GARDINER &THEOBALD

'ALL ELECTRIC' BUILDINGS – THE FUTURE?

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INTRODUCTION

The construction sector is a dynamic industry which, with the development of new materials and technologies, is continually evolving and providing exciting design solutions across the breadth of the built environment. Yet over the past decade there has been little change in utilising gas boilers and Combined Heat and Power (CHP) and Chillers as the standard method for heating and cooling a building. However, there is a sea change moment on the horizon, as new buildings are increasingly utilising electrical power for both heating and cooling.

This shift throws up several questions, challenges and opportunities. Will buildings still require gas supplies and large risers to distribute flues? How will the alternative plant be accommodated? How are the domestic hot water load requirements met whilst still achieving the energy performance targets? Is there availability in the local electrical supply grid to provide the buildings with the additional electrical load?

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Why Now?

The New London Plan (the Plan) provides the statutory Spatial Development Strategy for Greater London. The Plan sets out an integrated economic, environmental, transport and social framework for the development of Greater London over the next 25 years. A key target within the plan is to minimise both carbon emissions from new developments and greenhouse gas emissions. This target aligns with the UK government's ambitious target to reduce carbon emissions by 80% of 1990 levels, by 2025. As the use of fossil fuels as the primary source for heating and cooling buildings is a substantial contributor to London's carbon emissions, its continued use by the construction industry is likely to impact the UK's ability to achieve this target.

The decarbonisation of the electrical grid is a key consideration for meeting the targets set out within the Plan. The quantity of electricity supplied from renewable energy sources such as wind, solar and thermal has steadily increased over the last 50 years. As a result the carbon emissions factor for the electricity grid has more than halved over the same period, and Energy & Emissions Projections (EEP) forecast that it will continue to fall as more grid electricity continues to be supplied from renewable energy sources. The graph below shows the UK Government's 2017 EEP for emissions intensity compared with the emissions intensity of natural gas.

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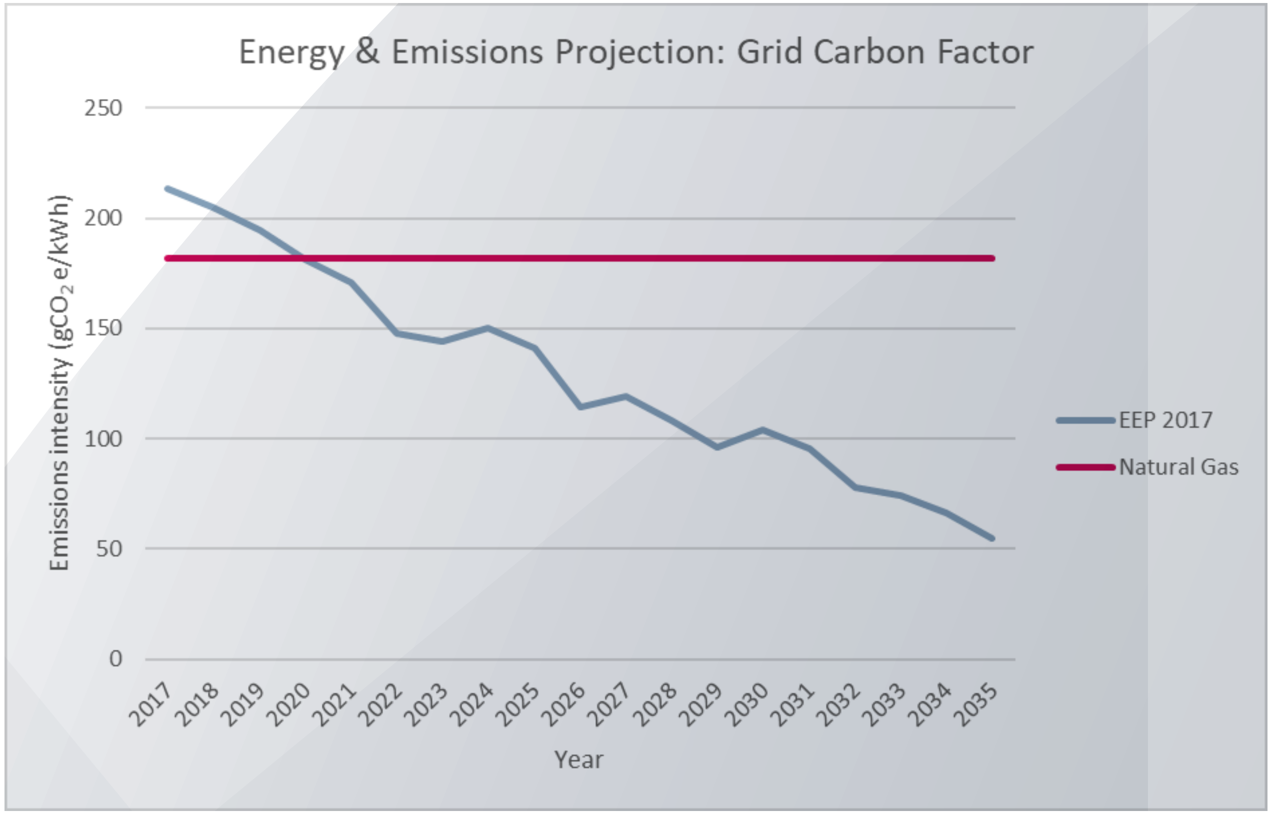
The graph forecasts that the carbon factor for grid supplied electricity will reduce to 100 gCO2e/KWh by 2030 and that the electrical grid will have a lower emissions intensity than natural gas from 2020. These figures indicate that a high efficiency electrical heating and cooling plant would be a more carbon-viable option than 'on-site electricity generation' from fossil fuels ie CHP plant is a less viable carbon option.

