House build treatment for Mechanical, Electrical and Groundworks

for Megan and Niall

29-30 Ard na Si Banteer

52.129877,-8.898256 altitude 74m
fully serviced 0.14 ha (0.35 acre) empty site
in centre of Banteer village North Cork

Last updated: 4th July 2022

Background

The development has received approval for planning, and its application can be viewed at:

http://planning.corkcoco.ie/PlanningDocumentDisplay/documents/18a-224853

If you wish to explore the design in virtual reality with the lighting accurate for noon on the 1st April at the site location, I have placed a copy you can explore virtually online at:

https://twinmotion.unrealengine.com/presentation/xy1MGtTaLoDcB2Th
Password: WLj1jHVq

The design motivation is to construct a dwelling which is not only A-rated under the upcoming 2029 NZE (Near Zero Emission) regulations, which will soon replace the 2019 NZEB regulations, but also to be A-rated under my best guess at the likely 2039 energy efficiency regulations which will undoubtedly include total lifetime environmental impact including construction and materials. I also want to achieve this without spending more than a typical Irish new build, ideally around €1,500/m^2 (312 m^2 x €1,500 = €468,000). I appreciate that this will sound unrealistic, especially given recent house build price inflation, however by the time the build begins I expect house building to be into recession.

Note that it is **very important** that the bank's mortgage not value the property including land above €500,000, otherwise we will be excluded from the Help to Buy subsidy of €30,000. Please remove whatever it takes from the construction drawings to be sent to the bank to ensure they value the property including land below €500,000.

We expect the house to achieve Passive House **Plus** certification i.e. it generates as much energy in a year as it consumes, which is one step above Passive House classic. For the average climate and year at our location, I estimate this will be 4,200 kWh total energy consumption and 4,300 kWh total energy production. PHPP thinks the space heating demand will be 8 kWh/m^2/year and primary energy demand will be 36 kWh/m^2/year, with the primary energy renewable demand at 26 kWh/m^2/year, which is well below the alternative criterion of 30 kWh/m^2/year, thus enabling us to fit only twenty five solar panels for around 8 kW of electricity generation to meet Passive House Plus.

(Be aware that PHPP uses Cork Airport for the climate data. https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP says that Cork Airport receives approximately 15% more annual solar irradiation than Banteer does. It is also around 1 C warmer. PHPP is probably therefore off reality)

Robert Ryan from https://www.earthcycle.co/ is expected to be our Passive House certifier. If we are successful in certification, I expect this house to feature prominently in the national and international house building press, and of course to be listed in the official international list of certified Passive Houses. It is currently believed that this will be **the first** certified Passive House Plus in Ireland, and as such would occupy a unique place in Irish history. Given where European energy efficiency legislation is heading, sustained ongoing interest in how and why this house was designed is likely.

The site is approximately 40m wide by 35m deep, with the southern site boundary lying in the middle of a drainage ditch circumnavigating the estate. To the north is the footpath, exactly in the middle is a lowering in the footpath for vehicular entry approx 5m width. To the west there is an existing retaining wall running approx 2m high, except for a section towards the north where it drops to 1.2m high. We received planning permission to raise most of that dropped wall to 1.8m high. To the east there is a concrete post wire fence delimiting the boundary.

The site was chosen for its almost directly south facing direction and the presence of the drainage ditch, whose bottom is approx 2m below the site ground level. There ought to be static pressure underground between the soil under our site, and the exposed open air of the ditch, causing a steady flow of groundwater towards the ditch. This makes it possible to fit a ground-air heat exchanger (aka ‘earth tube’) to pretemper the air entering the MVHR inlet for the house to inhibit summer overheating. If successful, this should avoid the need for a heat pump, which has a high lifetime environmental impact.

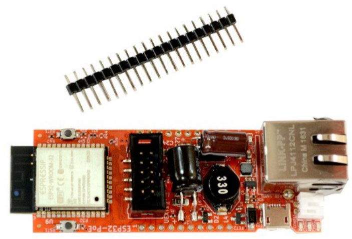
Services, which look to be electricity, foulwater and mains water, are installed on both of the sites in the north middle and their connections poke up out of the ground. I don’t see a connection to the storm sewer, however it runs alongside the footpath, and so is surely easy to connect into.

