The eco-renovation of Gibson Mill

Gibson Mill is the eco-renovation of an abandoned and dilapidated former water mill, located in a deep wooded valley, one and a half miles from the nearest road, near Hebden Bridge. This landmark project creates the National Trust's first self-sustaining and autonomous (non mains connected) Grade II listed building. **Andrew Yeats, Eric Parks** and others who worked on the project report ...

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Gibson Mill from the entrance courtyard

The completed project now provides a national visitor/ education facility, reliant solely on the natural resources found on the site including: renewable energy to power it; spring water to sustain its café; and eco toilet systems to biologically treat its human waste streams. The eco renovation interventions demonstrated on this exemplary project are an example of what could be done throughout the UK to improve environmental performance standards of our extensive collection of historically sensitive listed buildings. Such listed projects are normally exempt from the new Part L of the building regs and allowed to consume unlimited natural resources to sustain their precious historic fabric with no regard for energy consumption or their carbon emissions. However, Eco Arc can demonstrate how not only the historic building but also the environment can be protected for future generations as well.

The challenge

In 1992 the National Trust was at a loss with what to do with Gibson Mill. Built in circa 1800 as a working cotton mill, the dilapidated and unsafe building has been owned by the National Trust since the late 1950's. Situated in a deep, heavily wooded valley next to Hebden Water, the large woodland estate attracted 40,000 walker visitors a year, with a peak of 700 people a day on summer bank holidays. The building's remote location, one and a half miles from the nearest road, was an obstacle in finding a new viable use. Initial utility enquires suggested a mains electric connection would cost in excess of £50K. In addition to the high connection cost there would have also been the difficult task of digging a below ground route for the cable through the densely rooted forest floor. Insufficient funds from the initial 1950's legacy would not cover essential building fabric conservation works, let alone provide mains utility services or convert the building into a viable 21st century public use. However, the Trust did not have the luxury of doing nothing. As a listed building heading for the buildings at risk register, The National Trust had a 'duty of care' to conserve the building fabric to the highest standards and provide public access for the enjoyment of its current members and future generations.

The client brief

As is so often the case The National Trust (NT) decided to turn the problem in to an opportunity. To make a virtue out of necessity, the NT developed an adventurous carbon neutral sustainable brief to deliver a demonstration visitor / community education centre that would utilise only the natural resources available on the site. In another leap of faith

The weaving shed was transformed into a 'walkers' refuge' café with the Kakkelovn as the centrepiece
© National Trust

they appointed us as relatively inexperienced eco architects and lead design consultants to build a project design team and deliver the sustainable project. In 1992 we had experience of designing zero CO_2 autonomous new buildings, but had little experience of the specialist vagaries of historic conservation works to listed buildings.

