TARGET ZERO
COST EFFECTIVE ROUTES TO CARBON REDUCTION
IN ASSOCIATION WITH TATA STEEL BCSA
How do we design zero carbon, steel-framed buildings? That was the question we wanted to answer in 2008 when we commissioned Aecom and Cyril Sweett to carry out this study into the routes to low and zero carbon.

The findings aren’t just limited to the steel frame. And as you will see if you read on, the choice of structural material actually has little or no impact on a building’s operational energy use and carbon emissions.

We think that you will find some of the answers surprising. We hope that you will find them useful.

Our intention is that clients and designers will use the results of this study at the feasibility stage of a project to help guide their decision-making and budget-setting in relation to energy efficiency and renewable energy targets for their buildings.

This foreword wouldn’t be complete without a gentle plug for steel: a material that is naturally recycled and re-used continuously, we believe that when whole-life impacts are fully considered, steel is the ultimate sustainable material.

Derek Tordoff
director general, BCSA
WHAT IS TARGET ZERO?

The British Constructional Steelwork Association (BCSA) and Tata Steel have just spent two-and-a-half years and £1m on a study which wasn’t primarily intended to compare steel favourably against concrete. Can that really be true?

It can and it is. The study in question is called Target Zero. Its purpose is to determine the most cost-effective combinations of materials and technologies needed to make low and zero carbon buildings a reality. Its results give clients and designers a clear steer on early decisions for the five different building types studied: schools, warehouses, supermarkets, offices and mixed-use.

“The research was about understanding the government strategy to achieve zero carbon buildings,” says Alan Todd, Tata Steel’s general manager. “Targets were being set, but there was very little guidance available to inform people about what was needed to achieve them. Without good guidance people have to make their own assumptions. In order to make correct decisions people need good information on key factors like energy and cost.”

We know government has set tough deadlines for achieving zero carbon buildings, but there’s little guidance about how to actually make it happen. Now BCSA and Tata Steel’s Target Zero study should address that.

STARTING FROM ZERO

There are major cost implications. But they don’t impact in the choice of structural frame. The work by consultants Aecom and Cyril Sweett, showed a building’s structure has almost no impact on its regulated carbon emissions. In fact it’s more important to make the right choice of lighting strategy.

“When it comes to choosing the structural material, it’s the normal decisions you should be taking: what is the best material for what you want the building to do?” The same still applies to low or zero carbon buildings,” say David Moore, BCSA’s director of engineering. “I don’t think that was clear two or three years ago.”

For most buildings, the capital cost of reaching the next level of energy efficiency required in the proposed 2013 revisions to the Building Regulations is not unreasonable. But the costings in this research demonstrate that it will get painful if the government decides on a definition of zero carbon that calls for a higher proportion of on-site low and zero carbon (LZC) technologies.

Decisions taken early on impact hugely on the possible routes to zero carbon, and on the costs, both capital and lifetime. “There are various ways of getting there, some of them cheaper than others,” says Ann Wilson, Aecom’s head of sustainability.

One striking finding across all the building types is the huge impact of lighting on a building’s carbon emissions. While many new buildings will already have high efficiency lamps and luminaires, Aecom says that further carbon savings can be identified by using thermal dynamic modelling at the very early stages of design.

Some may be surprised to read that wind turbines are a cost-effective solution for many of the building types, albeit with caveats relating to site and planning hurdles. “Wind is good in the right location,” says David Cheshire, Aecom’s project manager for Target Zero. “We are really influenced by fashion in this industry. Everyone started out saying micro wind is great. Then they decided that none of it works. We should be taking a more scientific view and look at the size of the turbine and its location.”

Most building types struggle to get anywhere close to zero carbon without...
WHAT IS ZERO CARBON?

As the government’s chief construction adviser Paul Morrell once said: “If they talk about zero carbon, they don’t mean zero and they don’t mean carbon.” Our quest towards “zero carbon” means we are trying to produce buildings that generate the little energy they require, using the low and the naturally derived sources like PV or heat pumps. However, this isn’t visible at the moment, so zero carbon has to take in other possibilities too.

At the moment embodied carbon seems like an issue for the future

2010 we are still waiting. The government has set the date for when new non-domestic buildings must be zero carbon 2019. Public buildings and schools must get there earlier: 2016 and 2016 respectively. There is a four step plan of sorts to get there: Part L of the Building Regulations was stepped up in 2010 to give, on average, 20% lower carbon emissions than the 2006 version; Part L 2013 will do the same. And then there’s a mighty leap to reach a definition of zero carbon, which is likely to include emissions from the building and also from the equipment inside it (see "What is zero carbon?, left). Aecom and Cyril Sweett also worked out the costs of achieving BREEAM ratings of "very good” "excellent" and for the first time "outstanding", which was introduced in the 2006 revision BREEAM that rates buildings against sustainability measures. This work also highlighted the most cost-effective route to go in order to achieve the various ratings, which varied markedly depending on the site of the building.

