DESIGNING FOR NATURAL CAPITAL:

Understanding and communicating the natural capital benefits of built asset design improvements

Prepared by Trucost

SEPTEMBER 2016

CREDITS

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ABOUT TRUCOST

Trucost helps companies and investors to achieve success by understanding environmental issues in business terms. Our data-driven insights enable organizations to manage risks and identify opportunities for growth.

We are the world's leading experts in quantifying and valuing the environmental impacts of operations, supply chains, products and financial assets. By putting a monetary value on pollution and resource use, we integrate natural capital into business and investment decisions.

With offices in Europe, the US and Asia, Trucost works with businesses worldwide to increase revenues, improve communications, meet marketplace expectations and comply with regulatory requirements.

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EXECUTIVE SUMMARY

Sir Robert M^{c}Alpine, a British construction company, and Hammerson plc, a major owner, manager and developer of retail property, jointly commissioned Trucost to undertake a net impact assessment of two development project sites. Both companies strive to minimise impacts on the environment through collaborative approaches to design new assets using green technologies, resource efficiency, and where possible, renewable or efficient energy – either onsite or through responsible procurement.

The two sites assessed in the report are:

- Brent Cross, London: A natural gas fired combined heat and power (CHP) energy centre
- WestQuay Watermark, Southampton: Photovoltaic panels generating electricity to power energy efficient lighting

This assessment quantifies the environmental impacts associated with the activities of the two sites, including supply chain, use and disposal, compared to a business-as-usual baseline over a 15 and 10-year lifetime. For each activity, Trucost considers the most important environmental key performance indicators (eKPIs) including greenhouse gases (GHGs), air pollution, human and eco-toxicity and water consumption. It uses a combination of primary and secondary data sources to quantify each impact.

Trucost placed a monetary value on each impact including both the new technologies and the baselines. This represents the external non-marketed costs (externalities) that would need to be paid for the impacts caused and the services nature provides that enable companies to produce and distribute their products and services. Sir Robert M^{c}Alpine and Hammerson can benefit from using monetisation of externalities to identify potential business risk in the future. Increasingly, these externalities are being internalised by business through environmental taxes, penalties, as well as less tangible factors such as reputational risk. In particular, supply chain vulnerabilities can be identified and these may create operational challenges and increased cost of supply in future developments.

The Brent Cross site was modelled using available data on the planned energy centre that will provide heat and energy to local residents, retail and other non-residential organisations in the vicinity. CHP is a more efficient means of energy production than many conventional power plants, as the heat that would typically be lost to the environment is captured and utilised.

In the UK, electricity is increasingly produced from renewable sources as part of the commitment to reduce GHG emissions by at least 80% compared with 1990 levels by 2050. It is therefore likely that the GHG emission factors of the UK electricity grid will change over the course of the modelled period. To account for this, the Brent Cross CHP was compared to both scenario forecasting from the Department for Energy and Climate Change (DECC), as well as known capacity generation planning, to determine potential lifetime implications of the technology. Based on the conservative decarbonisation scenario, CHP offers a 20% lower natural capital cost when including construction, installation, operation and disposal of CHP technologies[1]. The avoided natural capital cost of CHP over a 15-year life expectancy of the technology is £2.6 million. However, as the grid becomes increasingly decarbonised, the benefit reduces, and after 15 years the net benefit is significantly reduced. After 15 years, transition towards non-fossil fuel based feedstock for CHP is recommended.

The assessment identified that through the use of onsite solar generation of electricity, the WestQuay Watermark retail site has a potential reduced natural capital cost of £53,000 in a 10-year project life, or 93% of the total natural capital costs were the electricity to be supplied from the National Grid[2]. If the site were to be powered using electricity sourced using a green tariff (using an electricity supplier and selecting renewable energy electricity supply), the use of onsite solar generation still provides over £11,000 of avoided natural capital cost.

The natural capital cost of the production, use and disposal of lighting was also calculated, comparing scenarios of energy efficient lighting with electricity from the National Grid, onsite PV generation, and renewable energy tariff, alongside the use of business-as-usual lighting, in which standard lighting such as T5 lights and compact fluorescent lamps (CFLs) were modelled for impacts. Through the use of energy efficient lighting, production costs were significantly reduced, with project lighting replaced 10-25 times less frequently than conventional lighting. As a result, the project site with efficient lighting and PV over a 10-year life expectancy provides £48,300 reduction in natural capital costs over 10 years.

Table 1 displays the natural capital costs of one unit of energy, as assessed in the different scenarios within the report.

Energy scenario	Natural capital cost of energy supply (p/kWh)
Grid (current)	5.4
Grid (forecast[3])	3.01
Purchase of green electricity	0.90
Natural gas fired CHP (average thermal and electric energy)	2.41
Onsite PV	0.20

Table 1: Comparative natural capital costs of energy produced in different scenarios

Current grid impacts have the greatest natural capital cost, though this is reduced by 44% when considering the decarbonisation forecast for the UK national grid over the next 10 years. Onsite PV has the lowest natural

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[1] Including CHP engines, boilers and pipes, but excluding building to house energy centre.

[2] Accounting for forecast decarbonisation – if taken as current grid mix, the avoided natural capital cost is £89,000

[3] Average cost per unit over 10-year forecast

capital cost of all scenarios, with energy generation over its lifetime compensating for the impacts associated with manufacture of equipment.

Quantifying the reduced environmental costs achieved by different technologies, as well as trade-offs over developing efficiencies demonstrates how Sir Robert M^{c}Alpine and Hammerson can continue to improve whole-life performance of assets. Analysing the long-term environmental implications of key items of infrastructure early in the design phase will support more informed decision-making and lead to better outcomes, reducing both environmental damage and business risk.

INTRODUCTION

ENVIRONMENTAL IMPACT OF BUILT ASSETS

The built environment is necessary for business and society to function, creating work environments, leisure facilities, healthcare institutions and housing. However, construction is considered to be one of the most resource-hungry and least sustainable industries in the world (University Alliance, 2015). Buildings are responsible for more than 30% of global GHG emissions. If current trends continue, CO_2 emissions caused by the sector are expected to increase by 70% by 2050 and energy consumption will double (UNEP, 2015). In addition, construction uses valuable resources. Equipment installed in buildings such as air conditioning and lighting are associated with natural capital impacts across their lifecycles, including through their manufacture and use.

The sector is the focus of much regulation and public scrutiny, and clients are increasingly striving to reduce exposure to bad publicity due to environmental impacts. Poor management of sustainability issues has the potential to affect company valuation through impacts on profits, assets, liabilities and cost of capital (SASB, 2016). The construction of new assets provides an important opportunity to improve asset performance over a comparatively long product lifecycle. This can be influenced by decisions to select, for example, sustainable materials, efficient mechanical and electrical equipment, good asset design and onsite renewable energy production.

THE CONSTRUCTION SECTOR'S ROLE IN MEETING THE TWO DEGREE TARGET

Globally, a reduction of 3 gigatons of GHG emissions per year is needed by 2030 to keep global temperature increases within 2 degrees Celsius (State of Greenbiz, 2016). According to UNEP, the construction sector offers one of the most cost-effective and economically beneficial paths for reducing energy demand and associated emissions while at the same time supporting adaptation and resilience to climate change (UNEP, 2015). However, this trend has yet to be established.

Design of new assets offers significant opportunity to reduce building emissions through introducing efficiencies in energy requirements over the long life of the asset. This includes optimising building design for minimised heating and lighting requirements – for example, using natural lighting and appropriate insulation. Legislation is in place to help ensure energy performance of buildings is optimised. Under the Energy Performance of Buildings Directive, all new buildings must use nearly zero energy by 2020 (EC, 2016).

In addition, built assets also have an impact due to the resources used to produce them. Raw materials that form the basis of the built world can be hugely energy and carbon intensive, such as steel and cement. Through the use of alternative materials (where they are structurally and functionally appropriate), resource efficiency in design, and recovery and reuse or recycling at end-of-use, the sector can further reduce its indirect carbon impact.

THE PROJECT SITES

The objective of this research is to understand, quantify and monetise the net impact (positive or negative) of energy efficiency and renewable energy installations at the new Watermark development at the WestQuay shopping centre and the proposed Brent Cross shopping centre extension, using natural capital valuation. The two sites were selected as examples of built asset design for reduced energy consumption and efficiency improvement.

The research considers the supply chain, installation, use and disposal of equipment at the sites.

The following sections detail the project scope and boundaries for each of the sites.

Brent Cross shopping centre, London

Brent Cross shopping centre is located in north London, hosting over 140 shops and over 2,000 brands. As part of an energy strategy for the new Brent Cross Cricklewood Development, Hammerson has been working with partners to install a natural gas fired combined heat and power (CHP) plant to provide energy and heat to local businesses, residents and other non-domestic organisations.

