T4 Sustainability Ltd

Retrofit of T4 Sustainability's Industrial Unit

Revision 0030, 09/09/2013

Contents

1 Introduction

1.1 History And Context

T4 Sustainability Limited (T4) is an East Midlands company which has over tens years' experience delivering advice, energy efficiency, and renewable energy projects for businesses, local authorities, faith groups, third sector organisations, and householders.

The work it undertakes includes the provision of resource efficiency services, energy audits and opportunity assessments, carbon footprinting, and low energy and renewable energy system design and installation.

In 2012, it was decided to consolidate storage and office space at a single location, which would serve as a base for all installation and consultancy work. This led to the selection of an industrial unit in Ilkeston which is fairly central to staff's homes, which minimises commuting distance.

This document records some of the work done after the company moved into the unit, during autumn 2012 and spring 2013.

This document will be updated periodically as new developments occur, and as the effects of the projects undertaken so far are observed and monitored over time.

1.2 Initial Condition Of The Unit

When purchased, very little information was available about the unit. A summary of the key features of the unit are given below.

1) The building is steel framed, with brick and block-work in the lower portion.
2) The upper part of the walls and the roof are made from insulated steel cladding.
3) An inefficient (non-condensing) gas boiler had been installed with radiators throughout.
4) The main door was insulated internally, but draughty with worn weather seals.
5) Windows at ground floor level were double glazed, but some glazing cells had been replaced with rectangles of white chipboard.
6) The roof lights were no longer very transparent, and are only single glazed.

The unit comprises an area on the north east side (roughly 25% of the total), which accommodates office space, toilets and kitchen. This is partitioned from the rest of the space (storage and workbenches) by a block-work wall.

2 Retrofit Of The Unit

2.1 Heating Strategy

To make better use of passive solar heat (and to maximise the natural light available), one of the white chipboard panels in a south west facing window frame, has had the chipboard replaced with a spare glazing cell that was found in the unit.

The building needs to be heated to provide staff comfort and avoid pipes bursting in freezing weather.

Only those parts of the building which people are using are normally heated. For the vast majority of the time, this means that only one or both of the office rooms are heated, though other parts of the building may be heated if this is required to prevent the pipes freezing, or if staff spend a long time working outside the office space while it's exceptionally cold.

The gas supply to the site had been disconnected, and it was decided to use bio-mass heating rather than re-connect the gas (to reduce greenhouse gas emissions).

Zoning of the site, insulation of the most heated zones, draught proofing, ventilation, and heat recovery, were all considered in developing the heating strategy, in addition to the sources of heat to be used.

2.2 Zoning

The building has been zoned into areas with different uses, so that the heating can be controlled to avoid heating unused parts of the building unnecessarily.

The office area comprises two rooms. These are both used frequently, but not necessarily at the same time, so each is treated as a separate zone, with thermostatic valves on the radiators allowing heating when required.

The space heating pump is controlled by a timer. Rather than running on a fixed schedule, the timer runs for one, two or three hours from the time it is started by a member of staff, and will not start automatically. This avoids running the heating when staff are not cold. A timed period of heating can be cancelled if heat is no longer required.

The workshop and storage area of the unit does not generally need heating other than to avoid freezing of the heating, hot, and cold water pipes, though heat can be provided via the existing central heating radiators if necessary.

The toilets and kitchen are unheated, and the accessible pipes have been insulated where possible to reduce the chance of freezing in winter. In sub-zero conditions, freezing of the pipes is prevented by heat leaking from the heating and hot water pipes, and the radiators being used if necessary.

2.3 Insulation

The external wall cavity was already insulated with 50mm of mineral fibre. We have noticed however, that this was not installed all the way to the top of the cavity, and it is not clear if anything can easily be done about this. The ceiling space above the office was found to be already insulated with mineral fibre to a depth of 180mm.

Insulation was added to the block-work internal wall that divides the offices from the workshop and storage area (on the workshop side). It was also added to the floor of the office on top of the concrete slab.

The wall insulation comprises 70mm of polyurethane insulation held in place by a studding, and covered with fire proof hardboard (on the advice of Building Control).