The third leg of the research looked at embodied carbon, comparing the whole life impacts of materials and in particular comparing steel with concrete and timber. At the moment embodied carbon seems like an issue for the future, small compared with a building’s emissions during operation. However, its importance will increase as operational carbon emissions decrease. This is a contentious issue. Should embodied carbon amount be limited to the energy expended to get a material or element into a building, as so-called "cradle-to-gate" calculations? Or should they encompass the energy spent in demolishing and recycling or disposal, known as "cradle-to-grave"? Steel is very much in the latter camp. Other materials with less impeccable recycling histories may diffuse.

Target Zero has answered some questions. And although no one claims the study provides absolute answers, it does inform developers and designers at the feasibility stage. The research also provides some robust methodologies for taking commercially based decisions.

<table>
<thead>
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<th>2010</th>
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<td>0%</td>
<td>20%</td>
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The government is steering building towards zero carbon via Part L of the Building Regulations which deals with the conservation of fuel and power (see diagram). The 2006 requirements were a 25% saving compared to the 2002 standards for naturally ventilated spaces, a 28% for mechanically ventilated and as conditioned. The 2010 revisions saw a further 15% reduction in average carbon emissions from buildings. In 2013, another 25% saving will be called for equivalent to 44% against 2006. After all, we’re not sure if the government will actually set a minimum level for the "white space" scenario outlined in its policy consultation document, only 20% improvement on 2006 will be called for using energy efficiently and on-site L2Cs. If they go for the challenging "on-site only" that figure dips to 10%. And the costing in Target Zero demonstrate how expensive every percentage point cost can get beyond the 40% mark, through the variations between building types.

Looking for solutions off site. There is one exception: warehouses can get there with energy efficiency measures and PV alone. When BCSA and Tata Steel commissioned the research they had yet to decide on a definition for zero carbon. In fact, despite the consultation on auto carbon non-domestic buildings ending in February 2008 for optimising building design,” says David Wilson. The research also highlighted the most cost-effective route to go in order to achieve the various ratings, which varied markedly depending on the site of the building. The third leg of the research looked at embodied carbon, comparing the whole life impacts of materials and in particular comparing steel with concrete and timber. At the moment embodied carbon seems like an issue for the future, small compared with a building’s emissions during operation. However, its importance will increase as operational carbon emissions decrease. This is a contentious issue. Should embodied carbon amount be limited to the energy expended to get a material or element into a building, as so-called "cradle-to-gate" calculations? Or should they encompass the energy spent in demolishing and recycling or disposal, known as "cradle-to-grave"? Steel is very much in the latter camp. Other materials with less impeccable recycling histories may diffuse.

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WHAT IS TARGET ZERO?

Target Zero was a government-funded research project to find the most cost-effective routes to low and zero carbon (LZC) technologies to work towards zero carbon by 2019. The project aimed to help architects and building designers develop buildings that are zero carbon: 2019. Public buildings and schools must get there earlier: 2016 and 2016 respectively. There is a four step plan of sorts to get there: Part L of the Building Regulations was stepped up in 2010 to give, on average, 20% lower carbon emissions than the 2006 version; Part L 2013 will do the same. And then there’s a mighty leap to reach a definition of zero carbon, which is likely to include emissions from the building and also from the equipment inside it (see "What is zero carbon?, left). Aecom and Cyril Sweett also worked out the costs of achieving BREEAM ratings of “very good” “excellent” and for the first time “outstanding”, which was introduced in the 2006 revision BREEAM that rates buildings against sustainability measures. This work also highlighted the most cost-effective route to go in order to achieve the various ratings, which varied markedly depending on the site of the building.

TARGET ZERO: HOW DID THEY DO IT?

The first challenge for consultant Aecom in carrying out the Target Zero research was finding the buildings. Unusually, BCSA and BCSA wanted to base the research on real buildings rather than model ones because they wanted to provide properly costed out answers for present-day developments. Adjustments had to be made to the five "typical" schemes – schools, warehouses, supermarkets, offices and mixed-use – to make some of the buildings “more typical”. The next big hurdle was deciding on the scope of the research. “Coming up with boundaries and sensible scenarios was challenging,” says Aecom’s head of sustainability Ant Wilson. The research has involved modeling and scenario-testing for Aecom and numbers rounding from Cyril Sweett, which also worked on the study. For each building type the researchers produced a report considering operational carbon (BREEAM) and embodied carbon. Three of the guides are available on the Target Zero website, with the final two due soon. All the buildings were built – and the study began – before the latest change in the Building regs Part L. So the comparative costs of energy efficiency measures and LZC technologies were taken from a 2006 Part L compliant level, as does the government’s using consultation paper on zero carbon non-domestic buildings.