Contents

Fixed design choices

A number of design choices have already been made and are fixed. Most others depend on your expertise saying whether what is proposed is wise or not, and if not, what else to do instead.

Most of the valves, switches and lighting will be operated by these little industrial microcontroller boards (https://www.olimex.com/Products/IoT/ESP32/ESP32-POE/open-source-hardware):



These run off Power over Ethernet (PoE), and I shall be writing the control software for them myself (this is my day job, so it's not a problem, and I have already built and tested prototypes at home to ensure it will all work). I have already ordered and paid for fifty of them as the lead times are about four months.

The central house computer shall run https://www.home-assistant.io/ as its main operating system and the industrial microcontrollers shall run https://esphome.io/. Third party device compatibility with Home Assistant is a hard requirement, and as we shall see later, this greatly limits our menu of components often down to single choices.

The outdoor lighting will be provided by 250 metres of 12w/metre RGBW waterproof strips running at 24v DC. These will be PWM dimmed via MOSFETS wired into the ESP32 boards into any hue and brightness you want, all dynamically controlled from the central house computer. Each ESP32 board can drive fifteen metres of strip, with three five metre strips individually controllable per board. I expect to fit them around the garden and to act as house exterior lighting i.e. into the eaves. I have already purchased these, as the lead times are about three months and their price is only going upwards.

At full brightness the 250m of RBGW strips and their boards and other PoE items around the garden (e.g. security cameras, ground air heat exchanger intake fans, garden water pumps) would consume 4000w of power directly, including DC-DC power conversion losses. For power efficiency, I have already purchased two centralised high end three phase AC to DC power converters, one with 4000w and the other with 3000w max output at 60v DC, which is the same voltage for PoE. I have also purchased two dozen industrial 40-60v DC to 24v DC max 48w converters to provide stable 24v for the LED strips, and 150m of waterproof outdoor UV stable ethernet cabling plus 100m of thick solid copper core electrical cable to connect everything up.

The house will have a three phase 20 kVA domestic mains power connection. The inverter will be the Fronius Symo GEN24 Plus with 8 or 10 kVA capacity costing around €3,700 inc VAT and delivery (https://www.europe-solarstore.com/solar-inverters/fronius/fronius-symo-gen24-plus/fronius-symo-gen24-10-0-plus.html), paired with the three phase Fronius Smart Metre TS 65A-3 (https://www.europe-solarstore.com/fronius-smart-meter-ts-65a-3.html) at the mains power inlet and electromechanical mains inlet relays which default to no contact, so mains power can be completely isolated from the house three phase network. This inverter works well with Home Assistant, and can switch to off grid power generation if mains drops out. The lithium battery storage will be BYD Battery Box HVS (https://www.europe-solarstore.com/batteries/manufacturer/byd/byd-battery-box-premium-hvs-5-1.html) either with 5 or 7.5 kWh capacity costing around €4,700 - €6,416 inc VAT and delivery. DHW solar bypass is to be provided by the three phase Fronius Ohmpilot 9.0 (https://www.europe-solarstore.com/fronius-ohmpilot-9-0-3.html) costing around €1,037 inc VAT and delivery, which can supply up to 9 kW of heating to the thermal store. I have not purchased these yet as there are none to buy anywhere in Europe, however I intend to do so as soon as stock is resupplied which is expected to be around October 2022. As there will be a short window before stock disappears again, I cannot wait.

I have not purchased anything else currently, nor do I intend to until your final construction drawings are complete. I needed some of the above to install a temporary onsite office and secure container storage in order to take deliveries of the harder to find components over the next year.

Malleable design choices

Electrical

As suggested earlier, the mains AC shall be three phase, thus enabling solar mains contribution of up to 11 kW, though neither our inverter nor our solar install will be capable of so much. As described already, it is expected that up to 10 kW of 60v DC power (170 amps) shall be available for down conversion as needed to 24v and 12v DC by industrial DC-DC converters near to the point of need. The reason why the 60v DC power ring is attractive to me is because I don't need a RECI electrician to modify it, as it is below the legal voltage threshold for requiring a registered electrician. This, in turn, means I can do most of the electrics myself, which enables a degree of customisation not possible in a traditional build (plus, it also saves money both now and throughout the house's lifetime).