Insulation on the office wall, covered with fire proof plywood.

The floor insulation comprises 25mm polyurethane insulation covered with orientated strand board (OSB). Adding insulation has significantly reduced the energy demand, and therefore fuel required to heat the offices, (the peak heat load is estimated as 4kW).

Ideally we would have used thicker insulation, but this would have required us to raise the height of the door frames, which would have required a substantial amount of building work to be undertaken at significant cost.

Insulation of the floor –
polyurethane foam insulation covered with Orientated Strand Board.

Further insulation was added behind radiators to reduce heat loss through the walls. Floor insulation off-cuts we used for this. These have U values which are far superior to the thin aluminised plastic panels normally sold for use behind radiators.

The insulation was installed with the aluminised side facing the radiator, so that in addition to the insulation resisting the conduction of heat, the aluminium would reflect thermal infrared radiation away from the wall.

Insulation installed behind radiators

2.4 Draught Proofing, Ventilation And Heat Recovery

Seals around doors were installed to reduce draughts in the building, especially around the fire doors and pedestrian entrance. Since then, the decision has been made to install a biomass boiler, so we have stopped trying to draft proof the outer shell of the building further, as the boiler has a significant requirement for fresh air. If any further work was done to draft-proof the building, it would be to the offices, as these are used most frequently, heated the most, and not in the air path to the biomass boiler.

A ‘Vent-Axia Lo Carbon’ heat recovery fan has been installed in each office, to provide fresh air without losing a significant amount of heat. These suck stale humid air out of the building, and replace it with incoming fresh air which is pre-heated by the warm outgoing air. These reduce the energy required for space heating, and help to maintain comfortable humidity and carbon dioxide concentrations.

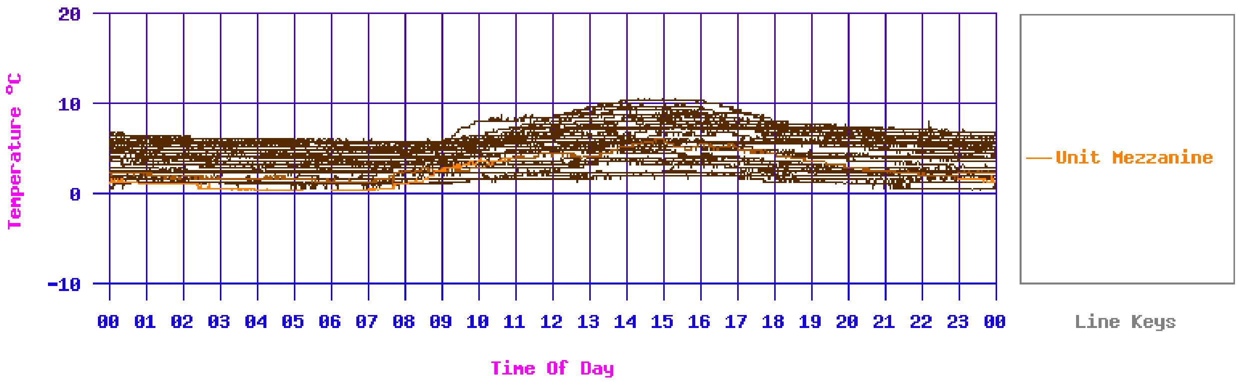
Heat recovery fan

2.5 Thermal Monitoring

In many buildings, heating is left on during the winter to ensure that pipes don't freeze and burst. This heating must happen whenever temperatures might fall enough for pipes to freeze. This low level heating is often used on a precautionary basis for hundreds of hours per year.

T4 has begun to record and monitor temperatures in the unit using open source software they have developed, which they hope to evolve into an open source Building energy Management System (oBeMS). The oBeMS software allows T4 to monitor temperatures remotely, so the heating is left off by default, and only switched on when necessary.

The graph below shows temperatures in the unit during the period January to March 2013.



The graph shows that for a period of some weeks, during some of which there was snow on the ground. The temperature fell in a range from a little above freezing to around ten degrees.