Because the study looked at the design of buildings to comply with the increasing requirements of the Building regs, it used dynamic thermal modeling software based on the National Calculation Method (NCM) to compare scenarios. The researchers did note the NCM does not tell us how buildings will perform in operation: "Building models are perfect at the early stages for optimising building design," says Daniel Cheston, Aecom’s Target Zero project manager. "But in absolute terms they are not great. Many buildings are so complicated and you can’t predict what will happen once you get people inside them.”

Below: New schools must be zero carbon by 2016, see page 88

Above: The mixed-use study was based on part of the GBC’s Salford Quays development.
What does a low carbon office look like? Perhaps not too different from this one. This is One Kingdom Street, in London’s Paddington Basin, designed by Sheppard Robson for Development Securities and completed in 2008. Aecom selected it as the building on which they would base their research into the most cost-effective routes to zero carbon for city centre offices.

One Kingdom Street contained some sound energy efficiency measures: higher levels of insulation than required by the Building Regulations at the time, a ground source heat pump to provide heating and cooling, solar panels on the roof for hot water, solar shading and solar control glass and good levels of airtightness. However, for the Target Zero study, all this good stuff had to be stripped out to create a base case building that just complied with the 2006 version of Part L of the Building Regulations.

Aecom, working with Cyril Sweett, then set about selecting the most cost-effective combinations of energy efficiency measures, on-site and offsite low and zero carbon (LZC) technologies to get the base case building and its unregulated carbon emissions from sources like office equipment to zero carbon.

The results, says David Cheshire, Aecom’s project manager for Target Zero, provide guidance for clients and designers at the very early stages of design: “This research starts to show what some rules of thumb might be about what you gain by optimising elements and how far you go in terms of cost,” he says.

So what did the study find? To get the most for your money, any client looking to develop low carbon buildings must set targets for carbon reduction early on. And – critically – they must communicate the target to the whole design team. “The target must be set in stone,” says Cheshire. “If there is something written down that says ‘this is the target’, then the QS and all the other parties will work towards it.”

Hand-in-hand with target-setting comes budget-setting. “There is no point in having unreasonable expectations,” says Cheshire. “Clients can’t always have the highest standard of comfort with high energy reduction targets, at no extra cost.”

But Target Zero can help by providing some ballpark figures from which to start. And the good news from this research is that you can get a good reduction in your building’s carbon emissions – and save money over the building’s life – for very little capital cost.

“For a relatively small outlay, really just a bit more care in the design and construction, you can get an enormous improvement in energy efficiency,” says John Dowling, sustainability manager at the British Constructional Steelwork Association (BCSA) who co-sponsored the research with Tata Steel.

It may be no surprise that the lighting strategy is vital to reducing energy consumption. In the base case office, it accounted for 27% of regulated emissions. To reduce emissions, the building’s orientation should be modelled much earlier than usual, according to Ewan Jones, Aecom’s low carbon specialist. This will give pointers to the architect about the best balance between daylight and heating.

“If you can optimise the model early on, you can give proper advice to architects about the orientation and window sizes,” says Jones. “Designers don’t do it enough.” Even on a city centre site, where the orientation is likely to be fixed, thermal simulation modelling can improve early decisions.

At this point, the designer should give the electrical engineer a call. This role is often left out in the cold at the early stages of a building’s design, while the mechanical specialists put their heads together. “We need to tap into the electrical engineers’ knowledge about efficient lighting systems,” suggests Jones.

It’s then a case of balancing the budget: should it go on more insulation, more efficient services, glazing or would it be better to try other ways of achieving zero carbon?
Here are the main findings from the Target Zero study into city centre offices. They apply to the base case building, which is a modified version of the actual building:

- The increase in capital cost of designing a city centre office that conforms to last year’s changes to Part L of the Building Regulations was 0.9% compared to a building that just satisfied 2006 Part L. However, these measures would lead to a 20-year net present value saving of £1.9m.

- Lighting accounted for 27% of the base building’s carbon emissions in operation (including non-regulated emissions). Dynamic thermal modelling was used to work out the best combinations of energy-efficient lighting, glazing and solar shading.

- Heating and cooling accounted for similar amounts of energy and therefore carbon emissions, so optimising them is a balancing act.

- Achieving reductions in regulated carbon emissions significantly above 42% is technically challenging for this type of building. The options for on-site renewables are limited. So a greater reliance on offsite LZC solutions would be needed to approach true zero carbon.