There will of course be a single phase 230v AC ring main for compatibility with consumer appliances. I assume (though I have no proof) that the Fronius inverter and the three phase DC converter will rebalance the phases if they experience minor mismatched loads, so I would assume that one would run single phase rings off each of the three phases designed to balance load as well as possible. Apart from consumer appliances such as cooker, dishwasher and dryer etc, I do not expect much use of single phase - the thermal store heating is three phase, the DC generation is three phase, most of the rest I expect to be DC powered such as lighting and the thermal store water pump.

Expected sites of substantial AC power consumption:

1. Kitchen (cooking hob, oven, fridge and freezer, up to two dishwashers). Single phase.
2. Utility (washing machine and dryer and MVHR unit, potential future heat pump). Single phase.
3. Potentially the external sliding front electric gate, though I note a lot of them actually run on 24v DC.
4. Potentially the DHW circulation pump, as it would run continuously. Single phase.
5. External cavity for future endless pool (32A). Probably single phase.
6. External future large capacity industrial oven for soil sterilisation. Probably three phase 25A?
7. External future EV charger. Almost certainly three phase 55A, the Fronius Wattpilot 22 J (https://www.europe-solarstore.com/fronius-wattpilot-go-22-j.html) costing around €1,000 inc VAT and delivery.

Note that every toilet needs both a 230v AC and a 60v DC connection nearby. The toilets will eventually all have affordable Korean clones of Japanese smart toilets (https://vovoeu.com/pages/bidet-seat), these run off 230v AC, but I may try to source 24v DC alternatives. A waterproof junction box adjacent to the toilet capable of later taking a RCD is sufficient.

I am aware that building control as demanded by the banks may require traditional lighting to be installed in order to achieve sign off. I would be keen that service cavities be easily accessible to me so I can later replace that lighting with my own. To this end, my architect has squeezed in a generous 50 cm service cavity between floors.

Lightning and Fire Sprinklers

I would like a simple mains water connected pipe connected to fire sprinklers running along the ridge of the roof internally. I would suggest a simple manual valve on the outside of the building to turn it on kept inside a box to prevent accidentally turning it on.

The same pipe can then act as a ground for lightning strikes, by electrically connecting it to a metal roof rail atop the ridge onto which I can connect a safety harness if I go up onto the roof.

I don’t think more sprinklers than that would be worth it. Statistically the most likely source of fire will be in the kitchen and main living space, and those are covered very well by a simple sprinkler pipe along the ridge thanks to the vaulted kitchen and living space.

Note that Home Assistant knows in the case of fire to turn everything off including ventilation, and it is connected into the household fire detection system. I wouldn’t want it to automatically activate the sprinklers however, I think those ought to be manual as there is no point dousing the house in water if it can be avoided.

Ventilation

The ground air heat exchanger (Earth Tubes)

The ground air heat exchanger is assumed to be [the 200 cm Awadukt Thermo 42m long model] costing €4,200 inc VAT. It will pretemper the MVHR inlet air by a percentage to ground temperature depending on air flow i.e. if the external air is X celsius and the ground temperature at 1.5m deep is Y celsius, the pre tempered air will be X + (Y - X) * R degrees. According to my regression of the manufacturer specifications for the DN 200 model:

- @ 150 m3/hr: R = 66% warming; R = 62% cooling.
- @ 200 m3/hr: R = 63% warming; R = 58% cooling.
- @ 250 m3/hr: R = 58% warming; R = 54% cooling.
- @ 293 m3/hr: R = 50% warming; R = 51% cooling.

The reason why cooling has reduced R is due to moisture condensation when warm air is cooled, the energy goes into liquefaction. This is why in summer a pump must be run daily to extract the condensate from the condensate trap.

Note that the 200 cm model has a max airflow of 293 m3/hr, which is less than the MVHR unit below. I expect to fit a boost inlet fan and a temperature and humidity sensor at the inlet of the ground air heat exchanger. This is to prevent cavitation in the inlet fans, which would burn out their coils, however note that the MVHR unit is controllable by Home Assistant and we shall prevent via software it ever running faster than the pipe allows.