Only on one evening did a clear trend emerge which indicated that the indoor temperature would fall below zero. The heating was then turned on to warm the whole building by a few degrees.

For the rest of this period, only the offices were heated, and these only while they were occupied. The monitoring T4 undertook avoided a sustained period of precautionary heating, perhaps reducing fuel consumption during the worst part of the winter by a factor of at least two.

2.6 Biomass Boiler

The gas boiler was removed and replaced with a 92% efficient 24kW downdraft gasifying wood boiler, which provides up to 40kWh of heat per batch of wood burned.

This burns wood (logs and old and broken pallets collected locally).

A Laddomat load valve is used to minimise corrosion of the boiler by acid combustion products.

In use, priority is given to heating the offices when there is demand for heat, and excess heat from the boiler is stored in the 2,700 litre water filled heat store.

Water is pumped to the radiators under the control of the heating timer as required by staff. The timer is switched manually when needed, for one, two, or three hours at a time, rather than running automatically at the same time every day. This way the heating cannot be switched or left on when the building is unoccupied.

The water fed to the radiators passes through a thermostatic mixing valve. This has the following effects.

1) The maximum surface temperature is controlled to avoid skin burns on contact with the radiators.

2) The user can lower the flow temperature in milder conditions, thereby minimising the disruption of the stratification in the cylinder. This enables the heat store to operate more effectively.

3) The user has the option to increase the radiator temperature in particularly cold weather, to increase the heating rate.

As the heat store is very well insulated, it only loses around two degrees per day when there is no demand for heat. As the heat load of the offices is very low due to the installed insulation, the boiler need only be fired every few days, even in cold conditions.

Without other call for heat, the heat store retains enough heat to eliminate the risk of freezing if necessary, even if the boiler is not lit for many days in the middle of winter.

The flue for the boiler did not require planning permission, as it is the only flue on the roof, and is less than 1m higher than the ridge.

Biomass boiler with the top door open

The heat delivered is metered, and earns income from the Renewable Heat Incentive (the thermal version of the Feed In Tariff).

The weight of wood burned, the moisture content, and the amount of energy produced, are being recorded to find out more about the behaviour of the burner.

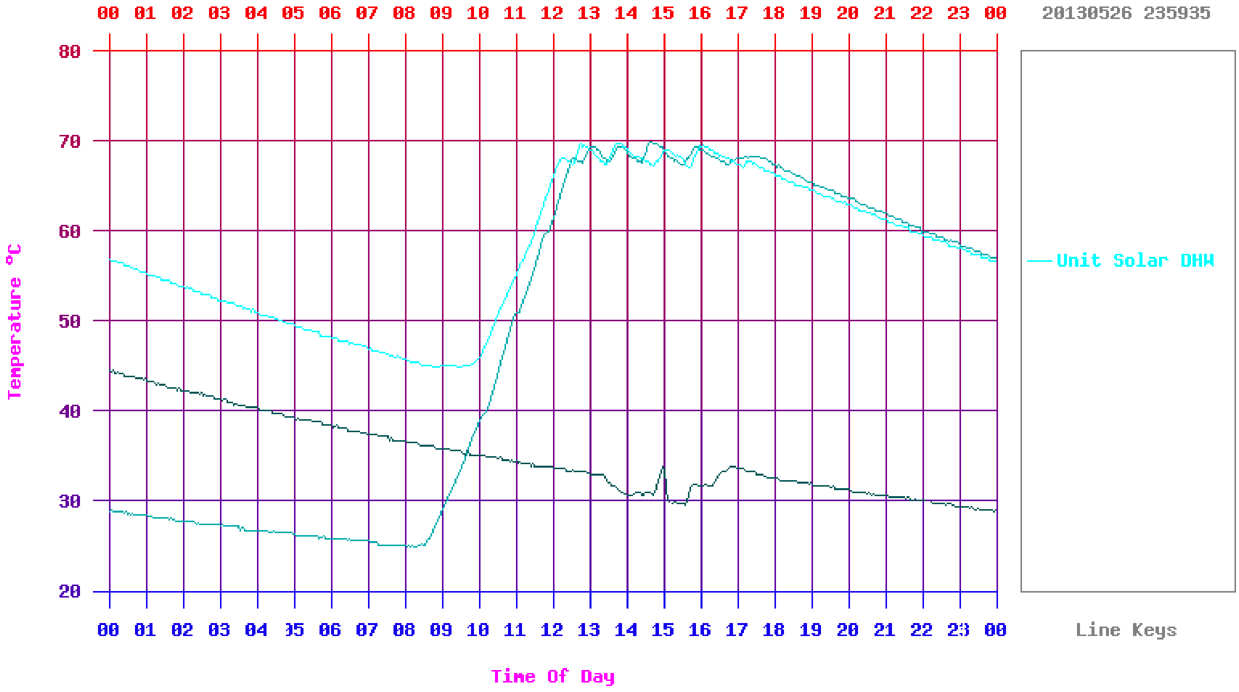
This gives T4 experience which they share with their clients, and which helps them to design better heating systems.