- The estimated capital cost uplift of the base case office building to achieve BREEAM rating is:
  - 5% for “very good”
  - 9% for “excellent”

- The impact of the structure on the building’s emissions rate was found to be small. The building emissions rate (BER) varied by just 0.05% between a steel-frame composite and a post-tensioned concrete structure.

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This research starts to show rules of thumb about what you gain by optimising elements

measures by cost-effectiveness: 25-year net present value (NPV) per kg of CO2 saved. A fairly modest energy efficiency package which includes elements such as improving the efficiency of mechanical kit and lighting, optimising the glazing and adding active chilled beams, costs just £72,400 or 0.12% of the building’s capital cost, while reducing the building’s emissions by 42%. And over 25 years, these measures lead to a saving of £1.85m.

Keep boosting the energy efficiency measures up, however, and carbon saving becomes expensive. A more advanced energy efficiency package saves 52% of carbon emissions but attains a capital cost increase of 2.79%. And a yet more advanced set of measures saves just 3% more carbon but brings the capital uplift to 3.41%.

But if you do want to go further than the 42% achieved with modest energy efficiency improvements, Cyril Boueat’s calculations show that the best way to reduce carbon is to start looking at on-site and offsite LZC technologies.

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BREEAM tips: Seven things you need to know

By David Cheshire, Target Zero project manager, Aecom

What does it cost to get a BREEAM “very good” rating? Or “outstanding”? Or “surrounding”? The amount of course depends on the location of your new building, but also on the time the design team takes in deciding what works best.

Considering each of the five building types in the Target Zero study, we took all the available BREEAM credits, and costed all those that went over and above standard practice. We then divided the capital cost of the credits by their weighting, as assigned by BREEAM, to produce a weighted value for each credit.

This gave us a ranking of credits which we used to define the most cost-effective route for a range of scenarios, using the base case building study reports. We then took the highest BREEAM rating, but that cost too much, which meant you could theoretically end up with a building that had a high BREEAM rating but was not that energy efficient.

1 Carbon reduction costs

The latest version of BREEAM, launched in 2008, introduced the concept of minimum standards in some categories. Before then, all credits were mandatory, which meant you could theoretically end up with a building that had a high BREEAM rating but was not that energy efficient.

2 Ecology isn’t cheap

Additionally, if your building is on a rural site rather than a city centre one, it will cost you more to get the full credits relating to “Mitigating ecological impact”, £5. That is because you have to go quite a long way to mitigate the impact of the new building, before you start gaining.

3 Not all costs are BREEAM costs

When calculating the capital cost of achieving BREEAM ratings, it is tempting to look at every credit and allocate the cost of that item or element to BREEAM, making it appear costly to obtain high ratings. However, in our calculations we did not attribute costs to BREEAM if satisfied was likely to be part of standard practice anyway. For example, the average score across all sites under the Considerate Constructors Scheme is 52/60 which achieves two credits; since this is standard practice, we didn’t attach a cost to it.

4 Urban beats greenfield

If your building is on a greenfield site, you’re going to cost more to get to the higher BREEAM ratings. Urban sites tend to score more credits in the Transport (Tra) and, Land Use and Ecology (LE) sections. Conversely, if you are on a greenfield site, you can’t get those credits, so you have to go after others. In the school building for example, the researchers showed that the most cost-effective credits to go after for a greenfield site were in the Water (Wat), Materials (Mat) and Health and Well being (Hea) sections.

5 Innovation is cheap

The 2008 version of BREEAM introduced innovation credits, with any building being allowed to score up to 10. There are three ways of getting there: by meeting “exemplary performance criteria” for an existing BREEAM issue such as increasing daylight factors from 2% to 3% by the client setting a specific BREEAM performance target and appointing a BREEAM accredited professional throughout the project; and by using something new and different.

In order to have the new feature, system or process accredited, you must apply to BREEAM Global, which can decide that your take is “innovative” and award you the points. Recent examples include an energy dashboard in reception to give building users feedback on how much energy they are using and easy-clean floor surfaces to cut down on the use of environmentally harmful cleaning products.

Getting after a “true innovation credit” can sometimes be a cost-effective way of helping to secure those last few points to push you into the next rating band.

6 BREEAM experience counts

Designers with BREEAM experience are more likely to be aware of the credits which are directly achievable. For example, on the office building we identified the following credits which should be incorporated as standard practice: BREEAM Construction Scheme is 52/60 which achieves two credits; since this is standard practice, we didn’t attach a cost to it.

7 Early decisions save cash

If you’ve got an experienced team of designers on board they will be well aware of the credits which are already included in the brief. And they will save themselves money by employing consultants and a contractor who are well-versed in BREEAM.

Projects will have costings from similar projects to refer back to, which will help with early budget decisions.

And what it really costs...