The energy centre of Brent Cross Cricklewood responds to the ‘Lean, Clean, Green’ energy hierarchy as set out in the Greater London Authority ‘London Plan’ to minimise energy demand and carbon emissions. The development will be served by an energy centre proposed on the Southern site, with a Phase 1 energy centre provided on the Northern site. The specifics of each site and phase of development are detailed in the table below:

Equipment	Phase 1	Phase 2
CHP Engines	1 x 2,000 kW gas fired CHP Engine	2 x 2,400 kW gas fired CHP Engines 1 x 1,400 kW gas fired CHP Engine
Gas boilers	3x 8,000 kW Natural Gas Boilers	5 x 10,500 kW Natural Gas Boilers
Thermal store	1 x 100m^3 Thermal Store	2 x 750m^3 Thermal Stores
Other	5,085m district heat piping length	14,650m district heat piping length

Table 2: Energy centre equipment installations planned for Brent Cross Cricklewood Development

To determine the benefit of the installation and use of a gas fired CHP plant, impacts were calculated and compared with impacts associated with UK national grid emissions for electricity use, and individual mix of fuel types for heat provision, largely natural gas, fuel oil and electricity.

WestQuay Watermark shopping centre, Southampton

WestQuay Watermark is situated adjacent to the WestQuay Shopping Centre in Southampton. The existing shopping centre is co-owned and managed by Hammerson, and sustainability was a key aspect of its development and design. Alongside initiatives such as environmental lease provisions (requirement for tenants to sign and commit to on leasing), water efficiency, low-use drainage systems and use of recycled content in construction materials, the site is installing energy efficient lighting and photovoltaic panels on the roof. It is this lighting system and onsite energy generation that is the subject of this research to determine the net natural capital impact compared with the baseline. Two baseline scenarios are considered – use of the UK national grid to power conventional lighting on the site, and purchase of renewable electricity through the Smartest Energy Renewable Energy Commitment (a 'green' tariff used to supply electricity at some other Hammerson sites).

NATURAL CAPITAL QUANTIFICATION

Together, SRM and Hammerson engaged with their supply chains across both sites to collect site specific input data regarding technologies, installation requirements and equipment, as well as output data such as expected annual energy production (AEP).

The most important environmental impacts focused on for analysis include:

- **GHG emissions:** from fossil fuel combustion for energy generation, both onsite and in the manufacture of equipment procured
- **Air pollution:** including ammonia (NH_3), nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOCs) and particulate matter (PM)
- **Human and eco-toxicity:** associated with the chemical outputs of energy generation and supply chain of equipment
- **Water use**: in the supply chain of equipment and conventional energy generation

Secondary data sources such as lifecycle assessments (LCAs) were used to determine the impacts of physical indicators (such as kilowatt-hours of electricity, kilograms of waste or litres of water) in terms of change in natural capital. As an example, 1kWh of electricity used onsite purchased from conventional sources such as the national grid, will cause upstream emissions of GHGs at the source power plants. When GHGs are released, the different types of gases[4] have different abilities to trap heat, known as global warming potential. This GWP results in climate change, which impacts sea levels, crop yields and human health among others. These impacts are valued in monetary terms (see Figure 1).

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[4] GHGs include various gases that contribute to global warming including methane, carbon dioxide, hydrofluorocarbons and nitrous oxide (N_2O).

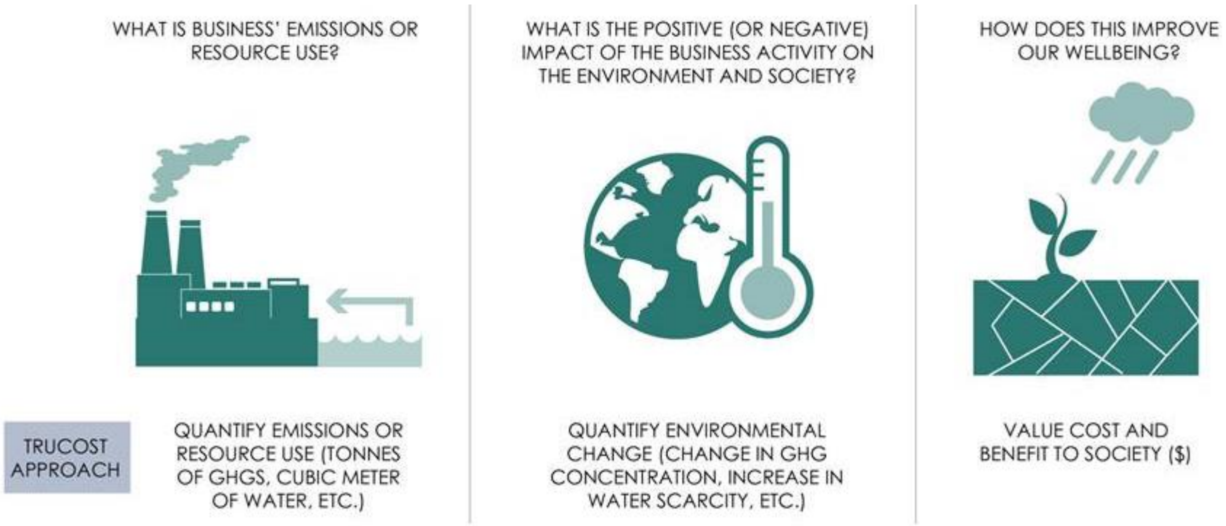


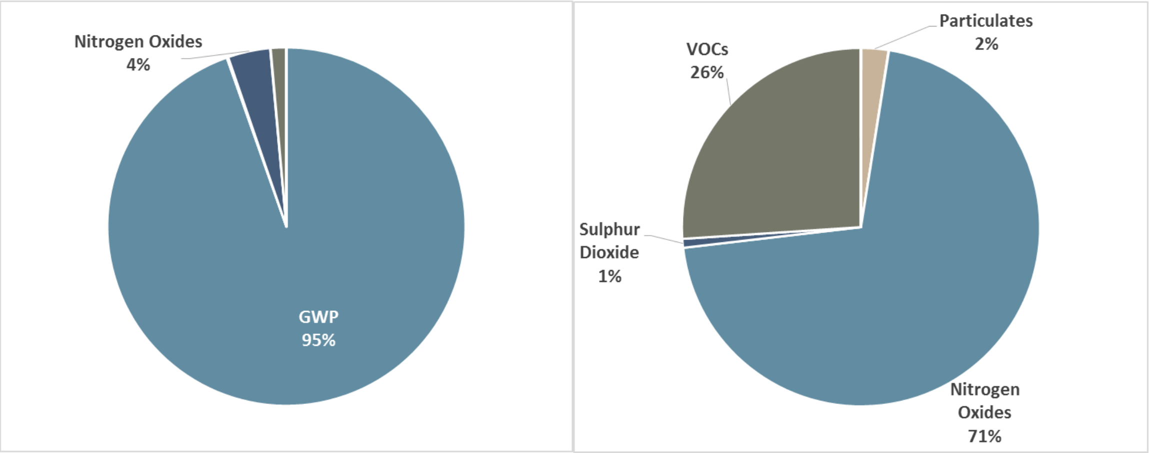
Figure 1: Natural capital quantification approach

The detailed methodology is provided in the Appendices.

RESULTS

COMBINED HEAT AND POWER AT BRENT CROSS

The most significant impact associated with the operation of gas fired CHP is GHG emissions, in particular CO_2 and methane, evidenced through the GWP. Figure 2 below shows GWP dominates impacts at 95%.



Figures 2 & 3: Proportion of natural capital impact associated with each eKPI for CHP operation, and excluding GWP on the right

Nitrogen oxides account for 4% of natural capital costs. Other air emissions are evidenced but these all account for approximately 1% of the total. While air pollution only accounts for 4.5% of total natural capital costs for the operation of the CHP, these have a more localised effect than GHG emissions, and therefore the Figure 3 shows the composition of non-GHG air pollutants. Sulphur dioxide (SO_2) is often raised as a concern when discussing CHP plants, and this is evidenced for some CHP plants, but natural gas fuelled plants do not emit this pollutant, unlike other fuel sources (DECC, 2008).

