htm
• Measures are taken to avoid accidents and limit their consequences.
• Necessary Measures are taken on the closure of an installation to avoid any pollution risk and return the site to a satisfactory condition.

After receiving a permit, the operator or industry must monitor emissions regularly and supply the EA with the required data for checking compliance with the permit. In addition, the EA will regularly have independent monitoring and inspection of the operator to check compliance. If the EA finds an incidence of non-compliance, the EA may do one of the following: enforce the set emission limits, suspend or revoke the permit, levy financial penalties, or prosecute offenders.

Local Air/Authority Pollution Prevention: Another program contained within the PPC is the Local Air Pollution Prevention and Control (LAPPC). This program is for generally less polluting industries, is enforced by Local Authorities, and only regulates emissions to the air. It is similar to the IPPC and falls within the same regulatory framework. 161

Office of Gas and Electricity Markets

Sustainable Energy Act: The Sustainable Energy Act is aimed at promoting sustainable energy. The four main goals of the act are:

• Cutting carbon emissions;
• Maintaining the reliability of energy supplies;
• Promoting competitive energy markets; and
• Reducing the number of people living in fuel poverty.

The act requires the Secretary of State to take steps to achieve these goals, including reporting on the progress the U.K. is making towards these 4 goals. The Secretary must also work towards sustainable energy in the residential sector, providing “at least one energy efficiency aim for residential accommodation.” Local authorities, if they are falling behind their requirements under the Home Energy Conservation Act, may be given direction from the Secretary to take actions to “improve the energy efficiency of residential accommodation” and “to give preference to measures that would also contribute to tackling fuel poverty.” A target was set (by the Secretary) at 15% by 2010 for the amount of the government’s total energy use that comes from CHP generation. Section 6 of the Act requires Ofgem to publish assessments, including environmental impact assessments of any action which:

• Involve a major change in the activities carried out by Ofgem;
• Have a significant impact on persons engaged in the shipping, transportation or supply of gas conveyed through pipes or in the generation, transmission, distribution or supply of electricity;
• Have a significant impact on persons engaged in commercial activities connected with the shipping, transportation or supply of gas conveyed through pipes or with the generation, transmission, distribution or supply of electricity;

161 Section 10.3, II, c, is entirely taken from “Integrated Pollution Prevention and Control” at http://www.defra.gov.uk/environment/ppc/ippc.htm
• Have a significant impact on the general public in Great Britain or in a part of Great Britain; or
• Have significant effects on the environment.

This will not apply “if it appears to the Authority that the urgency of the matter makes it impracticable or inappropriate for the Authority (Ofgem) to comply with the requirements of this section.” The Act also requires Ofgem to “pay up to £60 million into the Consolidated Fund from surplus funds arising from the Non Fossil Fuel Obligation (NFFO)” and “to use this money to promote the development of renewable sources of energy.”

Department for Transport

Transport Bill: This bill, currently progressing through parliament, “imposes a duty on local transport authorities to prepare and publish a local transport plan setting out their policies for the promotion of safe, integrated, efficient and economic transport facilities in their area, and to develop a bus strategy for carrying out their bus functions.” In addition, it “provides for a statutory form of ‘Quality Partnerships schemes’ between bus operators and local transport authorities in the interests of promoting quality public transport, helping limit traffic congestion and improving air quality.” Finally, the bill enables local traffic authorities to use road user charges and workplace parking levies to reduce congestion in urban areas, and requires that the money raised through these schemes go towards improving local transport.

National Cycling Strategy: The National Cycling Strategy for the U.K. can be found at the DfT’s website. Among other things, it suggests that policy makers and planners use existing resources to create more cycle friendly spaces. Much of the implementation of this strategy will fall under the domain of local authorities. For more information visit the web site at:


Department of Trade and Industry

Although the Department of Trade and Industry is committed to the concept of sustainable development in business practices, no legislations or programs that pertain to the goals of this paper were found to be under DTI’s domain. Nevertheless, DTI may still be a stakeholder in the North West site given the nature of its organization; for example any commercial developments will likely be subject to policies of the DTI. A further review of its powers is required, and future reports in this series will more fully examine this organization.


\[163\] Section 10.3, II, e, is taken entirely from “Transport Bill: Explanatory Notes” at http://www.parliament.the-stationery-office.co.uk/pa/cm199900/cmbills/008/en/00008x--.htm

\[164\] From DfT’s website, under National Cycling Strategy
http://www.dft.gov.uk/stellent/groups/dft_susttravel/documents/page/dft_susttravel_503877.hcsp
Appendix A: Asthma

Asthma is an important non-cancer effect from the exposure to air pollution and specific pollutants, especially ground-level ozone and particulate matter. For example, a a 10 $\mu g/m^3$ increase in PM$_{10}$ concentration leads to a 3.3 percent increase in hospital admissions for asthma. It is of special concern due to the number of people it affects every year, the associated health costs, and the decreased quality of life for individuals. In order to address sustainability and human health, the occurrence of asthma due to exposure to emissions from different energy sectors must be considered during the planning and development of the North West site.