The Target Zero study modelled a number of different routes that designers could take in order to obtain “very good”, “excellent” and “outstanding” BREEAM ratings. The research reports contain details of the variations in cost between the different scenarios. The table below shows the uplift costs calculated to achieve the top three BREEAM ratings for the actual case study buildings.

RATING SCHOOL INDUSTRIAL RETAIL OFFICE MIXED USE

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<tr>
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<th>SCHOOL</th>
<th>INDUSTRIAL</th>
<th>RETAIL</th>
<th>OFFICE</th>
<th>MIXED USE</th>
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<tr>
<td>Very good</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Excellent</td>
<td>0.7%</td>
<td>0.4%</td>
<td>1.8%</td>
<td>0.8%</td>
<td>1.5%</td>
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<tr>
<td>Outstanding</td>
<td>3.3%</td>
<td>3.8%</td>
<td>10.8%</td>
<td>9.8%</td>
<td>4.8%</td>
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www.targetzero.info
In the early stages of a project, it’s important to ask the right questions. And for a supermarket building trying to reduce emissions, they are likely to be about the electricity use for lighting and cooling.

Of course, the solutions are always compromises. A well-lit store is considered vital to attract buying customers, so any design decisions that impact on this element may not meet the client’s brief.

In the meantime, designers and clients need strong guidance and robust data to...
### Optimised Glazing

A key issue for a supermarket building is the positioning of the glazing. This has an impact on the risk of overheating and the requirement for artificial lighting and energy for space heating.

The optimum arrangement is to minimise east and west facing glazing as it is harder to control sunlight and heat through windows at this orientation. Toilets and storage are ideal for these rooms.

North facing rooms have low solar gain and could work well for server rooms, which will require less cooling, or offices. South facing rooms have high useful winter solar heat gain and, when shaded, low solar heat gain in summer.

For the retailer, the positioning of the building will also be governed by access, consumer patterns and the placing of the car parking. There will have to be a compromise between the best glazing strategies in relation to solar gain and the best strategy for attracting customers.

Optimising the glazing can often reduce the cost, but if additional solar shading were required, that would add to the cost.

### High-Efficiency Lamps and Lamínaires

This measure would effectively achieve a 25% carbon reduction on its own. While most retailers are aware how important lighting is and use high-efficiency lighting, they may not realise how much of the electricity bill goes on lights, unless stores have intelligent metering.

In the base case building, over 80 lights were up-rated, approximately one per store. We upgraded the mix of modular recessed luminaires and halo highbay luminaires and added high efficacy reflectors. Some fitting specifications were also improved.

When designing lighting, it is important to consider the store layout and position of the shelves. Designers should also be aware that the Building Regulations calculation method assumes one big open space, rather than one big open calculation method, as it is harder to control sunlight and heat through windows at this orientation.

### Motion Sensing Controls

This technology is routinely employed in modern supermarket buildings. It is not unusual for areas not frequented by customers. However, chiller, because of the Target Zero study did consider the energy savings that could be gained from using it in the store itself during opening hours.

Given the significance of lighting in the energy use of a typical store, this measure would contribute significantly to reducing carbon emissions and could be implemented cost-effectively. However, for retailers, bright lighting is critical in attracting customers to stores. To accept motion sensing controls would require a fundamental change of ethos and approach on their part.

The study assumed the building already included passive infrared (PIR) sensors in non-retail areas, and added two PIR sensors per aisle and one at each checkout. Together with some in the cafe and other areas, this gave 120 sensors, or about one per 47m².

### Photovoltaics

In a building with a huge roof where lighting and chillers dominate, electricity-generating PV panels make sense. With the added benefit of Feed-In Tariffs, where owners are paid for the electricity they generate, this is now a financially attractive way of reducing carbon emissions for a supermarket with a medium-term interest in the site.

The cost includes 4,000m² of amorphous type PVs integrated into the standing seam roof, with a roof area of 400m² used for the PV when the effect of offsetting the cost of standard roof panels is taken into account.

### Ventilation Efficiency

This means improving the efficiency with which air is moved around to provide ventilation and cooling. In the case of supermarkets, the report found a 20% reduction of power for supply and extract fans and four air handling units was quite achievable. Often a specification from the last similar store is used. But this exercise shows that it pays to fine-tune M&E systems. Retailers may look into this in more detail as pressures such as peak demand and carbon reduction commitments come into play.

### Reversing Cycle Air Source Heat Pump

The gas-fired boiler and chiller plant specified in the base case building were replaced with two-way heat pump units, configured to provide 5 kWkW heating output and 5 kWkW cooling. The cost takes into account additional pipework and power supplies.

Although this technology helps push the building towards lower carbon emissions, its impact is limited due to the relatively low proportion of a supermarket’s energy that is spent on heating and cooling.