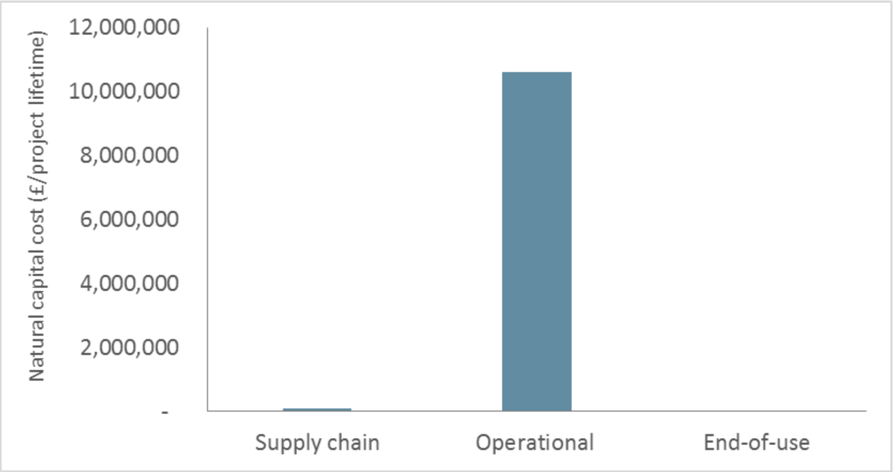


Figure 4: Environmental footprint of Brent Cross CHP by lifecycle phase

Over a 15-year project lifetime, the impacts are dominated by the combustion of natural gas to produce heat and electricity in the use phase.

Baseline heat and energy production

According to a report prepared by Buro Happold Engineering (2015), demand for heat comes from a mix of commercial, healthcare, leisure and residential properties. Should the CHP plant not be developed, a baseline comparison of typical provision to the various users (detailed in the Appendix) was analysed, based on standard fuel use in UK, which is predominantly natural gas and grid electricity, based on forecasts of the grid mix[5].

The project operates over two phases, as detailed in Table 2. The impact per unit of energy is compared for Phase 1 in Figure 4 below. This shows an average of 0.45p per kWh of natural capital cost reduction, equivalent to 20%. This equates to a significant saving when considering the 29,600 MWh produced in Phase 1 per year, delivering a net benefit of almost £180,000 per year in natural capital cost reductions for the whole site.

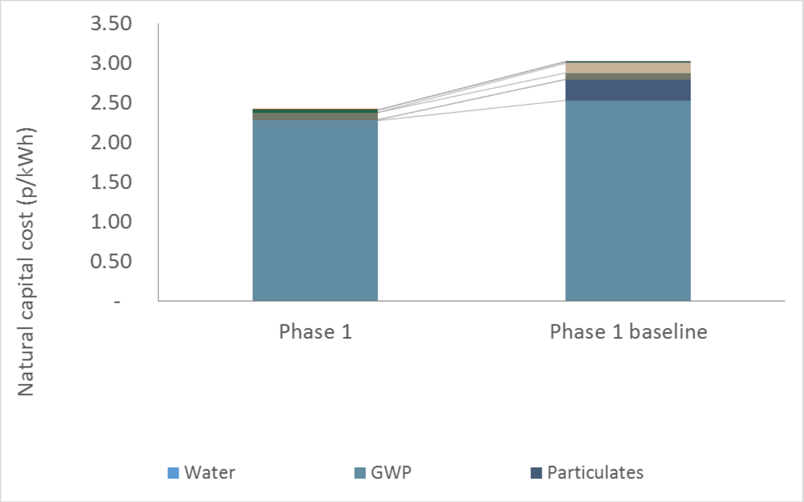


Figure 4: Natural capital impact comparison of Brent Cross CHP and UK baseline heat and electricity, per unit of energy

As the development will be utilised for many years, UK electricity grid emissions are forecast to 2035 to allow for the predicted decarbonisation trends. Two sources of forecast mapping were used: the DECC energy forecast and private company data mapping of the predicted installations of new, current and planned decomissioned power plants in the UK. Average emission factors per MWh were considered and compared to the 'average' emission factor for CHP generation (normalising the construction and disposal impacts over the entire lifecycle of the system).

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[5] Forecasting detail provided overleaf

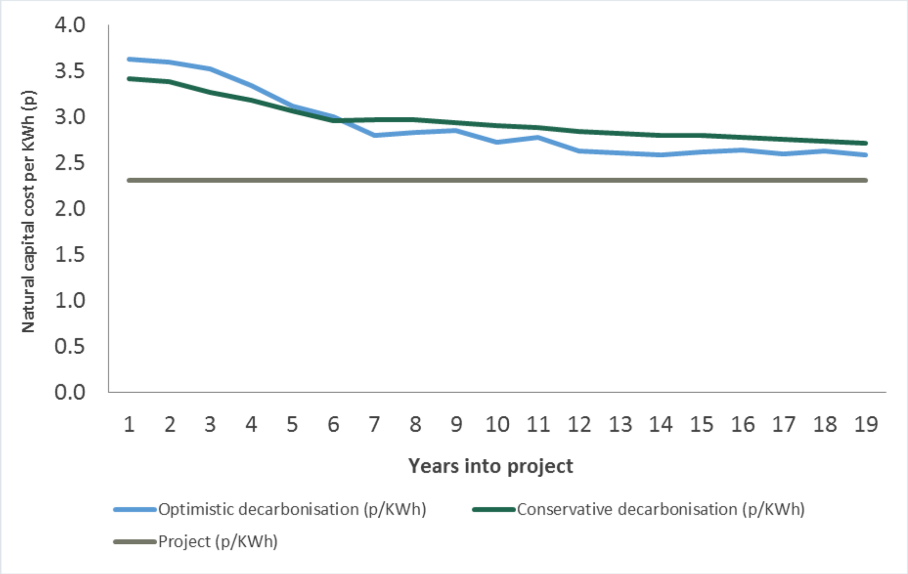

Figure 5: Natural capital costs of optimistic and conservative energy generation, and CHP system over the lifetime of the project, per MWh

This shows that natural gas fired CHP offers a greater benefit now than in future years, as the grid is expected to decarbonise. In year one of operation, the system shows a 36% benefit compared to estimated grid emmission factors, but this decreases steadily down to 11% in 15 years time (at the end of the CHP engine life expectancy).This provides a combined 20% benefit over the project lifetime. However, if the system is operated beyond that point, it is estimated that the benefit would soon disappear. While CHP offers improved efficiency due to co-generation of heat and electricity, the Brent Cross project still uses natural gas, a fossil fuel, resulting in GHG and other air pollutant emissions. Replacing it with a renewable energy technology at the end of its life would remove this problem.

Figure 4 above shows the impact of the CHP plant ‘Phase 1’ compared to the UK grid and heat forecast baseline across all users. However, for Hammerson, the retail site is the focus for natural capital assessment. Figure 6 below shows impacts associated with the retail allocation. The benefit to retail is allocated based on the proportion of energy demand, including both electricity and heat. While the site uses a very small proportion of the heat energy generated, it is not considered appropriate to disaggregate these two elements of generation as the benefit of CHP is a result of co-generation, and therefore the combined allocation is a more appropriate method of calculation. For Phase 1 of the project, the average natural capital cost savings are £670,000, or £45,000 per year.

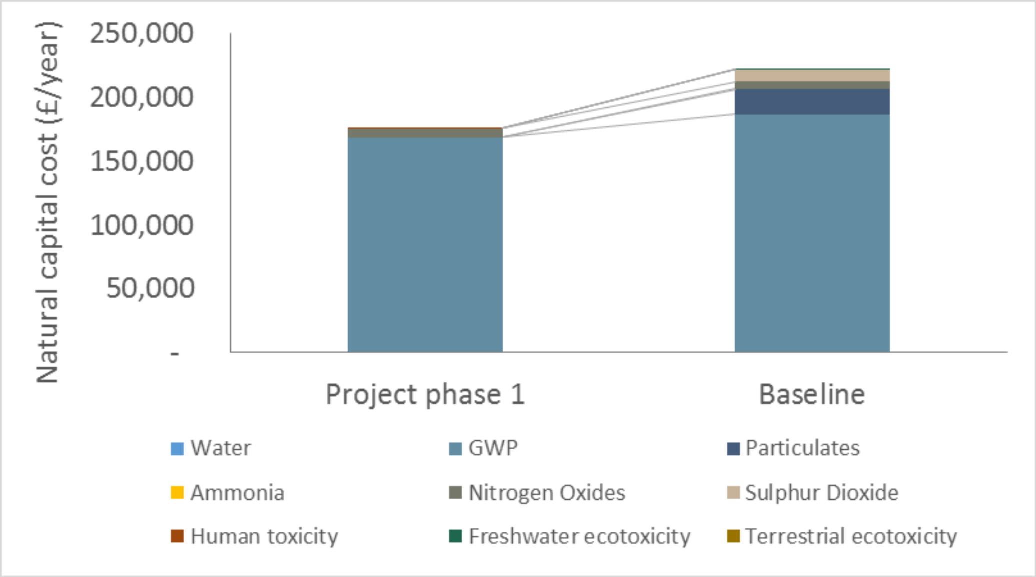

Figure 6: Natural capital impact comparison of Brent Cross CHP and UK baseline heat and electricity, allocated to retail per average year

Phase 2 of the project is larger than Phase 1, using three individual CHP engines and a generating capacity of 8,120 MWh for the retail site. This offers £168,000 of reduced natural capital cost associated with retail compared to the baseline heat and electricity. Over a 15-year expected lifetime of the CHP boilers, this equates to over £2.5 million in natural capital reduction.