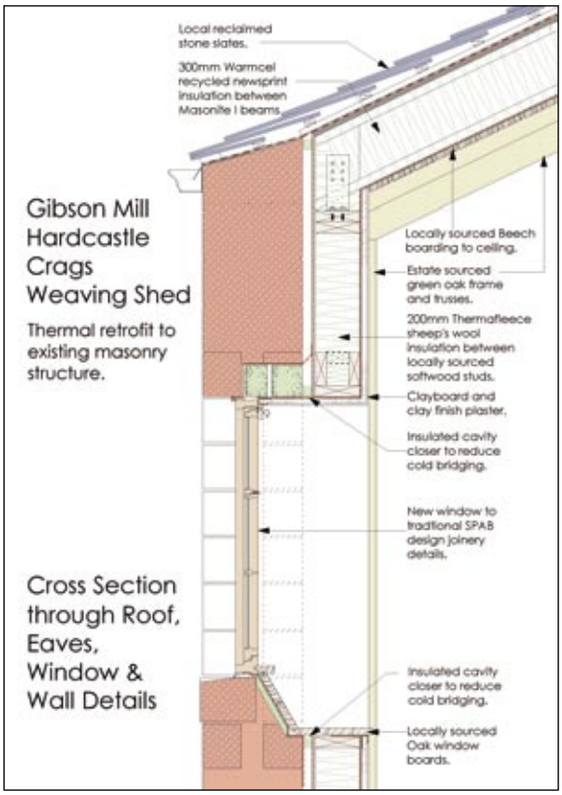
The design brief

Once we set out developing the brief with the regional NT client project team, we found ourselves on a steep learning curve. The objective of the project was to provide robust facilities for 60,000 to 100,000 existing and new walking woodland visitors, as well as the local community at Gibson Mill, without bringing in mains services to the building. The project would instead use the renewable resources available on site. These new facilities were to be set entirely within the historic fabric of the existing buildings and provide visitors with a variety of attractions in addition to housing an on-site warden. The dilapidated weaving shed was to be rebuilt to present visitors with a warm welcome in a 'walkers' refuge' café, which would serve a variety of hot drinks and simple, nutritious, locally sourced seasonal food. There would also need to be educational, exhibition and information facilities on three floors of the Main Mill building. These three floors were primarily for use by the local community and would aim to explain the principles of sustainability. A new three storey fire escape stair case was required and a manually powered lift for the disabled. A site warden (and any family) would require permanent residential accommodation in the former workers' cottages. Staff room facilities and staff toilets would be provided in the former Toll House, which was adjacent to the bridge over the Hebden Water. Across the bridge in the former stable block, next to an existing wild flower meadow, would be the toilets for visitors.

Detailed design

Weaving shed reconstruction

The original weaving shed had lost its roof many years ago and the existing natural stone masonry walls were a long way out of plumb, with a 12" bow at the head at the worst point. The beautifully marked existing stone flag floor was very damp and many of the stones were severely cracked. A new green oak frame and trussed roof structure forms the basis for the new heated enclosure. The oak was selected from the Trust's existing woodland and dressed for use by a local mobile sawyer. The breathing roof was insulated with Warmcel recycled newspaper between 300 deep Masonite rafters, and was covered externally with locally sourced natural reclaimed stone slates. The open cathedral ceiling was underdrawn with Sisalkraft 410 breather paper and finished with beech boarding sourced from the site woodland. Extensive computer daylight modelling and the need to minimize the use of internal energy-consuming electric lights determined the size of the central ridge Vitral roof



glazing. Every third roof light along the ridge can be manually opened with a telescopic pole to avoid summer over heating and provide good ventilation. The final roof with a design generated from the combination of locally sourced materials and thermal, daylight and ventilation performance criteria, looks remarkably like the historic archive photos that emerged after most of the design work was completed.

There were two main factors that determined the approach taken to retrofitting the existing walls. Although the existing thick masonry walls provided thermal mass, there was no insulation to retain heat and the projected intermittent use of the main space required us to provide a lightweight insulated enclosure that would allow a quick room warm-up period after lighting up the space heating biomass stove. We chose to internally dry line the existing stonewalls with a ventilated cavity, panel vent board and 200mm of Therma Fleece sheep's wool insulation between locally sourced softwood studs. To avoid the high energy used to make gypsum plaster board, we internally lined the walls with Sisalkraft 410 breather paper and 25mm thick natural clay board plastered with Claytec plaster and finished with natural casein distemper paint.

Given that around 7% of the world's CO_2 emissions are caused by the manufacture of concrete and their associated products we aimed to minimise and avoid the use of the traditional concrete blocks for the new internal structural walls. We achieved this by forming the internal structural walls with 150mm wide natural clay blocks which were finished with natural clay plaster and casein distemper paint to match the other walls in the space. The existing floor was accurately surveyed with each flagstone drawn out and numbered. The stones were lifted up and set aside for re-use. The new floor was insulated with 150mm of insulation and the existing flags were reset in exactly the same position on a lime mortar bed and re pointed.

With its central biomass space heating stove, the new super insulated space provides a warm and naturally daylit public facility with environmental performance standards in excess of current part L building regulation standards, all set within the historic fabric of the listed building. From the outside casual visitors or the local authority conservation officer would have no idea about the major internal transformation.