2.7 Solar Hot Water Installation

A Schueco solar hot water collector (pictured below), was installed on the roof to provide hot water. The pipes enter the roof through waterproof entries, and run to the cylinder in pre-insulated stainless steel pipe.

T4 connected the collector in a unique system using a very small cylinder so that the water heats to a high temperature very quickly. Once the small cylinder is heated, the heat can be diverted, and used to preheat a larger cylinder (though this has yet to be installed). The system is eligible to earn income from the Renewable Heat Incentive (the thermal version of the Feed In Tariff). The system generates enough hot water for hand washing and washing-up during the day for much of the year, due to the use of a small cylinder, but the biomass boiler will provide backup via a plate heat exchanger in winter.

The following graph shows a typical range of operating temperatures for the solar thermal system. On dull days where hot water is used, cylinder temperatures can be very low, but on bright days where little water is used, the temperature climbs rapidly to nearly 70°C, at which point it is limited by the controller to avoid scalding, and to reduce the deposition of lime scale on the heat exchange coil in the cylinder.



The periods of low temperature represent some degree of Legionella risk, but this has been mitigated by the following features of the system.

1) Mains water is used to provide domestic hot water. Mains water is likely to be nearly sterile when supplied to the building, and also low in nutrients.

2) The small size of the cylinder ensures that temperatures rise quickly to levels which are fatal to legionella. Heating of the cylinder to over 60°C, which happens frequently, will eradicate Legionella.

3) The cylinder size and frequent use of hot water combine to limit the amount of time bacteria can divide in the cylinder prior to use of the hot water.

4) The use of a copper cylinder also reduces the risk, as even very small concentrations of copper ions reduce the growth of Legionella and other bacteria.

5) Lastly, the water is used to wash hands and dishes. It is not used for showering, so opportunities to inhale inspirable droplets (PM10 or smaller), which may contain bacteria such as Legionella, are limited.

T4 therefore believes the Legionella to risk to minimal.

In future, heat from the wood burner at 60°C or more, will also be available via a plate heat exchanger to ‘top up’ the heat from the solar collector. This will provide additional Legionella control.

2.8 Photovoltaic Systems

Two separate PV systems were installed on the roof to compare the performance of monocrystalline and polycrystalline panels. The roof has a low pitch, and the panels were installed by fixing through the roof into the steel purlins below.