Comprehensive cost benefit analysis is not included within the research, but a simplified financial cost comparison was undertaken for electricity and heat produced by the Phase 1 Brent Cross CHP plant compared to the equivalent sourcing of electricity from the grid. The following calculations are highly indicative and should be used as reference only.

Based on capital expenditure on CHP engines provided by Hammerson alongside fuel costs estimations using DECC forecast price estimations (2015), a simple Internal Rate of Return (IRR) can be calculated. In financial terms, the savings derived from using a CHP engine payback the additional upfront investment after three years and gives a very worthwhile IRR of 36% over the 15 year CHP engine life. If the natural capital costs and benefits of the system are also incorporated, pay back of the system still takes three years, but the IRR improves further to 45%.

PHOTOVOLTAIC INSTALLATION AND ENERGY EFFICIENT LIGHTING AT WESTQUAY WATERMARK

The natural capital assessment of the WestQuay Watermark site comprises two aspects of improved technology: photovoltaics (PV) installed on the rooftop to provide electricity onsite and energy efficient lighting within the complex itself.

Photovoltaic comparison to alternative electricity sources

The total installation of PV at the WestQuay Watermark site is 180 kilowatt peak (kWp), with a total area of approximately 1,100m^2 of panels. Energy production from PV depends on the level of solar irradiation hitting the panels. The annual energy production (AEP) was estimated as 173,600 kWh per year. This was tested using calculations detailed in the Appendix based on product specifications and meteorological data. The figures were within 97% of each other, demonstrating confidence in their use.

The most significant impact associated with the supply, installation, operation and disposal of the PV panels is GHG emissions at 86% of the natural capital cost. This is largely associated with the manufacture of the PV panels.

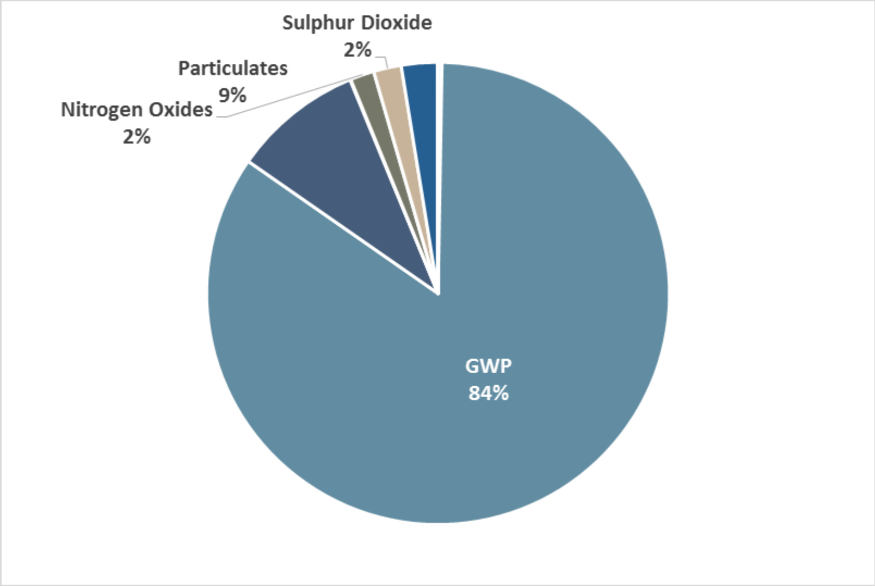

Figure 7: Proportion of natural capital impact associated with each eKPI for photovoltaics installed at WestQuay Watermark

Particulate matter is the second most impactful eKPI, though sulphur dioxide and nitrous oxides are also important albeit in a smaller volume.

Operation and disposal of PV has minimal impact compared with the manufacture of panels, as shown in Figure 8.

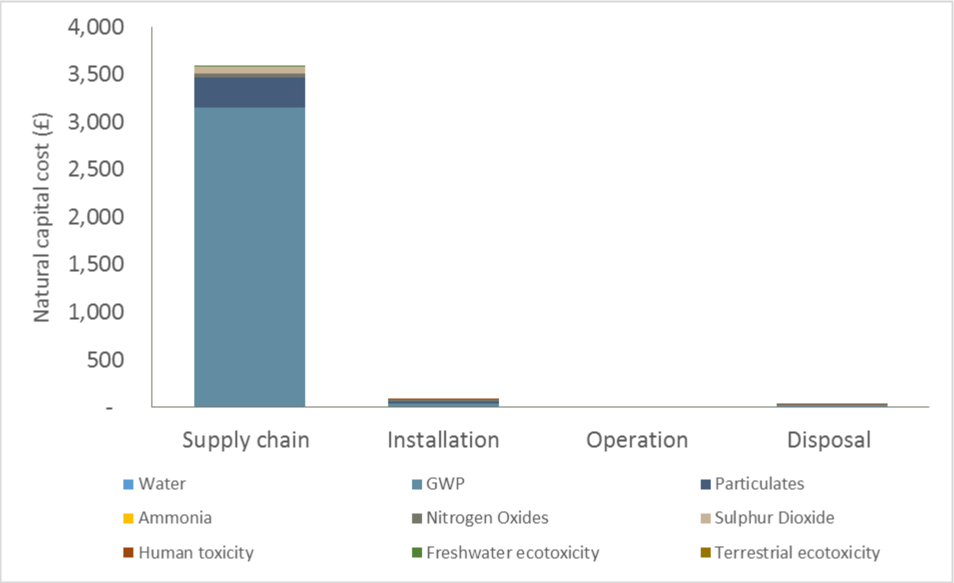

Figure 8: Environmental footprint of photovoltaics by lifecycle phase, based on a 10-year project life

The supply chain impacts occur at the initial stage of manufacture, and the PV panels are then used for an estimated life expectancy of 25 years. The electricity generated by the PV is estimated to be 173,600 kWh per year, and if the system were not installed, the site would need to source the energy from elsewhere. If supply chain impacts are allocated per unit of energy generated in that lifetime, then comparison can be made to units of electricity from these other sources to determine the optimum choice for natural capital implications.

Four scenarios were evaluated:

- Generation of electricity using onsite PV
- 'Business as usual' – UK grid based on current emissions
- Purchase of renewable electricity through a 'green tariff'[6]
- UK grid forecast – considering the potential decarbonisation trends predicted (as per the Brent Cross forecast)

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[6] Hammerson provided the green tariff used at other retail sites. Emission factors were calculated based on energy provider disclosure.

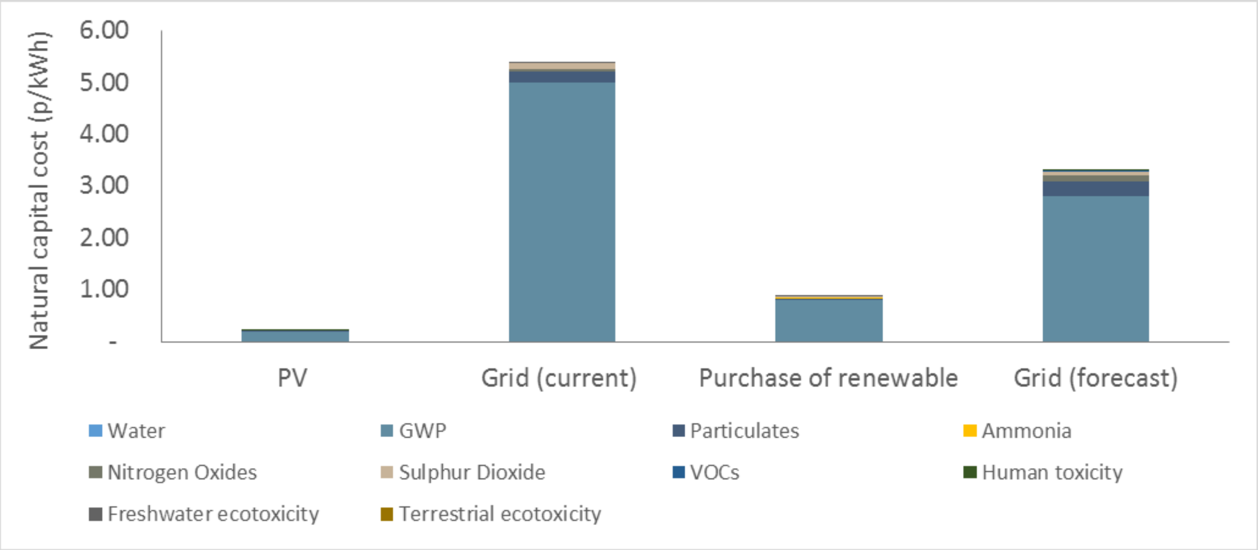


Figure 9: Natural capital cost comparison of different electricity sourcing at WestQuay Watermark, per kWh