Detailed solutions

Fire escape and lift

Following meetings with the fire officer and a local disability group, it became clear the existing narrow and steep staircase was completely inadequate both as a means of access and escape. It was also apparent that a disabled compliant lift was required to get less able-bodied people to the first and second floor exhibition spaces. A triple height stairwell void was created in the existing mill extension and a new three storey galvanised steel and oak tread stair case was specified and fabricated utilising recycled steel strings with locally sourced oak treads and handrail. The requirement for a fully accessible lift was met by working with George Johnson Lifts to design the UK's first non-electric, manually operated passenger lift. The lift can be run by a single individual and relies on traditional pulleys and pull ropes, much like an oversized dumb waiter.

Renewable energy

The key to the project's renewable energy design strategy was to minimise demand through design. There were several aspects of this strategic approach, including the following: careful selection of low energy consuming facilities we offered to visitors; selection of the very best low energy appliances; and the use of natural daylight to reduce the need for electric lighting. We realised our strategic aims by opting for existing proven technologies and avoiding advanced complex units requiring specialist maintenance input. We also optimised use of the renewable resources available on site and integrated them seamlessly in to the building design and operation. It was also deemed important to allow visitors to see how the energy is being generated, stored and used on site. This was realised by displaying all of the meters and switchboard gear on the ground floor of the main mill building. A commitment was made at the outset of the design to ''BAN THE USE OF IMPORTED FOSSIL FUELS'' – even for standby operation. Although it was easy to say 'no fossil fuels' it has been a tough task to carry out, but our perseverance has paid off in

the final design resolution.

Hydropower

As part of the strategy to make use of the existing on site resources, the original 1926 Gilkes Francis turbine was carefully removed from site and fully refurbished in the nPower workshops at Ferrybridge. Once the turbine was refurbished, the open flume machine was built back into the sump wall in the main building. The turbine is designed to a rated maximum water flow of 390 litres per second at a rated head of 4.8m to generate a rated shaft output of 14kW. This output figure was down rated to 9kW to allow for its worn condition, but in reality it has performed much better than expected, giving an unexpected surplus above its designed output. Because the main turbine would only work at times of good river flow rate a smaller cross flow type turbine was installed to use at low flow rates of 30 to 50 litres per second to provide 1.5kW. Both machines abstract water from the lower weir on Hebden Water via an existing sluice gate and lower millpond adjacent to the main mill building. They then discharge via the existing tailrace tunnel back to Hebden Water. The hydro energy output from both machines is integrated into the building energy management system in a fully automated manner and works within the bounds of the abstraction regime designated by the Environment Agency.

The original 1926 Gilkes 'Francis' type water turbine was reconditioned.
© Dulas

Solar photovoltaics

After much debate on the ideal location for a PV array with the NT Internal Architectural Review Board, it was concluded the only sensible place was up on the main mill roof clear of most tree solar shading and out of the reach of vandals and thieves. The rooftop positioning of the PV array was accepted only on the grounds that it could at some point be removed with negligible impact on the listed building historic fabric. For this reason the PV array was set up above the existing stone slate roof on proprietary 150mm 'stand off' Oatey integrated upstands and flashings. Proprietary stainless steel and aluminium rails formed a framework to support 24 Kyocera 120Wp (peak) PV modules and 24 60Wp PV modules. The total PV array rating was 4,320Wp connected in parallel to a junction box mounted in the roof attic space and hard wired to the public display switch gear exhibit.

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The solar PV panels on the main roof. The solar hot water panels are at the far right-hand end (out of photo).
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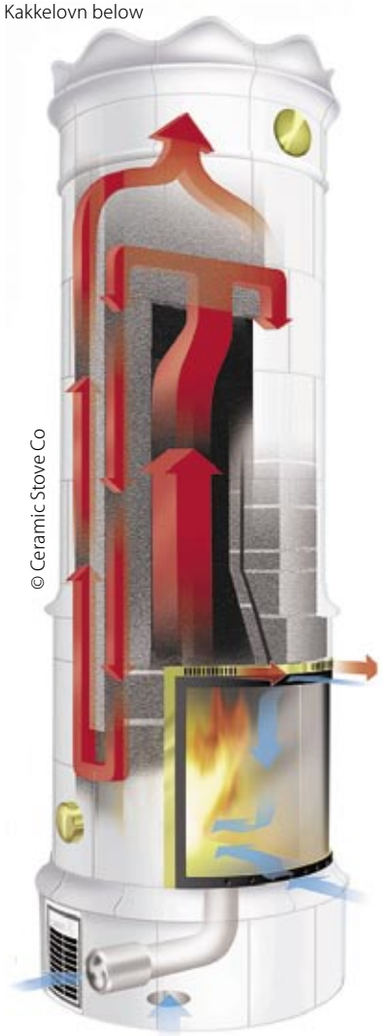
The 60 kW log burning boiler above and 14 kW Kakkelovn below