Note that ground air heat exchangers have a failure rate of about 50% within ten years, mainly due to either unanticipated poor performance, or incorrect installation. Therefore the ability to later retrofit a heat pump if this occurs is **vital**.

The MVHR unit

It turns out that out of the **entire** MVHR market there is only one possible choice here given that I want to easily integrate the ventilation into Home Assistant, as only a single manufacturer supports open source control without trying to lock you solely into their proprietary smart home system. This is the Zehnder ComfoAir Q series (the Home Assistant plugin is at https://www.home-assistant.io/integrations/comfoconnect/). There are three models:

Q350
Q450 (min 70m3/hr, max 345m3/hr, heat recovery 88%, uses 0.21 Wh/m3, 47.0 dB)
Q600

Fortunately all three are on the list of passive house certified components (here is the page for the Q450 HRV: https://database.passivehouse.com/en/components/details/ventilation_small/zehnder-group-nederland-bv-comfoair-q450-hrv-comfort-vent-q450-hrv-0954vs03).

An all-Zehnder Q450 whole house kit is available in Ireland from https://www.versatile.ie/product-page/150m2-complete-home-heat-recovery-pack for about €5000 inc VAT. **Note this is missing the optional LAN module which we absolutely need for Home Assistant control.** There are at least three further Irish vendors of Zehnder kit, and at least six Irish installers from what I can quickly find. It is therefore probably safe for parts/servicing etc long term.

The MVHR air inlet is the ground air heat exchanger, though this ought to be easily retrofittable with an alternative air inlet if a heat pump is later needed. The MVHR air outlet ought to be the greenhouse, so the plants can benefit from the slightly warmed air and the slightly raised CO_2 levels for improved yields.

Cooking air extraction and Hob

Airtight houses normally fit recirculating cooker hoods, with carbon filters to remove cooking contaminants, before returning that same air into the house.

In our current home I have PM2.5 sensors around the house. It is a very leaky house and we have a cooker hood, yet PM2.5 has been seen to build up to very high levels not just in the kitchen, but getting itself around the house into the bedrooms. I am therefore highly unconvinced that a recirculating cooker hood will ever be of much use, especially once any carbon filters get a few weeks onto them. Despite the obvious impact of lots more ventilation on a passive house, I don't see any alternative to external venting. I believe, however, that this can be made to not suck for a reasonable cost.

An insulated 150 mm airtight cooker hood damper kit suitable for air blower test venting to outside costs €90 inc VAT https://munsterdiy.com/collections/ventilation-dampers/products/150mm-airtight-cooker-hood-damper-kit-blower-door-certified.

This IKEA induction hob has a built in hob-level extractor fan which can vent to a 130 mm pipe. Costs €1250 inc VAT https://www.ikea.com/ie/en/p/foerdelaktig-induction-hob-integrated-extractor-ikea-700-black-50449403/. It runs at 245m3/hr normal, 550m3/hr at high, 700m3/hr at boost.

We also need a range hood to vent the oven. This IKEA model is both quiet and powerful for €500 inc VAT https://www.ikea.com/ie/en/p/foeljande-wall-mounted-extractor-hood-stainless-steel-60392321/. It runs at 218m3/hr normal, 434m3/hr at high, 810m3/hr at boost. It vents to 150 mm pipe, but has an adapter for

120/125 mm pipe. This range hood would be power on-off controlled by Home Assistant via a PM2.5 sensor, so if and only if the air quality deteriorates would it automatically switch on. From our current home, I can say with authority that most ordinary PM2.5 comes from the hob e.g. frying, however if you burn something in the oven, or don't clean it frequently, then the oven can dump out **enormous** quantities of PM2.5.

Two separate ventilation units probably seems overkill, but I'm minded that they vent two very separate things: the hob ventilation will have to handle large amounts of grease and fat, and indeed, will do a very great job of sucking oil splatter down itself rather than coating everything else. So on that alone, it's a great move because it avoids a lot of cleaning. Meanwhile, the range hood normally deals with smoke and/or steam, and is more for emergencies; it won't be on unless the house's normal ventilation gets overwhelmed, at which point it then roars into action. And just to be clear, the house ventilation is capable of running itself up to 290m3/hr, and possibly temporarily prioritising the kitchen over the rest of the house.