### 330kW Wind Turbine

This was the largest wind turbine that we felt could be modelled on site. Obviously, the viability of a wind turbine is very site-dependant. Wind turbines should not be positioned within “turbine distance” of any occupied buildings or where they will have significant impact on residential buildings.

### Improved Chiller Efficiency

The big supermarket chains would be carrying out this sort of analysis for themselves and upgrading chillers, because of their impact on energy bills. The performance of chillers improves on almost a monthly basis and new products are constantly coming onto the market. Designers should make sure they have the very latest details from manufacturers.

In the study building, the efficiency of the chiller was increased to a SEER (Seasonal EnergyEfficiency Rating) of 6.00 by introducing air cooled chillers in lieu of direct expansion cooling to the air handling units.

Refrigeration heat recovery is a cost-effective way to provide hot water.

**Cost**

**Cost/M²**

**% OVERALL COST**

**% SAVED**

**WHOLE LIFE COST** (NPV OVER 25 YEARS)

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**Energy Efficiency**

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**Cost**

**Cost/M²**

**% OVERALL COST**

**% SAVED**

**WHOLE LIFE COST** (NPV OVER 25 YEARS)

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**Cost**

**Cost/M²**

**% OVERALL COST**

**% SAVED**

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**WHOLE LIFE COST** (NPV OVER 25 YEARS)

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**Cost**

**Cost/M²**

**% OVERALL COST**

**% SAVED**

**WHOLE LIFE COST** (NPV OVER 25 YEARS)
What is the most cost-effective option? Ultra insulation or a 50kW wind turbine?

A: The wind turbine

A lot can happen in two-and-a-half years. When the Target Zero study into the most cost-effective routes to zero carbon buildings began, no one quite knew what zero carbon would mean.

Today, plans for the UK’s first zero carbon school are well advanced. Willmott Dixon is to build a zero carbon primary school and nursery as part of the £13m Crouch Hill Community Park in Islington, London. Crouch Hill will reach its zero carbon target with energy efficiency measures and an energy centre, combining a biomass boiler and gas combined heat and power (CHP), which will share its heat with a neighbouring housing development.

For schools not in such dense urban areas, however, community CHP schemes become less viable. According to the Department for Energy and Climate Change the potential for community heating nationally, could be as high as 20% of heat demand, but that figure is likely to be lower for schools as they are generally in suburban areas.

The Target Zero study helps us understand where the most cost-effective cut-off points are. By combining energy efficiency measures and low and zero carbon (LZC) technologies, 44% savings in carbon compared with 2006 can be achieved for just 0.26% increase in capital cost. Beyond that, saving carbon really starts to eat into a school’s building budget (see diagram, p20).

“Building the work that came out of the schools study began to inform us it would be far too expensive to use only local measures in the school to achieve zero carbon,” says David Moore, director of engineering at the British Constructional Steelwork Association (BSCA), which funded the research with Tata Steel.

“It becomes prohibitively expensive even to achieve zero carbon in terms of regulated energy emissions. Zero carbon in terms of use zero is even more difficult to achieve.”

All new schools are meant to be zero carbon by 2016, so Aecom and Cyril Sweett carried out research to find some cost-effective solutions.
School designers have got a tougher challenge on their hands than ever, as the government has set the target of all new schools being zero carbon from 2016, compared with 2014 for all public buildings and 2015 for all non-domestic buildings. And zero carbon means cancelling out emissions from the building (known as “regulated”) and those from the equipment inside it (“unregulated”), which account for about 20% of a school’s total carbon emissions.

The Building Schools for the Future (BSF) programme, which aimed to build or refurbish every secondary school in the country until it fell victim to the coalition or refurbish every secondary school in the (BSF) programme, which aimed to rebuild or renovate schools, has already been under way for several years. However, the researchers discovered more cost-effective routes by combining different energy efficiency packages with various LZC technologies (see diagram, below).

The diagram shows the most cost-effective combination to achieve a 44% reduction in regulated carbon compared with 2006, which is the probable level which the 2013 revisions to Building Regulations Part L will require. To get to 70% on-site measures, which was the target set for zero carbon housing, would add 5% onto capital costs.

Air source heat pumps, a 50kW wind turbine, a PV 1,300m² array, large photovoltaics, a biomass boiler and solar thermal panels can save 27% of a school’s total carbon emissions from the building and the plant flying over there, many regarded work placement as a process chemist with targeted LCA. As a student, he landed himself a best case.”

Some would argue that it’s unfair to assume current practice for the end of life, when they were the best case.”

But there is more to life cycle assessment than “product only”, or life time.”