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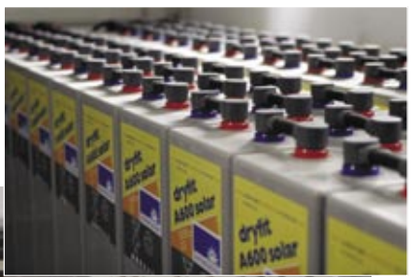
Working Diagram of Ceramic 'Kakeloven'

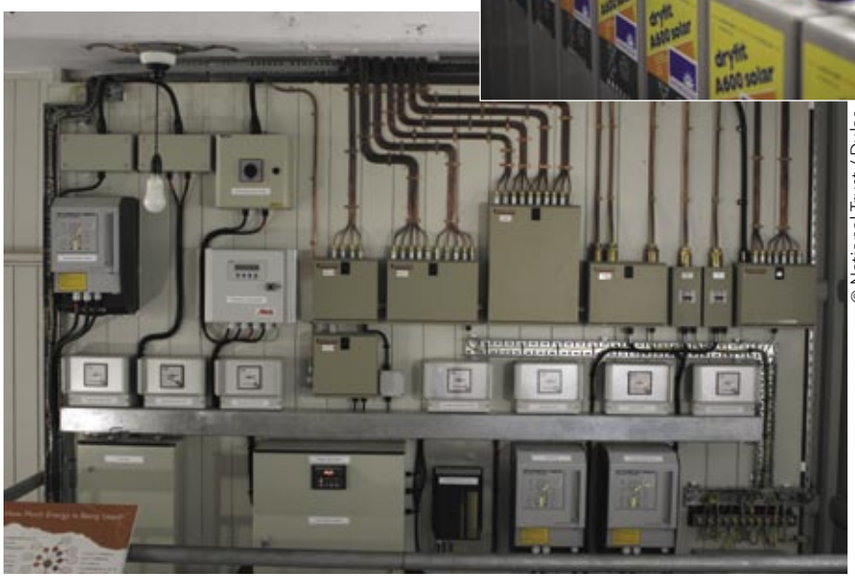
Biomass heating systems

A 60kW peak downdraft log burning boiler was installed in the former engine house, supplied by Econergy. The boiler has a batch feed hopper and is capable of operation under natural draught conditions. The boiler was oversized to allow once a day firing, and will operate at a higher than required temperature to minimise environmental effect. A single skin stainless steel flue exits from the stove outlet and runs inside a new lining up the existing tall mill chimney. This primary stove supplies hot water to a 1200 litre pre-insulated stainless steel accumulator tank located in the café kitchen to provide 85 degree water for hot drinks and 65 degree hot water for washing up etc. The hot water for hot drinks is topped up to 100 degrees with an electrically operated instantaneous water heater at the café serving hatch.

A 14kW traditional Swedish 'Kakkelovn' thermal mass log burning space heater stove was installed in the café seating area by The Ceramic Stove Company. It draws air from the room through a duct, past, but not through, the firebox and out through vents in the doorframe. The five-channel flue system was developed in 1767 by Cronstedt and Wrede in Sweden and is still the system in use in most stoves of this type to this day. While passing through this extended internal flue, the flue gases impart their energy to the thermal mass, dropping in temperature from the initial burn temperature of 900-1100°C to less than 200°C before exiting to the chimney. After only one burn process at the beginning of the day the heat deposited into the thermal mass of the stove is emitted over a 12 hour long period during the rest of the day. The ceramic stove is the principal source of high-quality heat permeating throughout the walkers' refuge café space. This efficient heating system saves on the use of traditional precious fossil fuel, extends the life of the heating system output beyond the initial burn process and reduces indoor pollution.