Quick summary of ventilation so far:

- The whole house heat recovery ventilation peaks at 293 m3/hr. It must balance air brought in with air expelled in order to perform heat exchange. We can therefore treat it as balanced i.e. it does not supply additional air it itself does not exhaust.
- The proposed induction hob will exhaust 245 - 700 m3/hr.
- The proposed range hood will exhaust 218 - 810 m3/hr.
- Therefore the kitchen exhaust may try to expel up to 1,510 m3/hr from an airtight house which has no incoming air inlet to source from.

Obviously driving up to 1,510m3/hr out of the kitchen in an airtight house simply won't work. So I would suggest an additional 150 mm 'emergency' air inlet pipe to supply the additional fresh air. I would suggest putting a motorised control on to that inlet direct from outside so it is usually closed. This normally closed valve costs €180 inc VAT https://munsterdiy.com/collections/ventilation-dampers/products/150mm-motorised-damper and it requires 230v AC applied to make it open. As usual, we would have Home Assistant via an ESP32 board with mechanical relay open that valve when it turns on the range hood, and we just need to ensure that that extra air inlet is emitted perhaps at the base of the oven to absolutely minimise the amount of cold air allowed to enter the house.

NOTE that this may need the foundations modified to have an underfloor pipe laid such that the emergency air inlet emerges just underneath the front of the oven, thus blowing the PM2.5 from the oven up into the range hood for expulsion.

NOTE that this motorised control valve is clearly a thermal bridge! One may wish to prefix it with the same insulated damper kit above in order to reduce thermal bridging.

Finally, the obvious place to place the inlet for this emergency air ventilation is high on the wall above the external greenhouse-conservatory. Ideally the outlet should not fire oil droplets and gunk over the greenhouse roof, so an alternative exit not above the greenhouse would be ideal (would underneath work?).

Space Heating and Domestic Hot Water

The house does not require much space heating for an entire week even in the depths of winter, so I reckon a big tank of water is good enough:

- 1000 litres of water heated to 60 C contains 45 kWh.
- 1000 litres of water heated to 90 C contains 80 kWh.
- 1000 litres of water will sink 1.16 kWh per degree temperature raised.

For the summer, I expect to only heat the top 500 litres or so, and reduce operating temperature to 60 C to reduce house overheating (this being controlled by a physical switch to swap the Fronius Ohmpilot from using the lower immersion to the upper immersion).

The proposal is to charge the thermal store at the weekends, when Electric Ireland will give you free electricity, or if they remove that plan then using cheap night rate electricity. Obviously any power generated by the solar panels not captured by the lithium battery storage will charge the thermal store - only if the batteries AND thermal store are full will excess solar electricity be contributed back to the grid. In the Irish winter it is not uncommon to get the odd bright winter day, that may be enough to charge some of the thermal store.

PHPP thinks that this house will consume around 2,600 kWh per year for DHW and space heating with the worst month being December, at 677 kWh, where the average temperature is 6.1 C. One would need on average 180 kWh for eight days in December. Therefore a thermal store of 2,250 litres @ 90 C would be sufficient for eight days of space heating in the average case.

Let us imagine the worst possible eight days, which I simulated by reconfiguring the location in PHPP to be Stockholm in Sweden. Now one would need an average 490 kWh for eight days due to it being -3.2 C outside. This would be 6,125 litres @ 90 C.

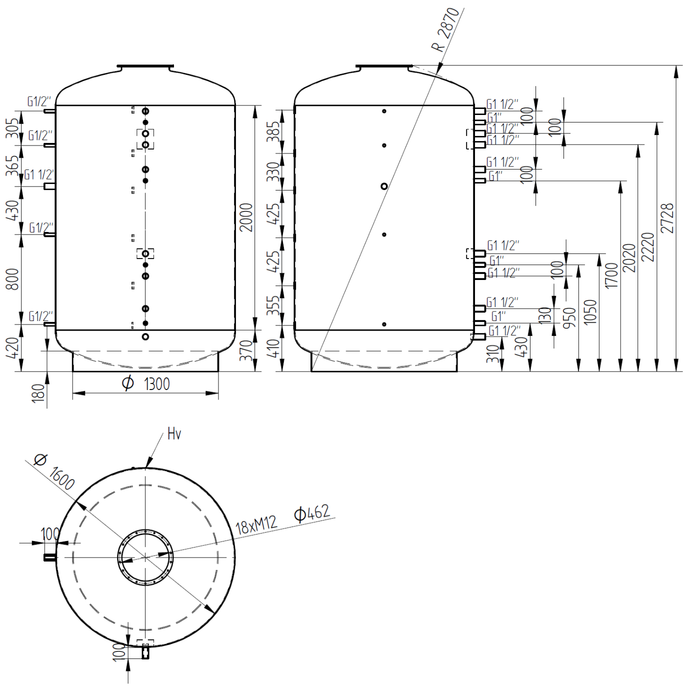
Let us imagine somewhere in between, Dundee in Scotland where the temperature averages 4.0 C in winter and one would need an average 288 kWh for eight days. This would be 3,600 litres @ 90 C.