Use of PV onsite has 93% less natural capital cost per unit of electricity than the forecast grid supply, equating to £53,000 of avoided natural capital cost over the project lifetime. Purchase of renewable electricity through a green tariff has 73% lower natural capital cost than forecast grid. Recent developments in the reporting of electricity grid emissions considers not only the total emission factor, but also the residual emission factor. According to Reliable Disclosure Systems for Europe, a country's residual mix represents the shares of electricity generation attributes available for disclosure after the use of explicit tracking systems, such as guarantees of origin, has been accounted for (Reliable Disclosure Systems for Europe, 2015). This excludes any obligations, renewable energy certificates or other contracts used to buy renewable energy from the grid, to avoid double counting. In real terms for the UK, this increases the emission factor associated with the national grid electricity as it excludes a proportion of renewable generation under contractual instruments. Data was not identified to assess the full natural capital cost of the residual mix of the UK, though carbon emissions are available for 2014. These are 10% greater than the standard grid emissions of the same year (542g CO_2e/kWh and 494g CO_2e/kWh respectively) (Defra, 2015 and Reliable Disclosure Systems for Europe, 2015).

In 2014, approximately half of European electricity produced from renewable energy sources was tracked through obligations. This could potentially increase further as a proportion (even while renewable energy generation increases) as consumers require evidence of the source of renewable energy procurement. In impact terms, this would result in sourcing of electricity without a renewable contractual agreement being linked to increased emissions in the future. This is important when designing energy supply at a site, as it may be outside of the control of Hammerson as to what external electricity supplier is used, therefore impacts could be significantly worse than forecast should tenants choose to source electricity without a green tariff.

Energy efficient lighting

The electricity generated by the photovoltaics will be used across the new site, but in particular, assessment of the joint benefit of energy efficient lighting installations alongside onsite renewable energy generation was sought.

Energy efficient lighting installed at the site includes several types of fixture, therefore the impact assessment required a simplification of lighting to LED, halogen and compact fluorescent lamps (CFLs). Details such as lamp life hours, electricity consumption and life expectancy were taken from a detailed assessment of lighting installed at the High Cross Shopping Centre – a similar style of installation, with comparable lighting types. Specific numbers of fixtures and lighting types were based on actual site data. Energy efficient lighting was found to have a twofold benefit – the life expectancy of each unit is longer than conventional lighting (up to 25 times longer, depending on the specific lighting type), and a reduced consumption of electricity per hour.

Table 3 shows the difference in number of replacements required during the 10-year project life, with less than 10% of the total number of changes required, and a reduction of 59% of electricity required to power the lights.

Equipment	Total number of units required	Total electricity consumption of units (kWh)
Energy efficient lighting	1,400	226,000
Conventional lighting(baseline)	18,000	560,000
Difference	92%	59%

Table 3. Comparison of conventional and energy efficient lighting at the WestQuay Watermark site, over a 10-year timeframe

The impact of the supply, use and disposal of lighting over its lifetime (based on the assumption of using the PV installed onsite to power the bulbs) is most significantly associated with GHG emissions, largely from the energy use in the supply chain (Figure 10).

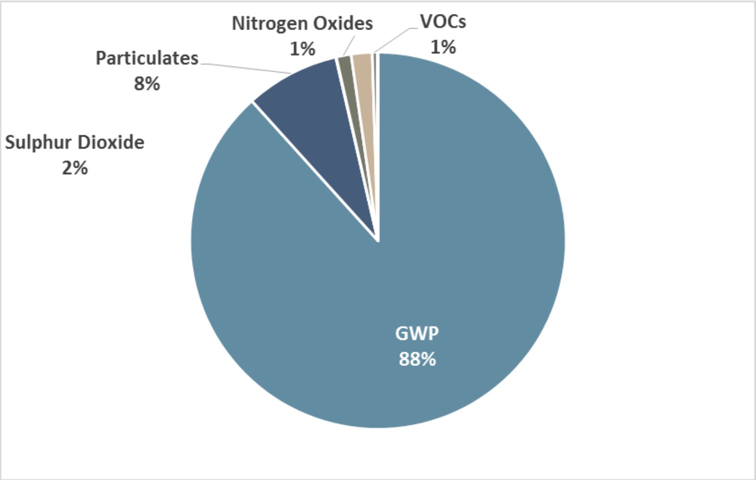
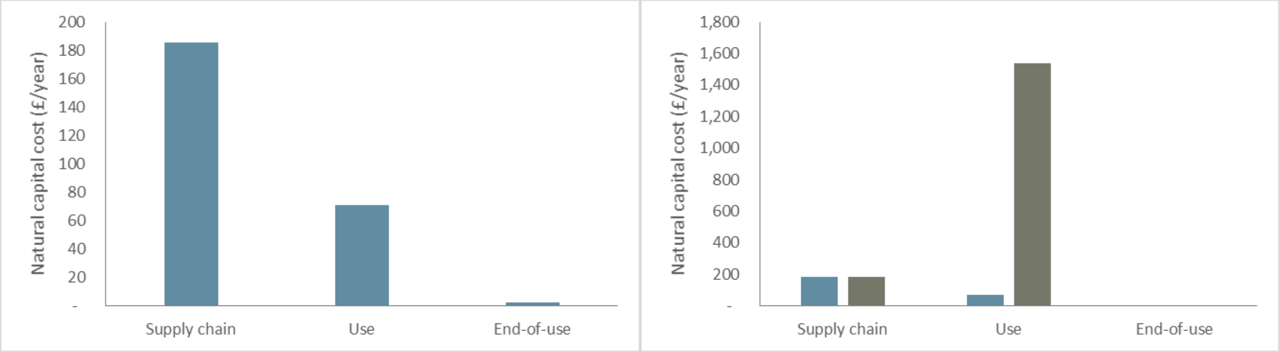


Figure 10: Proportion of natural capital impact associated with each eKPI for energy efficient lighting powered by onsite PV installed at WestQuay Watermark

Due to the low use phase impacts of PV, if using this source of electricity, the supply chain of the lights is the most significant impact stage, associated with 72% of lifecycle impacts Figure 11). However, if the grid is used to provide electricity, this decreases to 11% as use phase becomes the most significant impact due largely to GHG emissions associated with the generation of electricity to the grid (Figure 12).



Figures 11 and 12: Natural capital cost by lifecycle stage for energy efficient lighting powered by onsite PV or grid (forecast)

The financial implications of these decisions are considered in the next section.

Figure 13 below compares the impact associated with the use of conventional lighting powered by forecast UK grid electricity compared to the WestQuay Watermark energy efficient lighting powered in four scenarios:

- Energy efficient lighting using onsite PV
- Conventional lighting using forecast UK grid electricity[7]
- Energy efficient lighting and forecast UK grid electricity
- Energy efficient lighting and renewable electricity[8]

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[7] Forecast grid emissions identical to those used for Brent Cross analysis

[8] As per previous, with green tariff procurement of electricity

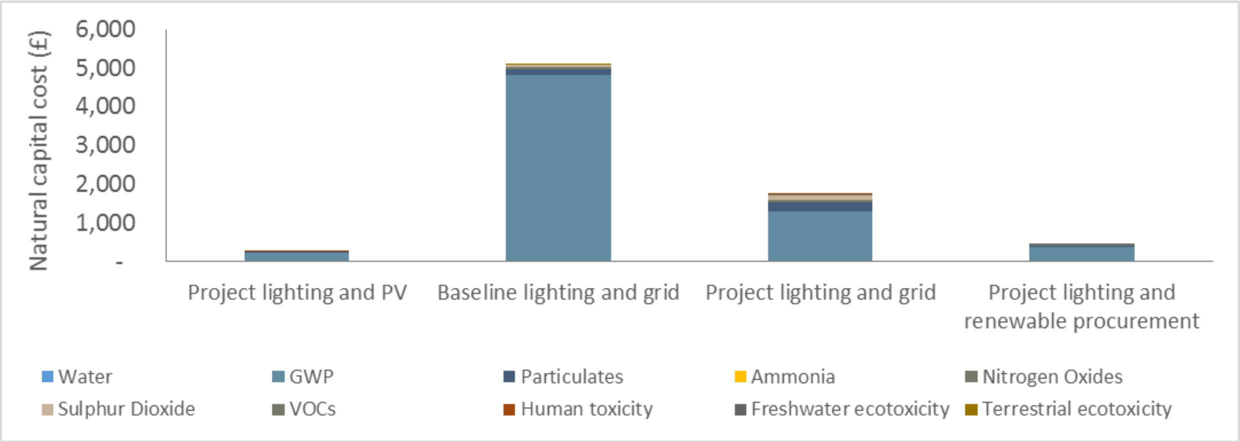

Figure 13: Natural capital cost comparison of conventional and energy efficient lighting at WestQuay Watermark for an average year

Compared to conventional lighting powered by forecast UK grid electricity, an average year of lighting at WestQuay Watermark will have a 95% lower natural capital cost due to less frequent replacement of bulbs, reduced energy consumption, and renewable energy use. This is most significantly associated with the GHG emissions from the use of fossil fuel combustion in the current UK grid mix. Should the residual mix be taken into consideration (see PV discussion above), this could potentially result in greater natural capital costs when excluding tracked renewable generation.