The Target Zero work demonstrates that targets must be flexible to accommodate the range of school locations. It does this by trying to avoid making significant corrections to the situation where it was reached by considering current practice and by setting targets beyond what is likely to be achieved by targeting carbon emissions rather than energy efficiency.

This, of course, means that there is no definitive answer to any one question. And sometimes, a fact that we have always assumed to be true may turn out to be wrong.

What the Target Zero work demonstrates is that targets must be flexible to accommodate the range of school locations. It does this by trying to avoid making significant corrections to the situation where it was reached by considering current practice and by setting targets beyond what is likely to be achieved by targeting carbon emissions rather than energy efficiency.
When it’s a power station. Slash your energy consumption with efficient lighting, says Target Zero, and the government’s feed-in tariff can turn your warehouse roof into a source of income.

When it’s a power station. Slash your energy consumption with efficient lighting, says Target Zero, and the government’s feed-in tariff can turn your warehouse roof into a source of income.

### FAST FINDINGS

Here are the main findings from the Target Zero study into warehouses:

- **Energy-efficient lighting alone can achieve the carbon reductions required between Part L of the Building Regulations 2006 and 2010, giving a 37% reduction in regulated carbon emissions.**
- **Energy efficiency measures alone are not sufficient to meet the reductions required of regulated emissions with a 4% reduction capital cost, or 9% of regulated emissions for a 3% increased capital cost.**
- **Efficient lighting systems combined with optimum rooftop design were key in delivering operational carbon reductions.**
- **Low and zero carbon (LZC) technologies providing heat were predicted to increase cost but decrease carbon emissions.**
- **Combining energy efficiency measures with either a large array of PV panels or a large (2.5MW) turbine would result in true zero carbon (including emissions from both the building and its activities). However, the use of wind farms would not have been suitable for the base case building’s site.**
- **The estimated capital cost uplift of the base case warehouse building to achieve BREEAM “very good” was 0.4% for “very good”, 0.4% for “excellent”, and 4.6% for “outstanding”.**

### Low and zero carbon (LZC) technologies

- **A large UK retailer, has an A rated Energy Performance Certificate, achieved a building emissions rate 56% lower than required by the 2006 Building Regulations and a BREEAM “excellent” rating (the highest available at that time). To create a base case building for the Target Zero calculations, the building was re-modelled, taking away energy-intensive systems as far as possible.**
- **A 17,200m2 of PV panels covering about half the roof area could produce a true zero carbon building. The capital uplift would be 37.3%, but there would be NPV savings of £3.6m over 25 years.**

### Q: Which heating method was predicted to produce the most CO2?

- Warm air blowers, due to the fan power required

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### BELOW LEFT

 Warehouses could benefit from having photovoltaic panels installed on the roof, slashing their carbon emissions. Warehouses are one of the few building types which can get there without having to resort to on-site technologies. The research showed that a combination of energy efficiency and 15,200m2 of PV panels covering about half the roof area could produce a true zero carbon building. The capital uplift would be 37.3%, but there would be NPV savings of £3.6m over 25 years. For this particular site a more cost-effective option proved to be a smaller PV array with a 330kW wind turbine. A larger turbine shared with other buildings could be better, although not feasible on all sites.
SUPERMARKETS

The Frame

It is a closer run thing when the whole building is considered, as much of the embodied carbon of any building is found in the foundations and floor slabs. The total embodied carbon in the glulam building is 2.1% more than the steel framed one.

These findings create a conundrum for supermarkets. The most important thing for a supermarket’s profitability and financial sustainability is to keep the customer coming. And if shoppers perceive timber to be unsuitable, that perception has a value.

“If they are looking for a commercial argument for glulam, they may be one,” concludes Roger Potts, a consultant with BCSA. “But if they are looking for a technically sound argument about embodied carbon, there isn’t one.”

The second age of steel

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The estimated capital cost uplift of the base case supermarket building to achieve BREEAM ‘outstanding’ was 2.1% more than the steel-framed option.

The research showed that it is possible to achieve a zero carbon supermarket by using energy efficiency measures and on-site low and zero carbon 3.2GW technologies. However, this would incur a capital uplift of 3.7% and require a 3.5MW wind turbine and a bio-gas fired combined cooling heat and power (CCHP) system, neither of which would work on most sites.

The estimated capital cost uplift of the base case supermarket building to achieve BREEAM ‘outstanding’ was 2.1% more than the steel-framed option. However, smaller pile caps mean that the floor slab has to be hobbled up to span the longer distances. That was the case on the supermarket study, where the cost difference between steel and concrete piles was much closer.

But what about the noise of installation? Technology could be about to wipe out contractors’ perceived advantage, and machines now exist that can push a number of steel piles into the ground using hydraulic rams.

The combination of cost savings, sustainability and advancing technology can start to make designers think again about steel bearing piles.