Asthma affects the airways and disrupts the movement of air in and out of the lungs. The sensitive airways can be irritated by pollutants. When the irritation occurs, the body’s immune system responds by inflaming the airways. The inflammation narrows the passages and makes it difficult for oxygen to travel to the lungs, causing difficulty in breathing. Symptoms are shortness of breath, wheezing, tightening of the chest, and overproduction of mucus. Several triggers exist to cause such reactions, and man-made pollution is one detrimental trigger; ozone and particulates are triggers of special concern due to their ubiquity.

Asthma is a growing concern in the U.K.. As of the year 2000, approximately 1.5 million children aged 2 to 15 and 1.9 million adults older than 16 have asthma. Asthma can affect people of any age, but is most likely to occur in children by the age of five, in adults during their 30’s, and in individuals over the age of 65. The International Study of Asthma and Allergies in Childhood found the U.K. to be one of the top nations with asthmatic children. The U.K. also has the highest rates in Europe for wheezing, asthma attacks, and the use of medication among young adults. In 1997, 1,584 deaths in the U.K. were due to asthma. In 1996, the U.K. experienced 85,585 hospital admissions for the treatment of asthma. England’s total cost of prescription drugs for treating asthma in 1997 was £466 million. The cost of asthma treatment has increased 34.5 percent from 1993 to 1997. The National Asthma Campaign estimates the U.K. spends in excess of £2,000 million a year on treatment of the disease; this does not include costs associated with loss of productivity in the workforce. Along with an increase in deaths, hospital admissions, and health costs, asthma produces a decrease in performance level and quality of life.

Children and adults have a demonstrated decrease in performance level. In 1995/1996, asthma was the cause of 18.3 million lost working days and cost £161 million in sickness and invalidity benefit. The number of school days missed is also significant, totalling 38 percent of children missing more than one week per year and 8 percent more than one month. About 75 percent of children reported asthma as the cause for missing school. The 1996 Health Survey for England found that of students aged 7 to 15 suffering from wheezing and asthma attacks, about 48 percent took time off of school.

---

The development of the North West site could possibly increase the emissions of pollutants associated with asthma (especially PM and the precursors of ozone, NO\textsubscript{x} and VOCs). This could have an impact on the number of asthma cases reported each year in Cambridge. The associated health costs due to asthma alone may provide enough incentive to implement policies to control emissions of pollutants (although it must be noted that this study did not examine this issue quantitatively).

In order for the North West site to be a sustainable environment, the individuals living and working there must enjoy a high quality of life and experience little adverse health impacts, calling for careful consideration of the impact of the site on asthma incidence and severity. It is important to realize that the site may either increase or decrease PM and ozone, and hence asthma, as described in the section on Transport in the present report.
Appendix B: Risk Assessment Model for the CHP

In the model, the city of Cambridge was divided into a 21x21 matrix with 500 meter (on a side) grid blocks. The origin of the grid system was within the City Centre, right next to Guild Hall. The location of the CHP facility was assumed to be in the center of the North West site, at 2500 meters North and 2500 meters West of the origin. The population of Cambridge was assumed to be 110,000 with no population growth from the development. Only average risks to individuals in Cambridge were calculated; future risk assessments will assign the location of the population within the grid to more accurately calculate the risk to specific individuals. Given the relative uniformity of risk in the population (due to the fact that fish ingestion dominates the risk), this future improvement is unlikely to significantly affect policy decisions.

The model assessed the exposure to mercury through the pathways of air, water, soil, crops, beef, and fish. The figure below shows the exposure pathways and movement of mercury through the environment. The concentrations of mercury in each of the corresponding media were calculated.

Figure B.1. The Conceptual Model

First, the source term was calculated to determine the amount of mercury emitted from the CHP facility into the atmosphere. The source term depends on the efficiency of the plant’s filter and the flow rate of mercury into the plant’s stack from the combustion chamber:

\[ ST = ST_{in} \text{ (}\mu g/s\text{)} * (1 – E) \]

where \( ST \) is the amount of mercury emitted by the plant in micrograms per second, \( ST_{in} \) is the amount of mercury flowing into the plant’s stack in micrograms per second, and \( E \) is the efficiency of the plant’s filter. The \( ST_{in} \) values changed...
depending on the type of fuel used. We calculated the source term of natural gas (0.12 μg/s), coal (0.86 μg/s), and oil (0.43 μg/s) with air filter efficiencies of 0, 0.3, and 0.6.

The mercury was assumed to be transported through the air by buoyancy, diffusion and carriage on wind currents using a Gaussian dispersion model. See Figure C2). The molecules spread out vertically and horizontally in a normal distribution as they move downwind. Wind speed and direction measurements were obtained from the Department of Environmental, Food & Rural Affairs. These data were compiled to produce a chart describing the wind rose.

Figure B. 2: The distribution of mercury in the atmosphere predicted by the dispersion model

Particles settle out of air as they are being transported. This decreases the concentration of mercury in the air, but increases the deposition onto the ground. The model followed this deposited mercury as it moved into water, soil, crops, beef and fish. Risks were calculated both to the general population and to a sensitive subpopulation assumed to eat fish caught in the Cam at popular fishing locations to the north and east, and to consume beef grazing on grass in the surrounding countryside of Cambridgeshire (within 5 km of the North West site). The resulting EXCEL-based modelling software may be obtained by contacting the authors.