A simplified financial cost comparison was carried out using capital expenditure on the PV from Hammerson compared to avoided electricity costs (based on DECC pricing forecast, 2015). Based on these two aspects alone, the WestQuay Watermark PV installation has a financial return estimated within 11 years of installation, with an internal rate of return of 10% over the 25 year life expectancy of the PV. If incorporating natural capital accounting, the true cost of the PV is recovered after nine years, internal rate of return is 12%. When this is combined with energy efficient lighting, savings are realised within seven years of installation due to less frequent replacement of lights (though cost of energy efficient lighting is higher) and avoided electricity costs.

CONCLUSIONS

Both projects offer substantial natural capital net benefit when compared to conventional systems. Onsite energy generation, whether through PV or CHP, releases less GHG per unit of energy than grid sourcing, though the quantity differs between generation types. The Brent Cross energy centre generates a much larger amount of energy than achieved through PV at the WestQuay Watermark site. Though the benefits per unit are substantially greater using PV rather than natural gas fired CHP (93% lower cost per unit for PV, compared with 20% reduction per unit for CHP), the benefits of CHP in the short term are substantial due to the greater generating capabilities.

Energy scenario	Natural capital cost of energy supply (p/kWh)
Grid (current)	5.4
Grid (forecast[9])	3.01
Purchase of green electricity	0.90
Natural gas fired CHP (average thermal and electric energy)	2.41
Onsite PV	0.02

Table 4: Comparative natural capital costs of energy produced in different scenarios

CHP engine life can vary, and the net benefit seen through use of natural gas fired CHP is expected to reduce year on year as the UK national grid decarbonises and becomes fuelled by an increasing proportion of renewable energy. CHP is a long-term investment, and while the engines may need replacing after 15 years, the distribution pipework can be used for significantly longer. It is therefore recommended that renewable fuel solutions should be considered in the long term. The site was evaluated for refuse-derived fuel as feedstock and other alternative renewable fuels, though they were considered unfeasible at present. However, technology is evolving, and in 15 years, retrofitting generation plants with renewable or alternative fuel sources may be possible. Future fuel and plant options should be an integral part of the decision about any CHP installation.

The electricity generated using PV offers avoided natural capital costs of £53,000 over the 10-year lifetime of the project, based on estimated generation of 173,600 kWh per annum. If using energy efficient lighting, the PV energy generation potential is sufficient to power the lighting at the retail extension. Together, these technologies can achieve an expected 95% reduction of natural capital costs, equivalent to £48,300 per year.

Using natural capital valuation to determine the monetary cost of business impacts provides guidance on the potential magnitude of risk associated with operations. Increasingly, governments are issuing legislation and regulations to encourage businesses to reduce impacts, largely through financial penalties. The technologies analysed here will provide long-term defence against environmental penalties whilst onsite energy generation provides security of supply. Both support the business case for using natural capital analysis to inform capital investment decisions, in addition to the clear environmental and social benefits that accrue from reducing the negative lifecycle impacts of built assets.

RECOMMENDATIONS

The analysis of different energy and lighting systems has provided clear evidence of the benefit of renewable energy generation and energy efficiency at the sites reviewed. Integrating financial and natural capital accounting to better understand the return on investment provides a valuable insight into the important factors behind business decisions that should not be considered in isolation. Natural capital accounting can

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[9] Average cost per unit over 10-year forecast

help identify potential business risk from the internalisation of impacts through mechanisms such as environmental legislation, supply chain instability and environmental fines. To obtain maximum value from the research, it is critical that Hammerson and Sir Robert M^{c}Alpine now embed natural capital accounting into internal systems to help ensure that design, investment and other business decisions are fully informed. The following section outlines some general recommendations for each company to optimise the future design and development of assets.

Hammerson

- **Integrate natural capital alongside financial capital when making investment decisions:** By using natural capital as part of an integrated assessment of investments in technologies, materials, assets or other decisions. This can help protect against potential internalisation risk while also incorporating financial feasibility.
- **Conduct a top level internal natural capital materiality assessment of all new developments:** All new developments, whether retrofitted or new build, may have significant natural capital impacts. Hammerson should place a duty of responsibility on internal teams to assess materiality at the earliest stage. The Natural Capital Protocol identifies five criteria to assess materiality: financial, operational, reputational, societal and legal. Hammerson could potentially use these five criteria to develop internal specifications for materiality. This may be as simple as setting a cost threshold where, for example, projects under £50,000 are considered immaterial, or it may be more subjective, such as 'the project involves conversion of an area of wildlife that may be considered valuable to the local community'.
- **Undertake natural capital assessment of all important items within any major development or new build:** Having undertaken a materiality assessment, major new developments will be identified as potentially creating significant positive or negative natural capital impacts. These should be focussed on for detailed natural capital assessment to compare different options. This should be done in conjunction with cost benefit analysis to incorporate the financial trade-offs of different options. This will reduce any negative impact through procurement and installation of the most financially and environmentally appropriate building material and technologies.
- **Collaborate with contractors and engineers at an early stage to ensure decisions are appropriate and feasible:** Collaboration at an early stage allows for the input of varied expert opinions and captures technical aspects of design which may otherwise not be as well understood by analysts or designers. For energy-related assessments, engage with the energy service company that will be responsible for any operations.

- **Consider incorporating natural capital assessments into supplier codes of conduct across all new build or redevelopment projects:** By encouraging suppliers to do their own natural capital assessments of operations and materials, Hammerson can roll out natural capital assessment through its supply chain. This can influence decisions made across the supply chain, potentially reducing the indirect impact that Hammerson developments may have.
- **Consider strengthening sustainable procurement specifications in material selection processes based on natural capital accounting:** Hammerson already use sustainable procurement specifications to help ensure responsible material selection, but through the use of natural capital assessment, these criteria will become more scientifically robust and will allow a range of different types of impact to be compared, such as GHG emissions, water consumption and air pollution.

Sir Robert McAlpine

Natural capital accounting can help Sir Robert McAlpine to meet its 2019 vision and become the 'sustainable contractor of choice'. The following recommendations are given to help embed natural capital accounting into this process:

- **Integrate natural capital accounting into all obligations listed within the Vision 2019.** This will enable a better understanding of the benefits of efforts to achieve its goals, as well as identify hotspots of negative impacts that need to be addressed.
- **Integrate natural capital alongside financial capital when making investment decisions:** As recommended above, dual consideration of natural and financial capital in investment decisions can help protect against potential risk internalisation while also incorporating financial feasibility.
- **Collaborate with clients, contractors and engineers at an early stage to ensure decisions are appropriate and feasible:** As a contractor on a new project, Sir Robert McAlpine is well-positioned to help inform natural capital assessments and should encourage early discussions among all relevant parties.
- **Review natural capital impacts of building materials and alternative options when procuring site resources:** Different contracts may have varying levels of ownership and decision making in terms of what technologies, tools and materials are used. Where possible, Sir Robert McAlpine should use natural capital assessment to help inform procurement decisions. This would help Sir Robert McAlpine achieve its target of sourcing 100% of key materials responsibly by 2019.
- **Communicate to clients that natural capital assessment is part of its service offering:** Sir Robert McAlpine can position itself as a leader in the field by offering natural capital assessment as part of its service offering. This will differentiate it from competitors and may help increase demand.

APPENDICES

METHODOLOGY

Quantification of natural capital impacts

SRM and Hammerson engaged together and with stakeholders across both sites to collect site specific data regarding both inputs of materials such as technologies, installation requirements and equipment, as well as output data such as expected annual energy production (AEP). Two systems were reviewed:

- CHP gas fired plant at Brent Cross shopping centre including distribution pipework and thermal storage
- Photovoltaics and energy efficient lighting at the WestQuay Watermark development, Southampton

Data was collected from primary sources where possible, and then secondary LCA data was used to calculate the impact associated with the supply, installation, operation and disposal of each technology. To determine the benefit of technology use, this impact was then compared to the 'business as usual' baseline. This is the scenario that would have existed, if the particular technology system was not installed.