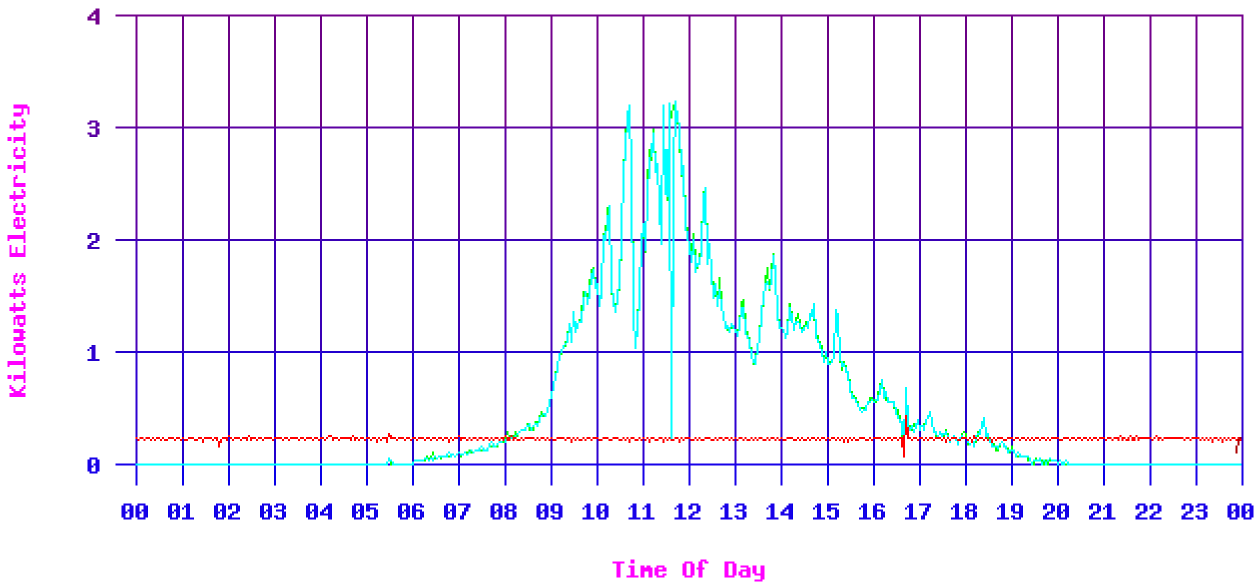
The roof was repaired before the installation to prolong its life, which in turn provides a further environmental benefit. ‘Cut edge corrosion’, where paint fails, and rust forms, at the edges of steel sheets that form the roof, was repaired before installing the panels. This involves removing loose paint and rust, then applying a silicon based primer and top coat of paint. T4 are now approved to repair metal roofs in this way.

T4 believe it is always best to repair roofs before installing solar panels, as PV and solar thermal systems can be expected to last over 25 years.

Each system comprises a Steca 3600 inverter and 15 Ying Li panels. Ying Li were chosen due to their low cost, and good score in the Silicon Valley Toxics Coalition Scorecard, Ethical Consumer Magazine and OKO report.