To service the resident warden's house, a 20kW Warmsler biomass timber fuelled kitchen stove and combined boiler producing central heating, cooking and domestic hot water was fitted in the kitchen hearth. A 5kW clean burning Clearview Vision space heating stove was also fitted in the warden's living room as a social





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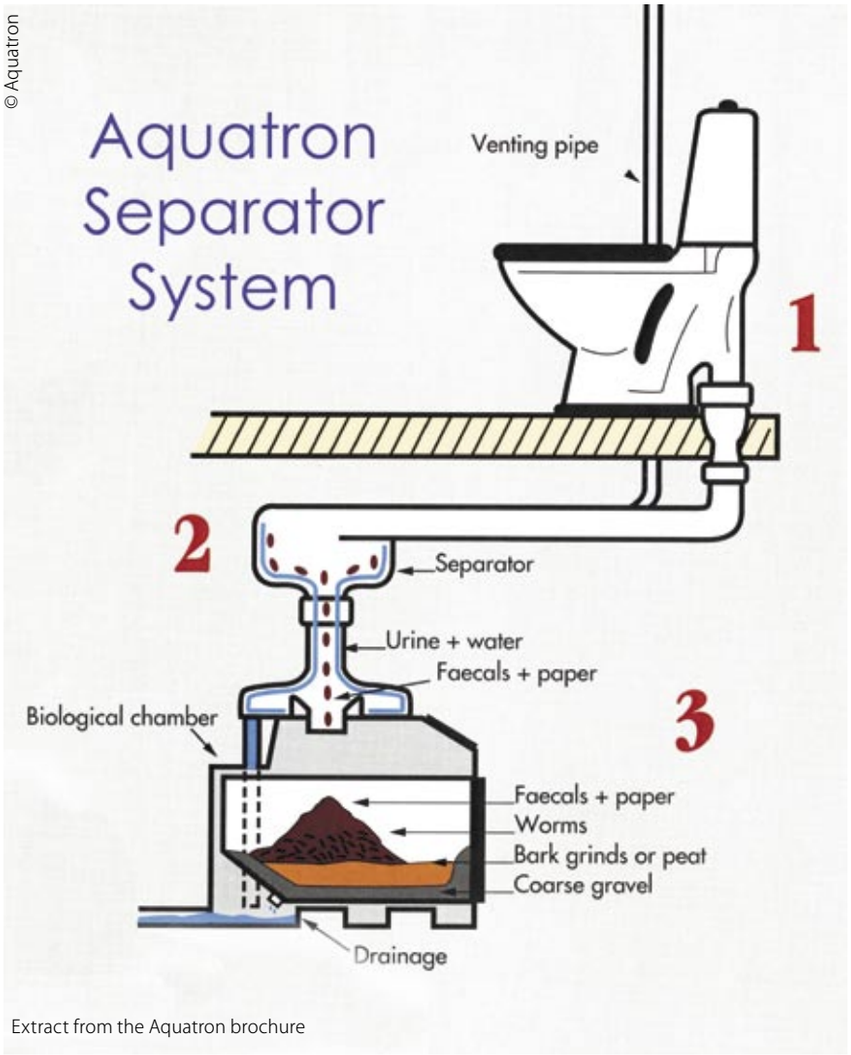
24 2 volt batteries and switchgear for all the renewable energy systems, all on show to the public to demonstration the renewables in action



Extract from the Aquatron brochure

focus and to provide alternative viewing to the TV.

It was calculated that the annual fuel requirement for the whole project is 17 green tonnes. This can easily be met from arisings from the woodland management on the estate's 66 hectares of mixed woodland under a new sustainable management regime.

Battery storage

A battery store consisting of 24, 2 volt lead-acid cells has a total available capacity of 48kWh. The store is utilised to "smooth" inputs and demand peaks, and to provide electrical energy to appliances in periods of low hydro and PV input. The battery cells are sealed gel, valve regulated maintenance free type. We are generally not keen on battery storage systems because of the environmental consequences of their future disposal but on this site we did not have the luxury of using the national grid for net metering or long term storage.

