**Introduction**

This paper is a report on the work carried out recently investigating the potential for reduction of the carbon footprint of the Hall. The main inputs were the Theatre Green Book and the consultancy work commissioned by the Hall from Harley Haddow, Consulting Engineers. From this work it is now possible to create an outline plan of action for decreasing the carbon footprint of operation in the Hall, ultimately to net zero, which the Board is asked to endorse.

**Theatre (Venues) Green Book**

Peter Cannell (QH Board Member and Chair of the Buildings Working Group Sub-committee) attended a seminar on the Theatre Green Book on 16th May 2023 organised by Edinburgh City Council, and notes from that event are attached. The main conclusions drawn from the event were:

* confirmation that for a venue, by far the largest factor in carbon emissions is heating.
* there is a marketing value in promoting sustainable policies.
* there is a real danger of being over involved in process and losing sight of the important targets.

The Green Book website includes an assessment tool which allows a Sustainability Interventions Plan to be generated from inputs about the property in question. This has been done for the Hall. The results generated were largely generic in nature and, not surprisingly, did not take account of the particular circumstances of the Hall, but the exercise did give a useful check that in generating the Harley Haddow report no significant items had been missed.

**Harley Haddow report**

Engineering consultants, Harley Haddow (HH), had been commissioned to consider the potential work required to reduce the carbon footprint of the operation of the Hall, potentially to zero. They had also been commissioned to consider options for the replacement of the air conditioning system and as it has transpired that these two activities are highly interdependent, both subjects have been covered by one report.

Their report is attached and is summarised below.

**Framework for consideration of actions**

Both the Theatre Green Book and HH use the ‘Lean, Mean (Clean), Green’ thought framework for consideration of potential actions:

* **Lean measures:** passive measures to use less energy, largely by insulation.
* **Mean measures**: active measures to use less energy with more efficient equipment and systems.
* **Green measures**: measures to incorporate renewable technologies such as heat pumps and solar panels.

**Summary of the Harley Haddow report**

HH have previously constructed a thermal model of the Hall which simulates the year-round variation in operations and atmospheric conditions under which the Hall operates. The model has been calibrated against real life metered energy usage and shows good agreement. Once so calibrated, the model has been used to simulate the energy flows under various different modification options, both singly and in combination.

**Lean measures**

The measures identified in the report are:

* **Insulation of roofs**. Relatively easy to achieve.
* **Insulation of walls**. More difficult in an A-listed historic building, but not impossible.
* **Improvement in insulated glazing**. The auditorium already has double glazing with secondary glazing for noise insulation, but there are significant opportunities for improvements elsewhere, particularly the bar roof windows, and the front windows to the box office and management office, as well as the main access stairwells windows.
* A particularly efficacious measure would be to **reduce the unregulated air in-leakage** to the building (draft proofing). It is estimated that the current in-leakage results in about 1 air change per hour (1 ACH) which could be reduced to around 0.5 ACH resulting in reduced energy required to heat the in-leaking air. However, with the current air handling system in the auditorium it is unknown what effect reducing in-leakage would have on air quality, so this measure would best be undertaken in association with upgrading the air handling system (see ‘Mean measures’ below)

If the combined lean measures were implemented to their full extent, there would be a reduction in total energy consumption by about 32% of the baseline, with a similar reduction in carbon footprint, and energy cost savings of about 25% at today’s prices.

The Insulation of roofs and draft proofing would be relatively cheap and easy to install – though, as noted above, draft proofing should be carried out in tandem with uprating the air handling system, which will be more complicated and expensive – see below. The insulation of walls is more complicated and expensive, and likely requiring listed building consent. An area by area plan will be required involving a mixture of internal insulation, possible ‘wrapping’ of the historic building with modern, insulated, building additions, and acceptance that some areas will not be improved.

**Mean measures**

The main system improvement to significantly improve energy usage would be to **upgrade the auditorium air handling (ventilation) system**, which is also a priority because of the age of the present system and its business criticality. A modern system could be supplied in a modular form which could be installed in the loft above the auditorium. The system would require 3 or 4 modules to provide the capacity but critically, it should be possible to install these incrementally as partial replacements to the existing system, hence allowing near continuous provision of air handling, and also allowing for incremental cost commitment as funding comes available. The dispersed modular design will also spread the load on the roof structure, which could otherwise be a critical factor; the roof will need to be subject to a structural assessment. The units would have intakes and exhausts through the flat roof, which would require permissions. The units would be thermally efficient with heat transfer from exhaust air to supply air via thermal wheels, and also with air source heat pumps incorporated to maintain the set temperature for the auditorium; these units would also provide cooling of the supply air if required. It should be noted, however, that initially raising the auditorium temperature to a set value would still require heat input from other sources.

The costs involved in full replacement of the air handling system are estimated by Harley Haddow at £275k in today’s prices, including professional fees.

Other possible mean measures which are less effective in reducing carbon, but are also less costly, are:

* **Ensure the Building Environment Management System (BEMS) is optimised** for efficient energy usage.
* **Ensure the domestic hot water (DHW) system is well insulated** and consider transferring all DHW heating to electricity to reduce the gas burn in the main boilers.
* It is possible that **replacement of the existing main gas boilers** with more efficient modern boilers may have a role in a programme to reduce carbon. By the time all the ‘lean’ and ‘mean’ measures above have been implemented the required boiler capacity would be about one third of that presently installed, and possibly by that time, hydrogenation of the gas supply may have progressed to a significant degree. Ideally, the ‘green measures’ described below would be implemented, but if that did not prove possible within reasonable timescales, boiler replacement could a relatively cheap and easily installed interim option.