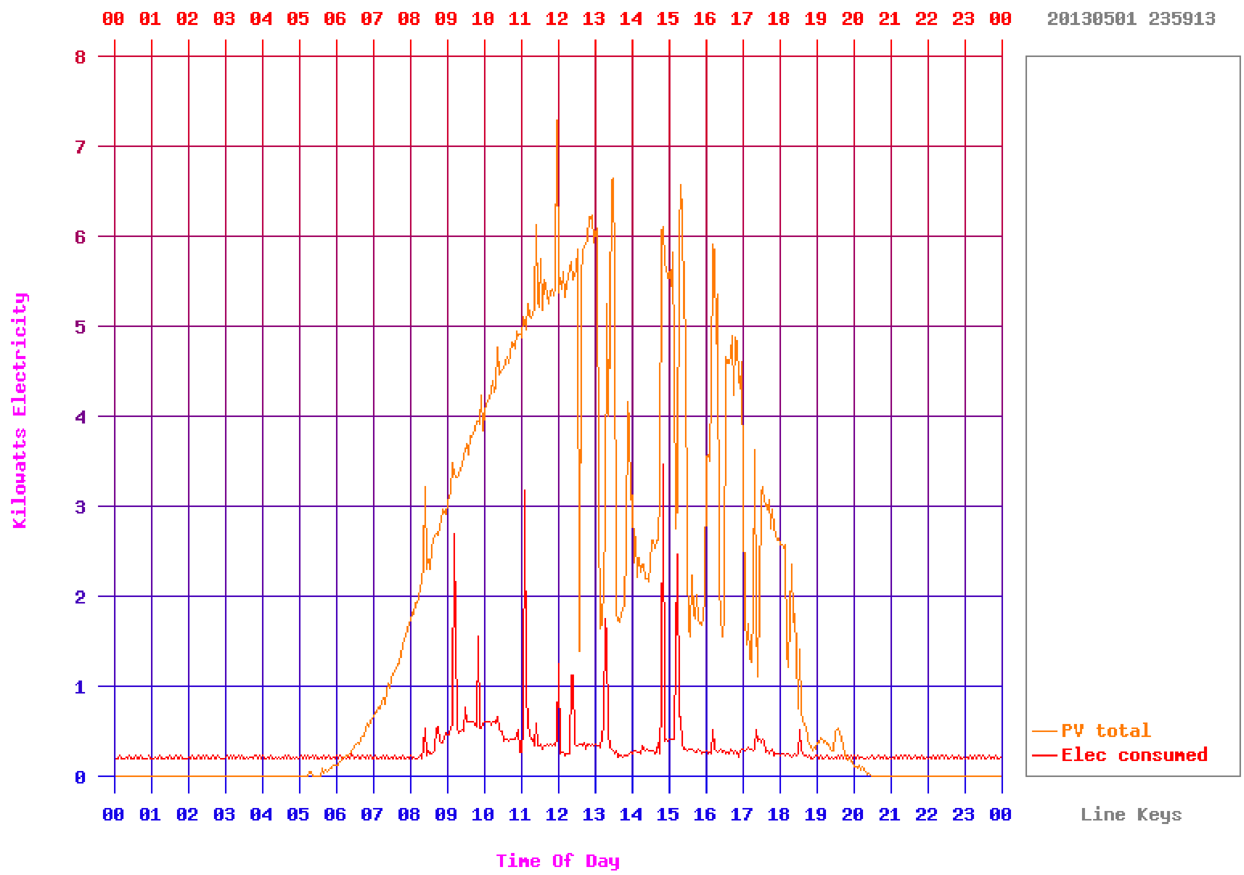
One system comprises 245W polycrystalline panels and the other 250W mono crystalline panels. T4's Open source Building energy Management System has been used for monitoring, and when the outputs from the two systems are plotted on the same graph, the two lines overwrite each other more or less pixel for pixel (showing the performance of mono and poly crystalline to be almost identical). The graph at the top of the next page shows base-load consumption (the red line) and the outputs of each of the two PV systems (green and cyan lines) on a rather gloomy Saturday.

On the basis of the first eight months operation, it would appear that although the mono-crystalline panels are significantly more expensive, the polycrystalline system has produced 0.49% more energy per installed watt capacity. Although these ratios may change over time, initially at least, there seems to be little to justify the additional cost of mono-crystalline panels.



While there will be many winter days where we are a net importer of electricity, for much of the year we will be a net exporter.

The following graph for the first of May 2013 shows electricity consumed as a red line and both PV systems total generation as an orange line. Even when the power tools or the kettle are used, consumption is generally much less than generation, and any periods of daytime electricity import are very brief.



2.9 Lighting For Safe Access

To leave the unit via the normal pedestrian entrance, it is necessary to cross the workshop and storage area.

This is hazardous in the dark, but the main lights in this area can only be controlled by a single switch at the pedestrian entrance.

This meant that people coming into the building could not turn the main lights off having reached the office, and that if the main lights were off while darkness fell, staff leaving the building could not turn the lights on until they reached the exit.

To enable safe ingress and egress from the building in the dark, LED lighting with daylight and PIR sensing has been installed near the office doors. These light a safe path across the unit, so that the main lights need not be switched on when people enter or leave at night.

This reduces the number of times the main lights need to be switched on for short periods, which is likely to extend their life, as well as save energy.

Because the PIR controlled LEDs switch off automatically, the risk of the lights being left on by accident is eliminated, and it is easier to carry things in and out of the building as manual switches need not be operated.

A minor issue with these lights is the daylight level sensing. The LEDs will switch on at ambient light levels at which it is perfectly possible to cross the unit unaided. This will waste a small amount of energy, though this is only a few watt hours per day per device.