Data was collected on the following factors:

- Installation:
    - Process of installation
    - Waste arisings
    - Fuel use/electricity
- Technology used
    - Product life estimation
    - Specifications of technology
    - Expected output (where relevant)
    - Number of units
- Operation
    - Maintenance requirements
- End-of-life
    - Expected disposal routes

These indicators were then quantified in impact terms, using GHG emissions, water consumption, air pollution, freshwater and terrestrial ecotoxicity and human toxicity. Waste is considered an intermediate indicator, as it in turn has implications for GHG emissions and pollution. Where possible and relevant, regionalisation of impacts (such as specific grid emission factors for energy use) was undertaken within LCA factors.

Calculating energy generation of photovoltaics

The annual energy production (AEP) of a PV system can be estimated using the following formula:

$$AEP = A * r * H * PR$$

AEP = Annual electricity production (estimated)
A = Total area of solar panels (m^2)
r = solar panel yield (%)
H = Average solar radiation in location
PR = Performance ratio coefficient for losses

Data sources

Project	Data point	Source	Comment
Brent Cross	Natural gas fired CHP impact associated with production of heat	EcoInvent: heat and power co-generation, natural gas, 500kW electrical, lean burn, RoW, (Author: Karin Treyer active), heat	Factors adjusted for size of engine where possible
	Natural gas fired CHP impact associated with production of electricity	EcoInvent: heat and power co-generation, natural gas, 500kW electrical, lean burn, RoW,	
	Energy demand and allocation to users	Burohappold Engineering (2015)	Detailed below in Table 6
WestQuay Watermark	Lighting specifications	Exterior lighting was determined using site maps from supplier	
	Installation energy, waste and water	Primary data from client	
	Area and specification of PV panels	Supplier proposal	
	Expected annual energy generation production (AEP) from PV	Supplier proposal/Trucost calculation	Trucost determined the expected AEP using the formula given in the methodology. This also was in line with the proposal from supplier.
Baseline	Forecast electricity for grid	Private data on planned, commissioned, developed and decommissioned power plants	
Baseline scenario 2 (Brent Cross only)	Forecast electricity for grid	DECC (2015)	
Baseline	Impact factors for all baseline sources of energy	EcoInvent	The individual factors for renewable energies, grid energy (current) and grid mix in future scenarios, were all sourced using EcoInvent.

Table 5: Data sources used in project

		Baseline Energy Demand (MWh/year)					% of total energy demand
		Space heating	Hot water	Cooling	Regulated electricity	Total	
Phase 1	Residential	2990	4540	0	1130	8660	29%
	Total non-residential	2890	4730	1850	11440	20910	71%
	Business	100	20	120	390	630	2%
	Leisure	310	730	130	380	1550	5%
	Retail	290	860	1460	4770	7380	25%
	Hotel	960	3030	100	5450	9540	32%
	Healthcare	0	0	0	0	0	0%
	Community	180	30	40	160	410	1%
	Industrial	1050	60	0	300	1410	5%
	Total phase 1	**5880**	**9270**	**1850**	**12570**	**29570**	**100%**
Whole development	Residential	12250	19070	0	4740	36060	38%
	Total non-residential	11090	9550	6740	32080	59460	62%
	Business	3540	570	4130	13910	22150	23%
	Leisure	420	1000	180	520	2120	2%
	Retail	320	950	1600	5250	8120	9%
	Hotel	1860	5850	190	10530	18430	19%
	Healthcare	1600	920	460	500	3480	4%
	Community	730	110	170	640	1650	2%
	Industrial	2610	150	0	740	3500	4%
	Total phase 2	**23330**	**28620**	**6730**	**36830**	**95510**	**100%**

Table 6: Energy demand forecast for CHP plant at Brent Cross Cricklewood Development

Valuation of impacts

The following section provides an overview of the different valuation approaches used to convert the biophysical quantities measured into monetised values.

GHG emissions

The social cost of carbon (SCC), marginal abatement cost (MAC) and the market price of carbon in existing emissions trading schemes are common approaches that can be used to value the marginal cost of each additional tonne of greenhouse gas (GHG) emissions (usually expressed in tonnes of carbon dioxide equivalents (CO_2e). The three differ significantly in their current estimates of cost, although in theory climate policy in its effort to balance the cost of abating pollution against the cost of pollution damage would set emissions reduction targets that result in a MAC that is equal to the SCC. In perfect market conditions, the price of carbon should also be equal to the SCC.

Trucost uses the SCC, because it reflects the full global cost of the damage generated by GHG emissions over their lifetime, and as such it is typically considered best practice. SCC is also applicable to emissions globally, which is not the case with neither the market price method nor the MAC. However, SCC valuations are highly contingent on assumptions, in particular the discount rate chosen, emission scenarios and equity weighting.

Over 300 studies attempt to put a price on carbon, valuing the impact of climate change on agricultural productivity, forestry, water resources, coastal zones, energy consumption, air quality, tropical and extra-tropical storms, property damages from increased flood risk, and human health. However, due to current modelling and data limitations, such as lack of precise information on the nature of damages and because the science incorporated into these models naturally lags behind the most recent research, these estimates do not currently include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (Ackerman and Stanton, 2010; EPA, 2013). As noted by the IPCC Fourth Assessment Report, it is “very likely that [SCC] underestimates” the damages.

To address these material omissions Trucost bases its SCC valuation on the Interagency Working Group on Social Cost of Carbon 2013 values reported at the 95th percentile under a 3% discount rate, which represents higher-than-expected impacts from temperature change further out in the tails of SCC distribution (IWGSCC, 2013).

Water consumption

Figure 14 summarises the overall approach used to value water consumption.

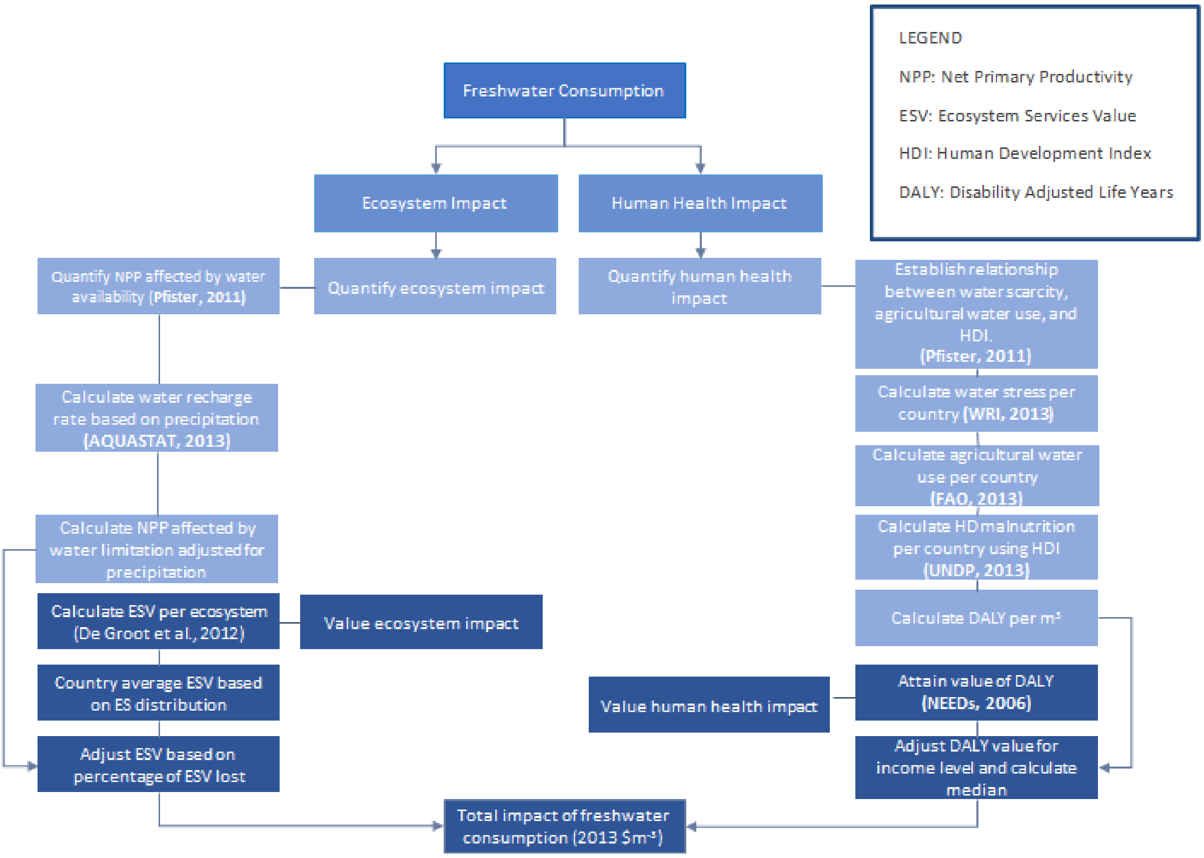

***Figure 14**: General overview of Trucost water valuation process*

Water availability can be affected when the demand for water exceeds the water available in a certain period of time. This situation usually occurs in locations where there is a combination of low rainfall and high population density, or in locations with strong agricultural and industrial operations. An unsustainable rate of water abstraction can affect access to water for the local population, provoke the intrusion of salt water in groundwater sources and in the more extreme situations, can lead to the disappearance of water bodies and wetlands (European Environment Agency, 2015).