Standard Assessment Procedure (SAP) calculations are used to demonstrate the energy performance of dwellings in the UK and are a key part of building regulations compliance. SAP 10, dated July 2018, has also shown a reduction in both Grid supplied electricity and natural gas emission factors. More importantly, where Grid supplied electricity was more than twice natural gas in Part L 2013, it is nearly equivalent in the current SAP 10 figures. This convergence will continue as Renewable Energy contributes more electricity to the electrical Grid.

Energy & Emission Projection 2017 – Forecast grid carbon factor



Natural gas and electric grid emission factors

Fuel	Current Building Regulations Part L emission factors – SAP2012 (kWh/kgCO²)	New Emission Factors – SAP10 (kWh/kgCO²)
Natural Gas	0.216	0.210
Electricity Grid	0.519	0.233

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Impact on Building Design

As the Construction Industry adopts an 'All Electric' approach, the engineering and design of buildings will be forced to change to meet new space and distribution requirements. Along with the challenges that this will pose there will also be opportunities to improve building function and efficiency.

The 'All Electric' design method is at the beginning of its life cycle and therefore the current design options are relatively limited. New technologies are coming to the market to meet this new requirement but are still relatively unestablished. The table summarises the most common design options currently being considered, with the associated challenges of adopting an 'All Electric' design approach outlined in Box 1.

Box 1: Key Challenges when adopting an 'All Electric' design approach

- Lower winter temperatures could mean inefficient heat pumps and higher capital costs, and potentially higher running costs.
- 60°C Hot Water doesn't suit ASHP which work better at lower temperatures i.e. 45°C.
- Total estimated maximum electrical demand is likely to be exceeded if not considered at the early design stage.
- Potentially higher electrical reinforcement charges.

All electric design options

Heating and Cooling Design Options	Domestic Hot Water Design Options
Centralised Air Source Heat Pumps (ASHP) or Centralised Ground Source Heat Pumps (GSHP) or a combination of the two	Centralised ASHP or GSHP - run at higher temperatures ie 65°C in morning, and 40°C for remainder of the day
Electric heater batteries and chillers	Water Sourced Heat Pumps (WSHP) – to uplift AHSP or GSHP heat pumps
Refrigerant based systems ie variable refrigerant flow (VRF)	Localised electric hot water heaters
Fuel Cell Technology via hydrogen	Solar thermal
Localised ASHPs	Localised ASHP c/w electric top up
Localised electric heaters	

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Evidence that building design is moving towards a predominantly electric approach can be seen in commercial kitchens. Improvements in electrical kitchen equipment control over the last decade has facilitated the transition to electricity as the primary source for cooking. This change has helped make the move away from fossil fuels more viable.

As a result of such adjustments in gas and electricity requirements, building gas connections may become obsolete whilst the electrical supply may require enhancements. Large risers to distribute boiler and CHP flues up the building will no longer be required and internal plant space requirements may reduce. However, the requirement for external plant area may increase subject to the design solution.

Heat via ASHPs is distributed within the building at lower temperatures and this will reduce the overheating effects within the landlord areas leading to a decrease in the requirement for mechanical cooling in these areas. The low temperature hot water (LTHW) pipework would have to increase in size to accommodate the reduced delta T and plant equipment may require modification, such as larger coils, to accommodate the new LTHW delta T and to meet the required output.