Above: Target Zero showed that steel-framed supermarkets and eco-stores with glulam have very similar embodied energy.

G

Gulam beams are becoming a prominent feature in some new “eco-stores”, with Tesco citing timber’s lower embodied carbon as the reason for their inclusion in the “most energy-efficient ever supermarket” which opened in Manchester in 2009.

As part of the Target Zero study, glulam’s embodied carbon credentials were tested. Aecom took the study building – Asda’s food stores in Stockton-on-Tees – and replaced its steel frame with a glulam one, a move which cost 2.4% onto the capital cost of the building.

Here are the main findings from the Target Zero study into supermarkets. They apply to the base case building, a modified version of the actual building.

- Building energy efficiency measures to upgrade a 2006 base case supermarket to BREEAM ‘outstanding’ saved 0.5% of the capital cost, 5% of carbon and £623,545 NPV over 25 years.
- Saving more carbon through lawnground energy efficiency measures further attracted higher capital costs of 0.8%, to save 9%, 1% of carbon, compared with the steel frame and 0.3% to save 5%. Both packages saved money over 25 years, the second one less so.
- Glulam’s embodied carbon is 2.1% more than the steel-framed option.
- The research showed that it is possible to achieve a zero carbon supermarket by using energy efficiency measures and on-site low and zero carbon 3.2GW technologies. However, this would incur a capital uplift of 3.3% and require a 3.5MW wind turbine and a bio-gas fired combined cooling heat and power (CCHP) system, neither of which would work on most sites.
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The combination of cost savings, sustainability and advancing technology can start to make designers think again about steel bearing piles.
The articles in this supplement have only touched on some of the findings from the Target Zero research. The first three guidance reports, below, can be downloaded and read free-of-charge from the Target Zero website, www.targetzero.info, now. The two others will be available shortly and you can pre-register to receive them.

**SCHOOLS**
The first Target Zero guidance report on a secondary school building was based on Christ the King Centre for Learning in Knowsley, Merseyside, built by Balfour Beatty under the Building Schools for the Future programme and opened in January 2009. Occupied by 900 pupils and 50 staff, the 9,637m² steel framed building is based on a 9m by 9m structural grid. The depth of the classrooms, which was a requirement of the local authority, means that mechanical ventilation is required.

**WAREHOUSES**
The warehouse study is based on the 34,000m² DC3 distribution warehouse at Prologis Park, Stoke, which was completed in December 2007 and is currently leased by a large UK retailer. The four span steel portal frame warehouse is attached to a two-storey office wing, providing 1,400m² of space. This report was written before the government introduced its feed-in tariffs for renewable energy sources in April 2010. A revised report taking the tariff into account will be published on the website shortly.

**OFFICES**
The building on which the office research is based is One Kingdom Street, near Paddington in central London, which Development Securities completed in 2008. Providing 24,890m² of open-plan office space over 10 floors, the building was designed to achieve the maximum floor plate depth in line with British Council of Offices guidance. The building has a steel structure, on a typical 12m x 10.5m grid, comprising fabricated cellular steel beams supporting a lightweight concrete slab on a profiled steel deck.

**SUPERMARKETS**
The base case building for the supermarket report is based on Asda’s food store at Stockton-on-Tees in Cleveland, completed in May 2008. The building has a floor area of 9,950m² over two levels. The retail floor area, including a 1,910m² mezzanine level, is 5,731m². The remaining (back-of-house) accommodation comprises offices, warehousing, cold storage, a bakery and a staff canteen.

**MIXED-USE**
The mixed-use building is based on a tower block on the Salford Quays, part of a much larger scheme which will house the BBC, incorporating three buildings and a new studio complex providing 70,000m² offices, 25,000m² studios, 6,000m² retail and leisure and two residential blocks of apartments. The block used for the study is attached to the main studio building and made up of office space in its lower half and a hotel above.

**TALK TO US ...**
The experts who worked on the Target Zero guidance reports are available to answer your questions. To benefit from this free service, please contact us on the Target Zero information line. Alternatively, if you have a training requirement or would like to know more about the Target Zero project, our experts are also available to deliver in-house presentations.

**HAVE FUN ...**
... why not visit the website anyway? As well as containing the guidance reports, newsletters and information on legislation related to zero carbon, you can play the Target Zero Turbine Challenge. Can you keep the wind at the optimum level to keep your three turbines turning and carbon emissions down?

Call or email us for further details or advice on the Target Zero project information line: 01709 825 544 email: info@targetzero.info
ON TARGET TO BECOMING CARBON FREE

The 'Target Zero' project is a free resource that will provide designers, architects and engineers with the guidance they need to meet the emissions reduction target set by government of zero carbon by 2019.

www.targetzero.info