2.10 Water Saving

The toilets were suitable for the retrofit installation of Saver Siphons, see picture on next page. Their installation roughly halves the water use of toilet flushing. Saver Siphons also have the advantage that unlike modern low-flush toilets, they do not leak constantly when the flush valves fail.

2.11 Carpet

The existing office carpet tiles were removed when the floor insulation was installed.

It was decided to use carpet tiles again, as stained or damaged tiles can be replaced without changing the entire carpet.

Huega carpet tiles from Interface (FLOR) were selected, as these have a high recycled content, low volatile organic compound content, and are certified by the Building Research Establishment Environmental Assessment Method.

The best of the old tiles were selected for reuse in the corridor between the offices, toilets and kitchen. The others were recycled.

3 Future Plans For The Unit

3.1 Daylight And Lighting Controls

To make better use of daylight (and passive solar heat), the rest of the white chipboard panels in the window frames may be replaced with high specification glazing cells. These would be argon filled, use low emissivity glass on the inner pane, and perhaps have laminated glass on the outer pane to enhance the security of the building.

T4 intends to install lighting controls to avoid electric lights operating when not required. These may include passive infrared (PIR) sensors in the toilets, and combined daylight and PIR sensors (with manual override) for the main lights in the workshop / storage area.

3.2 Light Fittings

Ultimately T4 intends to replace the current T8 50Hz magnetic ballast fluorescent lighting with more efficient fittings. A variety of modern fittings are available.

- Modern fluorescent lighting (perhaps T5 tubes with high frequency electronic ballasts) are readily available would offer modest savings, perhaps reducing the amount of energy used by 30 to 40%. These have the advantage that they are less adversely affected by frequent switching. Retrofit T5 solutions are also available, but given their cost, and the time required to install them, these appear to offer little advantage over the replacement of the entire light fitting.

- LED lighting is available which has the potential to offer greater savings, but its performance and longevity are relatively unknown as it is quite a new technology. The cost of LED lighting is still significantly higher than fluorescent lighting, but it is much more tolerant of frequent switching, and more ways of dimming LEDs are available. In our experience however, the reliability of some LED products has been disappointing.

Rather than replace the lighting in the workshop / storage area with newer fluorescent lighting, and then again with LED lighting once the technology matures, T4 has chosen to replace the existing lights with LED fittings once the old fittings fail, and / or LED lighting becomes cheaper and more reliable. This is due to the large number of lights in the workshop / storage area, and the infrequency of their use. We have also taken account of the environmental impact of replacing the fluorescent lighting before the end of its life, including the disposal of the old equipment which contains heavy metals, including rare earth compounds, and elemental mercury vapour.