Implementing all of the above lean and mean measures along with the boiler replacement would give an energy reduction of around 47%, a carbon reduction of 50%, and a cost reduction of around 30% in today’s prices.

**Green measures**

Potentially viable green measures for the production of energy are:

* **Photovoltaic (PV) solar panels**. Potentially, panels could be installed on the auditorium flat roof, but planning and listed building consents would be required. The estimated potential energy production with current technology is 7-10% of the energy requirement with all the above efficiency measures implemented, so at a currently estimated price of £41k the efficacy of this measure is debateable. The Hall’s main energy use is not during sunlight hours, so electricity produced would either have to be stored in batteries or sold back to the grid. Also given that the electricity from PV panels is displacing grid supplied electricity, which is decarbonising at a considerable rate, the efficacy from a carbon point of view is debateable, especially when one considers the carbon dioxide generated in the production of 100m2 of PV panels. PV panels are hence not a high priority from a technical point of view.
* **Air source heat pumps (ASHPs).** The incorporation of some ASHP capacity in the proposed air handling system has been described above. Beyond that, there is the possibility to install an ASHP replacement for the existing boiler plant. If all the above lean and mean measures have been implemented the unit would need to be provide around 100kW of power output. Units of this size currently are expensive, and their siting would be problematic; however, it is likely that the prices and designs will both improve in the future as demand increases. Hence, this is likely to be a medium-term option. If it were to be implemented with all the other measures above, the energy use reduction would be around 67%, with carbon reduction of 77%, but with a running cost reduction, with current prices, of only 20%.

**A note on energy prices**

The energy price cost reductions in this note are against current prices, which have been increased recently by, hopefully, one-off factors, and at some point could be expected to fall back again nearer to pre-Covid levels. However, it is also important to acknowledge that structural changes in the energy markets can be expected.

If governments are keen to phase out gas usage, presumably raising the price by taxation must be considered as a possibility. Electricity prices at the moment are heavily influenced by the price of gas, because this is the fuel for the production of the marginal unit of energy, but in the future the marginal unit will be produced by turning up a windfarm or taking energy units from storage, which will produce a completely different market economics.

In a rational world moving to a zero carbon future, carbon should be expensive, so green electricity should be cheaper. However, timescales for the onset of rationality are uncertain. In assessing our carbon reduction plans, we should be planning to reach net zero, but our route to that target may have to be influenced by medium term fuel costs.

**Action plan**

From the considerations in this note it is possible to lay out the following actions.

* **Step 1** - investigate the feasibility of
	+ obtaining consents for historic wall insulation (internal),
	+ obtaining consents for PV panels on the auditorium roof, and
	+ obtaining consents for auditorium roof penetrations for air handling units supply and exhaust ducts.
	+ ‘wrapping’ the historic building with modern, insulated building additions.
* **Step 2** –
	+ maximise the thermal efficiency of the existing domestic hot water system by improving insulation and controls.
	+ investigate the fitting of point of use electric heaters for hot water supply for points of infrequent use.
* **Step 3** – insulate exterior walls and ceilings where feasible; improve double glazing. The bar roof is a priority.
* **Step 4** – replace the air handling system by phases; lag the auditorium roof; improve draft proofing generally.

**At this stage the carbon footprint will be reduced by around 45%**

* **Step 5** – having completed all the lean and mean measures above, assess the achieved reduction in energy requirements, and the costs and benefits of replacement of the existing central boilers by either an air source heat pump or a modern condensing gas boiler, depending at that point, on the state of ASHP technology and costs, and the relative costs of gas and electricity. If a modern condensing gas boiler is installed **at this stage the carbon footprint will be reduced by about 50%**
* **Step 6** – even if an interim gas boiler is fitted, at some stage, the next step is to fit an ASHP.

**At this stage the carbon footprint will be reduced by around 77%**

* **Step 7** - If the Hall wanted increased decarbonisation, PV panels and battery storage could be fitted at any point but this would only increase the operational carbon reduction by around 2.5% of the baseline.

**At this stage the carbon footprint will be reduced by around 80%**

* At this point the Hall will be entirely powered by electricity and the further decarbonisation of the Hall will happen as grid supplied electricity is increasingly decarbonised, leading to full decarbonisation by 2050, on current targets. In the meantime, net zero could be achieved by purchasing carbon offsets.

**Positioning of the Hall as a pilot on this question**

During this work it has become apparent that arts sector venues seem to be struggling to formulate significant plans on decarbonisation and that government, and probably other, funding is also having difficulty in appreciating the interactive nature of likely solutions and the costs involved. While we do not pretend to have found any magic answers, it does seem that our thinking is considerably “ahead of the pack”. It is proposed that we use this position to promote the Hall as a suitable pilot project to engage government, funders and other venues in a co-operative manner, with the objectives of both securing funding for the Hall’s project and helping to promote meaningful solutions more widely across the sector.

**Recommendation**

The Board is requested:

* to **note** this paper.
* to **endorse** the outline Action Plan proposed.
* To **agree** that this paper be shared with relevant outside parties with the objectives of both securing funding and to promote The Queens Hall as a pioneer organisation in carbon reduction for public venues.

Approved by the Board 6th October 2023