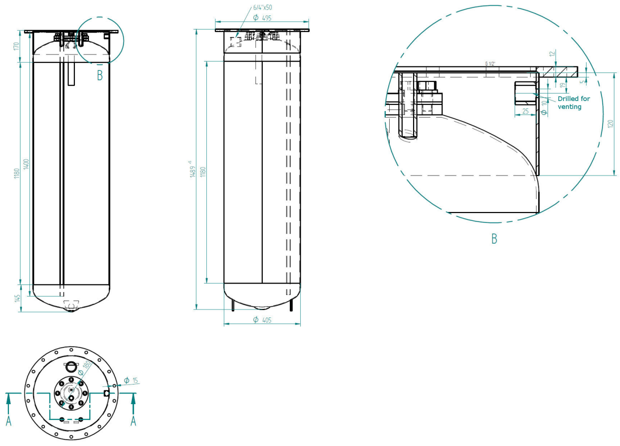
All this suggests that a 5,000 litre tank is the safe choice, and on my instruction Stephen my architect designed the house to accommodate a 5,000 litre tank. However, a 3,000 litre tank is much less unwieldy, so I will now describe both options. Please tell me which option you think is best.

The Thermal Store

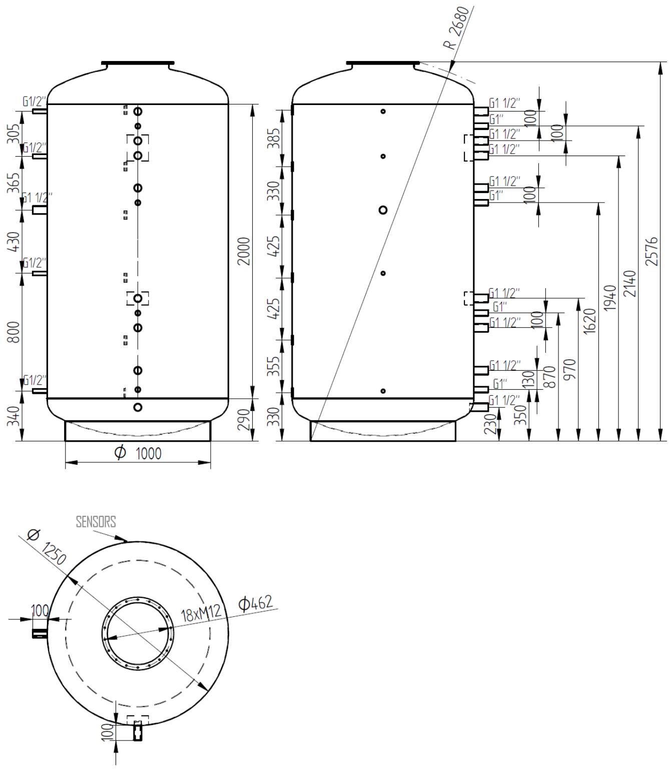
I have used as my model the thermal stores made by a company called Linszter in Eastern Europe. I am not locked into this specific vendor, they just seemed reasonably priced and had lots of useful detail online for me to work with, plus they use continental European thickness of insulation instead of the thin stuff common over here. They sell all over the EU and UK and appear happy to arrange delivery to Ireland for a fee. I examine only their models containing an internal 180 litre DHW tank, so domestic hot water gets mains pressure.