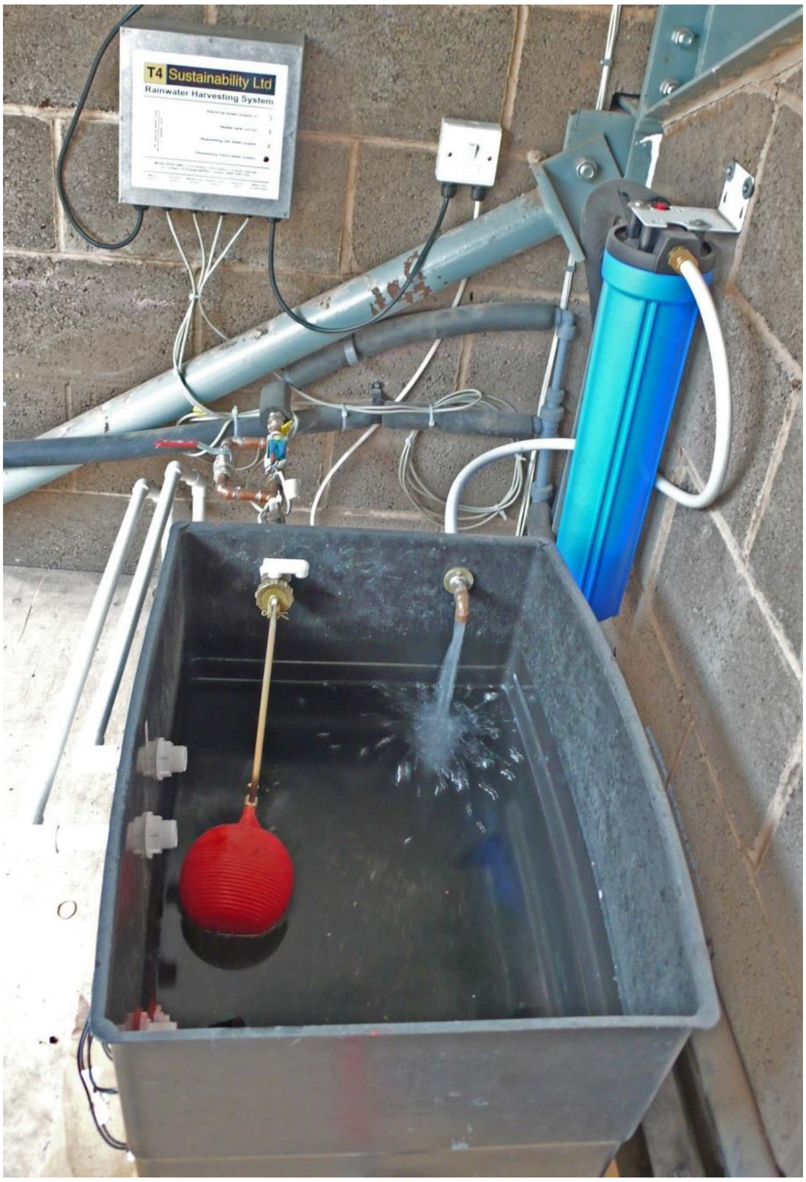
Lighting in the office may be replaced more quickly. Although natural daylight is generally sufficient to light the offices in summer, and LED task lighting can be used on each desk, the office lights are frequently used for much of the working day in winter when daylight is limited. In the office, a relatively small number of light fittings would have to be upgraded, which reduces the cost of investing in new equipment.

3.3 Rain Water Harvesting For Toilet Flushing

Water for toilet flushing is supplied by a header tank on the mezzanine, which makes it easy to install a rainwater harvesting system.

To avoid having large weights of water high up in a building, rainwater harvesting often uses large main storage tanks on, or buried in the ground outside of the building they serve. This requires the stored water to be pumped back up into the building for use, which requires energy.

T4 has previously installed rain water harvesting systems, making electronic controllers to run the pump which lifts water from the tank outside, to a small, low weight header tank, in a loft or on a mezzanine, see for example the rain water harvesting header tank and controller below, which allows the use of mains water as backup when necessary.



In this instance T4 would like to minimise energy consumption, by taking water from rainwater downpipes, and transferring it directly in storage tanks on the mezzanine which is strongly built. Although this eliminates the need for energy to pump water from storage at ground level or below, a small pump might still be required to push water through the necessary filter and other equipment.

In the past, we have reused Industrial Bulk Containers as rainwater storage tanks. We will consider if the mezzanine can carry this weight in addition to the existing loads.

3.4 Exterior Permaculture Design

T4 is responsible for maintaining the grassed area in front of the unit. Director Ed Sears has undertaken a permaculture informed design to improve the utilisation of this space. The design takes into account the constraints and opportunities that the site presents, (for example aspect, soil and access), and T4's requirements and aspirations (availability of daylight, creation of habitat, organic waste disposal, ash disposal, security etcetera).

We hope that it will be possible to dispose of food waste, green waste and possibly ash from the wood burner on site. Other materials such as shredded cardboard and paper could also be incorporated into the mix of material to be treated if this helps the process. These materials are otherwise recycled for their fibre content.

The disposal of organic waste might be achieved by composting, or by the use of a wormery. Either process would produce compost as a product, which could be used to help plants grow on site or elsewhere, and reduce the amount of waste that has to removed from the site. This would help close nutrient cycles and feed the soil.

4 Company Details

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