Commercial buildings have a lower heat load requirement both for heating and for domestic hot water, which is reflected in their design. Air Source Heat Pumps appear to be the preferred solution to provide heating and potentially cooling, subject to the availability of external plant area. Hot water needs can be met by adoption of localised electric hot water heaters, however these are not suitable for the higher hot water demands typically required to serve shower provisions in a medium to large commercial office building. In these cases Water Source Heat Pumps are a viable solution to provide the uplift in temperature from 45°C (as provided by the Air Source Heat Pumps) to 65°C, the minimum temperature for hot water. Alternatively, where the available space for external plant is constrained, Ground Source Heat Pumps or Water Source Heat Pumps can be a more suitable option.

Other options for electric heating systems include utilising electric heater batteries in lieu of centralised LTHW system, or hybrid variable refrigerant flow (HVRF) based systems. However, whilst both systems work in principle they appear to be less efficient in terms of space and energy. In addition, the distribution of refrigerant in occupied areas of the building should be avoided which constrains these types of systems.

The design of 'All-Electric' residential buildings must take into consideration the higher heat load requirements for domestic hot water. This design can be further limited by stringent acoustic requirements and the high value space at the top of the building minimising the available external space available for plant equipment. Accounting for these design factors, a hybrid solution appears to be the preferred option where an energy loop, fed from Air Source Heat Pumps and Ground Source Heat Pumps, is utilised with either centralised or localised Water Source Heat Pumps to support the additional hot water load. If cooling is required, then a Heat Rejection plant will often be used to remove excess heat from the energy loop during periods of higher cooling loads. At the lower end of the residential market, localised heating units and hot water cylinders can be adopted. Some considerations for the use of heat pumps are summarised in the below Table.

Pros and cons of using heat pumps

Pros of Heat Pumps	Cons of Heat Pumps
Meets the 35% carbon emis-sions reduction target	Less efficient in winter due to low Coefficient of Performance (COP) levels
No impact on local air quality	Higher capital cost
Potential to reduce area of riser and plant space within the building	High refrigerant volume in heat pumps
Highest carbon savings using SAP10	
Less maintenance	
Lower running costs	

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Cost Commentary

There are many factors to consider when comparing traditional design solutions for heating and cooling to an 'All Electric' approach, least of which being the capital and life cycle cost.

Capital Cost

The capital cost of adopting an 'All Electric' building design approach will depend on the final design solution within a particular building and the proposed design solution, if any, to remove the requirement for fossil fuels.

If the 'All Electric' design solution is considered from the outset of the project, it will allow the designers to develop the best strategy to meet the demands of the building and co-ordinate the required plant space. If it is a change in strategy, during the later design stages, a cost premium may be incurred through attempting to fit the 'All Electric' solution within a building designed with a traditional approach.

The primary cost drivers include:

- Utility connections
- Plant cost ie heating and cooling plant, gas.
- Plant space - There is the potential for less internal plant space and smaller cores resulting in improved building efficiency. This in turn may increase the net lettable or saleable area and therefore should be considered when evaluating the true value of adopting this design solution.
- Off-site electrical infrastructure - The offsite electrical infrastructure appears to have sufficient capacity to provide for the additional electrical loads in the current design evolution. However, it is considered that the current capacity in the existing grid is insufficient to replace the UK's heating load. In addition, it is becoming more common that off-site electrical reinforcement is required for larger buildings and therefore as more buildings adopt this all electric approach, the grid will come under more pressure. As a result, buildings may be subject to higher electrical reinforcement charges, which will need to be factored into the overall cost.
- Refurbished buildings – improving the external fabric performance in refurbished buildings to allow heat pumps to work efficiently, will be a challenge and key cost driver.

The capital cost appears to be higher for an 'All Electric' solution. Based on project experience to date, the additional cost would fall within the range of £3.50-5.50 per GIA m2 (subject to final design solution).

Additionally the cost of carbon offset payments should be considered when comparing the cost of an 'All Electric' building to a hybrid building. The carbon offset payment is currently £60/tonne per annum however the London Plan recommends that it is increased to £95/tonne. In addition, the calculation has been extended to carbon neutral, not simply the 35% as per previous calculation, which will add significant cost to the carbon offset payment.

Life Cycle Cost

The advancement in heat pump technology has led to significant improvements in the efficiency of the plant and lower running costs. A ground or air source heat pump can reduce the cost of heating because less energy is required to generate the same amount of heat, there is also less heat loss associated with the installation due to the use of lower temperatures. A heat pump can deliver approximately 4kWh of energy for every 1kWh of electricity used to power it – ie up to 400% efficient. In comparison, traditional heat sources can be, at best, 100% efficient, but often much less than that.