Renewable energy control system

A central feature of the public display sustainability exhibition was the renewable energy control system switch board and data logging panel, laid out to be easily interpreted by the lay public. The control panel was designed to be flexible, and automatically prioritises key loads in times of low energy input. The control system also incorporates easily understood status displays, easy to read metering dials and data logs giving staff the necessary information to manage the energy resource and avoid an embarrassing energy blackout during public visitor access times.

Solar water heating

A Filsol solar water heating system was integrated onto the end of the PV array to supply domestic hot water service to the warden's cottage during the spring, summer and autumn months. The solar heated hot water flow and return pipes feed into a twin coil hot water cylinder, located in the airing cupboard.

Site sewage treatment system

A private water supply and wastewater treatment system was the only practical option for this remote site but the autonomy brief also called for sewage solids to be treated rather than tankered away. Dry compost toilets were considered for the public but rejected by the client in favour of conventional looking but water efficient WCs. As well as the 'no tanker' brief, access to the public toilets is by a narrow bridge so a sludge-free system made sense.

The solution chosen was based around the Swedish Aquatron separator. This simple passive (non electric) device uses surface tension to separate the solids from the flushed water, for composting in one of two prefabricated bio-chambers

located in the room under the toilets. These dry composting chambers are primed with worms to accelerate the decomposition process of the solid faeces. In time the dried out and fully composted solids will be returned to the woodland floor as a benign fertilizer. The separated urine and flush water liquid effluent from the Aquatron separator flows to an un-powered dosing device, which delivers pulses of liquid black water effluent along a below-ground infiltration trench. The sandy soil provides filtration and biological treatment without odour, pollution or energy use and not a reed bed in sight.

Gibson Mill from across the Millpond

Robust but super-efficient 4 litre Ifö Cera WCs are used for the stable block toilets with traditional leak-free siphons and Ifö Cera waterless urinals. This winter was a good test when temperatures dropped to -13°C and everything froze solid but the urinals continued to work without the risk of bursts or flooding. Once the WCs had thawed they worked fine with no leaks or damage to the tough and simple siphon.

Located across the river from the Aquatron system, the staff and cottage needs are served by compact compost toilets. The historic buildings precluded the use of larger vault type toilets, which are more robust but would have required excavation of the building floor. The warden's cottage was fitted with a single Canadian Sunmar Excel dry compost toilet. The Toll House toilets for the disabled and staff were fitted with Swedish Separrett dry compost toilets linked to a single fan assisted extract flue fed up through the existing chimney.

Water supply

Fortunately a reliable and pure spring was found on site that was just high enough to supply all the buildings by gravity without the need for pumps or treatment. New fence enclosure constructions protected the source from deer and sheep droppings and wandering dogs. A concealed and landscaped header tank was built to provide a small backup supply if short-term demand exceeded the springs natural supply flow rate. A below ground pipe safely delivers the drinking water to the mill and outbuildings. Finding a free flowing source of water pouring out of the hillside might seem to make water efficiency measures redundant, however dramatically reducing the water use simplified wastewater treatment and onsite disposal design. Low water use design strategy also demonstrated best practice to the visiting public and in addition provided performance and reliability advantages. With limited power, hot water was not considered feasible for the remote toilet block but the use of spray taps minimises the discomfort from washing hands in unheated water whilst also further reducing effluent volumes.

Conclusion

As green architects it has been a fantastic project to work on, combining the very best of sustainable eco design ideas, integrated with historic building conservation works. The client representative, Rob Jarman, Head of Sustainability at the National Trust, succinctly described in a nutshell the merits of this project when he said: "*This is a flagship project for the National Trust. With a low environmental footprint Gibson Mill provides a vision of how to marry the needs of heritage conservation with strict environmental standards. A mixture of traditional and 21st century technologies are being used to light, heat and power the mill as the building enters its third lifespan. We've taken an holistic approach at Gibson Mill making sure that all elements of the visitors' journey, from getting to the mill through to the waste left behind, have green credentials. It provides a model for how many other Trust sites will need to operate and also, hopefully, a beacon for how we can all lead our individual lives in a more frugal and sustainable way*".

Andrew Yeats & Eric Parks

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EcoArc received the Queen's Award for Sustainable Development 2006

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