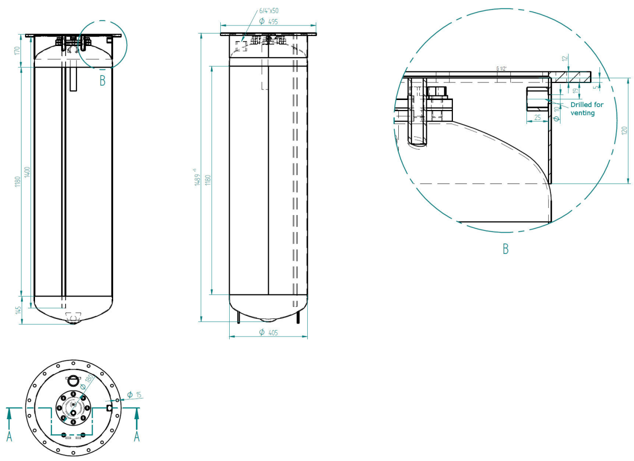
The 5,000 litre model
https://linszter.com/de/de/heizung/warmwasser-pufferspeicher/lmt-5000-0v-z180l costs around €3,600 inc VAT plus 100mm insulation
https://linszter.com/de/de/heizung/isolierung/lmt-5000-0-2v for €727 inc VAT plus jacket
https://linszter.com/de/de/heizung/isolierung/5000l-1800-x-2900mm for €236 inc VAT. All in: €4,536 inc VAT.
It is 2.8m tall and 2.0m wide.





The 3,000 litre model https://linszter.com/de/de/heizung/warmwasser-pufferspeicher/lmt-3000-0v-z180l costs around €2,150 inc VAT plus 100mm insulation https://linszter.com/de/de/heizung/isolierung/lmt-3000-0-2v for €523 inc VAT plus jacket https://linszter.com/de/de/heizung/isolierung/3000l-d1250-1450x2700mm for €182 inc VAT. All in: €2,855 inc VAT, which is €1,681 less. It is 2.7m tall and 1.5m wide.





In addition to its 10 cm of insulation (maybe 0.3 W/m2K?), I intend to place the tank plus its surrounding piping and equipment inside a very well insulated airtight box of Kingspan Sauna Satu insulation board which is happy at a constant 100C unlike most insulation. It is 3 cm thick with a U-value of 0.023 W/m2K. It costs €23 inc VAT/m^2. Assuming a box 1.5 m x 1.5 m x 2.8m (21.3 m^2), at 90 C a single thickness would leak a mere 34 watts of heat into the house if the box is airtight! I figure this would be important to ensure that the layers of water temperature in the tank remain stable over time, but also to prevent overheating in summer due to heat lost from the tank.

Note that you can get these tanks with one or two heat exchanger coils as well, and a wide variety of other configurations, including custom added extra ports, though I expect the standard config above is sufficient. Into the bottom two and upper two G 1 ½ ports I would install four 9 kW three phase immersion heaters (https://linszter.com/de/de/heizung/tauchheizung/etk-9-0-kw-400v), with the redundant immersion being there to avoid having to drain the tank when an immersion inevitably dies (I would manually switch it over). There are four G 1 ports and four G ½ ports remaining spaced roughly equidistantly up the tank for pipe connections.