The life expectancy of a heat pump should be similar to that of a traditional boiler at around 15-20 years, with much of the capital cost of a GSHP lasting a lot longer. Only the pumps and controls need replacing every 10-15 years, and the main heat source itself lasts more than 20 years.

Individually, heat pumps may incur lower maintenance costs when compared to a traditional boiler as there is no requirement for regulatory gas checks because heat pumps do not require gas supplies and are relatively safe to operate. There is a requirement to manage the refrigerant in accordance with the F Gas regulations and this will incur a cost for regular inspections. The design solution can also have an impact on maintenance costs. For example, if large heat pumps are used to feed an underfloor heating system, or individual units replace multiple fan coil units, the maintenance costs will be similar. In contrast, where multiple ASHPs, or local heat recovery units (HRU) are used to replace radiators, then the maintenance costs may be much higher and the design will need to make allowance for access to the units for regular maintenance. This highlights the importance of considering maintenance costs and access requirements in any design decisions, and not just energy savings.

Where designs require the adoption of multiple heat sources it can have the added benefit of reducing single points of failures. For example, should a boiler or HVAC unit fail, the whole building will be affected. However, if one of several ASHPs or HRUs fails, only the area it supports is affected. As GSHP are rarely the sole source of heat the impact on the building will be reduced in the event of failure.

If localised water heaters are adopted, a higher replacement and maintenance cost would be incurred when compared to those for the plant in a centralised system. Although, the replacement costs of individual units can be relatively low in contrast to a high volume central LTHW unit linked to a boiler.

Case Study – Commercial Office

Project X was a commercial office building project with a base design that included gas boilers, air-cooled chillers and domestic hot water via LTHW gas boilers. During design Stage 4, the heating and cooling strategy was changed to consider an all-electric approach. The boilers and chillers were located on the roof so there were opportunities to utilise both the boiler and chiller plant space for heat pump solutions.

Table 4 below summarises the main impacts from changing to simultaneous heating and cooling air source heat pumps from the traditional approach via boilers and air cooled chillers. The ASHPs supplied the heat for the domestic hot water. The higher hot water loads required in the morning where provided by running the ASHP at 60° for an hour coupled with an electric flow-heater.

Alternative options were explored such as only changing the boilers to ASHPs, and through changing the heating to localised hot water. However, these options were not viable as there was insufficient plant space and they exceeded the existing electrical supply capacity.

The cost uplift for this project equated to less than a 1% increase on the total cost of the Shell & Core Mechanical and Electrical works. In comparison to a design where the boilers are located in the basement and the flues are distributed throughout the building (or if the ASHP solution is considered at the early design stage), the cost uplift would be negligible and could potentially produce a saving. However, the plant space variance on this specific project was negligible as the boilers and chillers were located on the roof, and therefore the available space through omitting the boilers and chillers was sufficient for the ASHPs. In addition, there was no significant saving on riser space as there were no large risers to distribute flues through the building as the boilers were located on the roof.

Summary

- A change to 'All Electric' buildings is required to meet the carbon targets set by the UK government and to align with the requirements of the New London Plan.
- The 'All Electric' building will help to improve the air quality within our cities and reduce the carbon impact of the construction industry.
- In recent buildings, the main challenge in adopting this design approach has arisen from the option not being considered at the initial design stages. This has led to building designs progressing to suit traditional heating and cooling systems, with lighter electrical infrastructure and insufficient external plant space for the 'All Electric' option. The result is that buildings require potential costly re-design to convert to all-electric.
- If considered at the earlier design stages, the cost variance may be negligible or potentially produce a cost saving on the Mechanical and Electrical Installations.
- The design of MEP within buildings will continue to evolve so that it can apply newly developed technologies and plant materials to meet the continually changing regulations and environmental requirements.
- It is essential to continue to promote and adapt to the new approaches to maximise the opportunities for both our environmental footprint and best value design.

**Note. The cost uplift for the project excludes any potential Carbon offset payments for the base option. It is estimated these costs could reduce overspend by £1.00-1.25 per GIA m2.*

Case Study, Project X key metrics.

	Project Type	Cost per GIA (£/m2) (+/-)	Plant Space (%)	Riser Space (%)	Building Electrical-Supply (%) Cons of Heat Pumps
PROJECT X	Commercial Office 10,000 GIA m2	£3.75 uplift (less than 1%)*	No Change	No Change	8.3% Uplift