The scope of the water valuation methodology includes the impacts of water consumption on both human health and ecosystems. The impacts on human health due to water consumption included in the methodology are limited to those linked to the lack of water for irrigation, which leads to malnutrition. Water scarcity has been considered an explanatory variable for the quantification of impacts on human health due to water consumption. Country-specific water scarcity was determined using GIS data published by the World Resources Institute (WRI, 2013a). In addition, water scarcity was adjusted for inter-annual and seasonal variability using WRI data (WRI 2013b, WRI 2013c).

Impacts of water consumption on ecosystem quality were measured based on Net Primary Productivity (NPP). NPP is the rate at which plants store energy as food matter, excluding the energy dissipated through plant respiration (FAO, 1987). It can be expressed as biomass per unit area (for example g m-2 year-1). NPP was considered here as a proxy for ecosystem quality, as it is closely related to the vulnerability of vascular plant species biodiversity (Pfister, 2011). In addition, it is assumed that damage to vascular plants is representative of damage to all fauna and flora species in an ecosystem (Delft, 2010).

NPP can be affected by several parameters, such as temperature, radiation and water availability (Nemani et al., 2003). The objective of the biophysical modelling is to determine the fraction of NPP which is limited only by water availability. This was estimated based on the country-specific parameter NPP wat lim defined in Pfister (2011). However, as the effects of water consumption on ecosystem quality depend on local water availability, NPP wat lim was adjusted for water scarcity. Precipitation was used as a proxy for water scarcity, with country-specific precipitation data sourced from Aquastat (FAO, 2014). In that sense, countries with the same NPP wat lim but higher water scarcity (lower precipitation) will result in higher ecosystem damage due to water consumption. Thus, the parameter NPP wat lim adjusted reflects the percentage of 1 m2 that will be affected by the consumption of 1 m3 of water in a year (units are m2 year m-3).

Air pollution

The analysis includes valuation of ammonia (NH3), nitrous oxides (NOx), sulphur oxides (SOx), volatile organic chemicals (VOCs) and particulate matter (PM10). Each pollutant impacts one or more of the following categories in a unique way; human health; crop yields and; forest yields. The economic damage caused per unit of pollutant depends on the specific location, and is driven by population and crop and forest density. The valuations for each of the pollutants vary for each country depending on certain factors, such as population density.

Each pollutant is associated with different but overlapping types of external costs. Some effects are caused directly by the primary pollutant emitted and some are caused by secondary pollutants formed in the atmosphere from pollutants that acts as precursors (e.g. sulphur dioxide forming sulphuric acid as well as sulphate compounds which contribute to smog). As each pollutant has a unique set of effects, each pollutant is valued using an individual methodology (although there is overlap between methodologies).

Studies of the costs of damages from air pollution use the Impact Pathway Approach (IPA) to identify burdens (e.g. emissions), assess their impacts and value them in monetary terms, for example ExternE (2003). ExternE is a result of more than 20 research projects conducted in the past 10-years, financed by DG Research and the European Commission. In this approach, emissions are translated into physical impacts using dose–response functions (DRFs) which use peer-reviewed scientific data to measure the relationship between a concentration of a pollutant (the dose) and its impact on human health, building materials, and crops (the receptor). A financial value is then assigned to each impact.

Data was compiled from IPA studies on the cost of the damage caused by air pollutants on crops, timber, water and building materials. A meta-analysis was then conducted of available literature on the costs that each of these impacts inflict on society to derive country-specific valuation coefficients.

Trucost adjusted the country-specific data obtained from the literature based on receptor densities, such as the percentage of crop or forest cover in a country. Impacts on building materials centre on using maintenance costs which have been adjusted using purchasing power parity (PPP).

Terrestrial and freshwater ecotoxicity

Terrestrial, freshwater and human toxicity is expressed in kg 1,4 Dichlorobenzene (DCB) equivalent in Recipe Midpoint Hierarchist characterization model.

Toxic substances, here 1,4 Dichlorobenzene, have an impact on terrestrial and freshwater ecosystems through reduced biodiversity. To value biodiversity, a study must define biodiversity, quantify biodiversity losses due to emissions of toxic substances through dispersion and deposition models, and then place a monetary value on these losses. Research projects which have attempted the latter (such as ExternE (“External Cost of Energy”) and the NEEDS project (“New Energy Externalities Developments for Sustainability”) revolve around calculating the damage cost of pollutants released by energy generation. The ExternE study is the result of more than 20 research projects conducted in the past 10 years, financed by DG

Research and the European Commission. The NEEDS project (2006) was run by a consortium of organizations, including 66 partners from the academic, public and private sectors.

The NEEDS (2006) approach developed a formula to estimate the monetary cost per kilogram of toxic substances deposited on terrestrial and freshwater environments in each European country using the three following steps:

1. Calculate the willingness-to-pay to restore an area of land and freshwater

A meta-analysis of 24 studies and 42 value observations across regions and ecosystem types was conducted to calculate the willingness to pay to avoid damage to ecosystems. This is measured using a metric called Ecosystem Damage Potential (EDP), based on species richness.

2. Estimate the EDP of 1,4 Dichlorobenzene (DCB)

Trucost used the USES-LCA2.0 model (Van Zelm et al, 2009) to calculate the EDP of 1,4 DCB at a continental level.

3. Derive of a function to adapt the value to different countries using benefit transfer

Within the NEEDS project, a regression analysis between willingness-to-pay and several variables was performed. The EDP valuation is known to have a positive correlation with population – as more people live close to an area with high biodiversity there will be more people that value biodiversity. The EPD value is known to have a negative correlation with the ecosystem size – if an ecosystem covers a larger area, the value per unit area will be less. Similarly, as biodiversity change increases, the value per unit of biodiversity diminishes. Using these variables, the formula below calculates the value of EDP in different regions.

$\text{Ln}\ (VEDP) = 8.740+0.441*\text{In}(PD)+1.070*FOR-0.023*RIV+0.485*COA-2.010*dEDP-0.312\ \text{In}(AREA)$

VEDP= Value of ecological damage potential (willingness-to-pay)

PD= population density (‘000 inhabitants/km2)

FOR= dummy variable for forest ecosystems

RIV= dummy variable for river ecosystems

COA= dummy variable for coastal ecosystems

dEDP= change in EDP

AREA= size of ecosystem in hectares

The value of ecosystem damage is a function of the change in biodiversity due to the emission of 1,4 Dichlorobenzene (DCB) and the willingness to pay for biodiversity (adjusted for purchasing power parity).

Human toxicity

In order to value the health impacts of 1,4 DCB, Trucost first estimated the damage to human population, expressed in Disability Adjusted Life Years (DALYs) and valued DALYs.

Calculating the damage to human population of 1,4 DCB in DALYs

Trucost used the USES-LCA2.0 model (Van Zelm et al, 2009). USES calculates human toxicological effect and damage factors per substance with information related to intake route (inhalation or ingestion) and disease type (cancer and non-cancer) at a continental level.

Damage factors express the change in damage to the human population, expressed in DALYs, as a result of exposure. They consist of a disease specific slope factor, and a chemical-specific potency factor. USES includes cancer specific and non-cancer-specific slope factors. The chemical-specific factors relate to the average toxicity of a chemical towards humans, separately implemented for carcinogenic effects and effects other than cancer. USES's risk assessment is conducted at a continental level and comprises of an exposure, effect and incidence assessment.

Estimate the value of DALYs

In order to put a value on the years of life lost, Trucost used the NEEDS project approach (NEEDS, 2007; OECD, 2011). The results of this approach are based on a contingent valuation questionnaire applied in nine European countries: France, Spain, UK, Denmark, Germany, Switzerland, Czech Republic, Hungary and Poland. The value was adapted to other countries based on country-specific income levels. To avoid ethical criticisms on the value of life and disease incidence in different countries, Trucost applied the global median value to value DALYs in different countries.

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