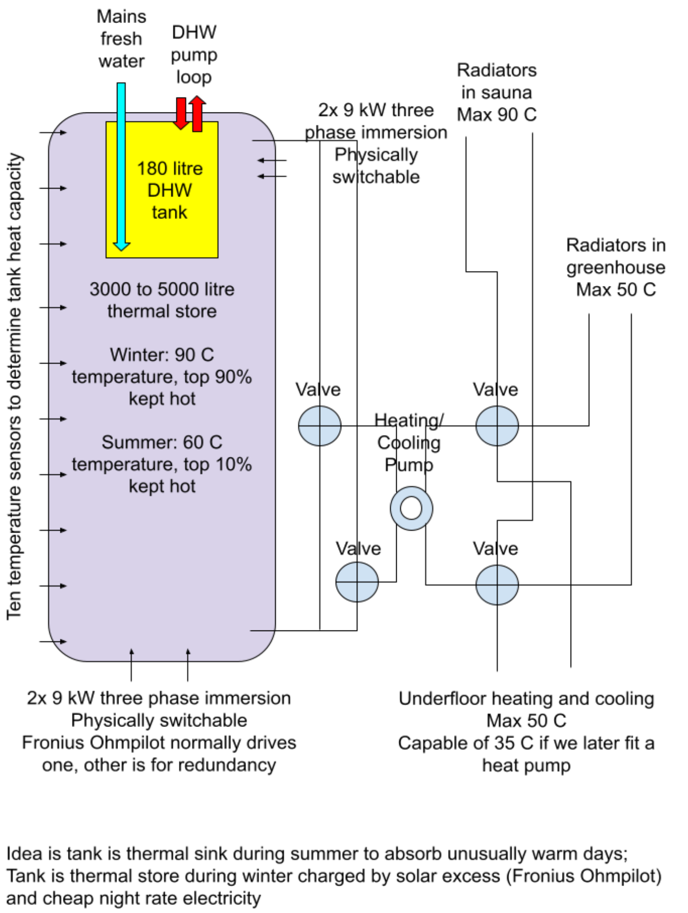
The Thermal Store would be connected to four things:

1. Its internal DHW tank is connected to the DHW loop (see later).
2. Radiators in sauna to quickly heat and cool the sauna (unmixed, 60 - 90 C).
3. Underfloor heating and cooling (temperature mixed to 35 - 40 C).
4. Radiators in the greenhouse (temperature mixed to 50 C).

To mix down the temperature except for DHW (which is covered later), water is drawn from the top and bottom of the thermal store to produce the desired temperature, then returned to the thermal store in the middle? I am aware that it is important that water layers itself in temperature in a column (i.e. thermocline), and it is important to not disturb those layers if you want to preserve the cold layer at the bottom and the hot layer at the top. This is a bit beyond my experience and understanding however, so your advice on this would be appreciated. **Would the 5000 litre tank thermocline layer better than the 3000 litre tank?**

In the Summer, one might draw only cool water from the bottom, and return warmer water to the middle, as a method of sinking excess heat on unusually hot days, which tend to be sporadic and not long lasting in Ireland. Perhaps up to 25 kWh could be thermally sunk using this method?

I made a diagram to be clearer:



Normally one would use a fixed mixing valve such as https://linszter.com/gb/en/heating/mixing-valve to produce 50 C or 35 C from a hot and cold source. However, because the thermal store's operating temperature varies by so much, one would need a set of two with different settings, and then have valves switch between them. I would therefore suggest fitting a thermostatic mixing valve which mixes to a specific temperature independent of inputs, however I am aware that they can be unreliable when it is 'radiator water' flowing through them with all the gunk that contains. Equally, one can buy a lot of them from Aliexpress for under €20 each, and just keep swapping them out as they clog up. Alternatively, fitting a replaceable filter just before the thermostatic valve might do the job nicely, and be beneficial at keeping the tank water 'clean'. As the store is vented, you're going to get sludge build up, so capturing the sludge into a filter seems sensible.

Speaking of which, we ought to try to stick to stainless steel components where possible to reduce galvanic corrosion. If we can avoid brass and copper, we will reduce the mismatch of ions in the system and keep the sludge build up lower. **An open question here** is whether to choose fluid inhibitor, which would be very expensive for 5,000 litres, or a sacrificial anode of magnesium? Note that the house design deliberately incorporates ample top access space to the thermal store, precisely in order to be able to replace metre long anodes without too much hassle, or to top up the store if its water level gets too low.

Note that in the design above one can do exactly one of at any one time:

1. Heat or cool the sauna.
2. Heat or cool the greenhouse.
3. Heat or cool the internal floor (probably in the living area).

I don't personally think this will be a problem, the house has such excellent insulation it can go periods without space heating.

The conventional choice would be to fit a 230v AC circulating pump between the thermal store and these three. The problem with those is they run at a fixed speed, and they are either on or off. I would suggest fitting a DC pump here instead, then I can vary its speed by PWM e.g. the sauna gets the pump running at 100% to minimise waiting times, whereas the space heating may only need the pump running at 50% or less, indeed Home Assistant could dynamically vary the pump speed according to space heating needed using a Kalman filter algorithm, which prevents on-off cycling of the space heating pump.

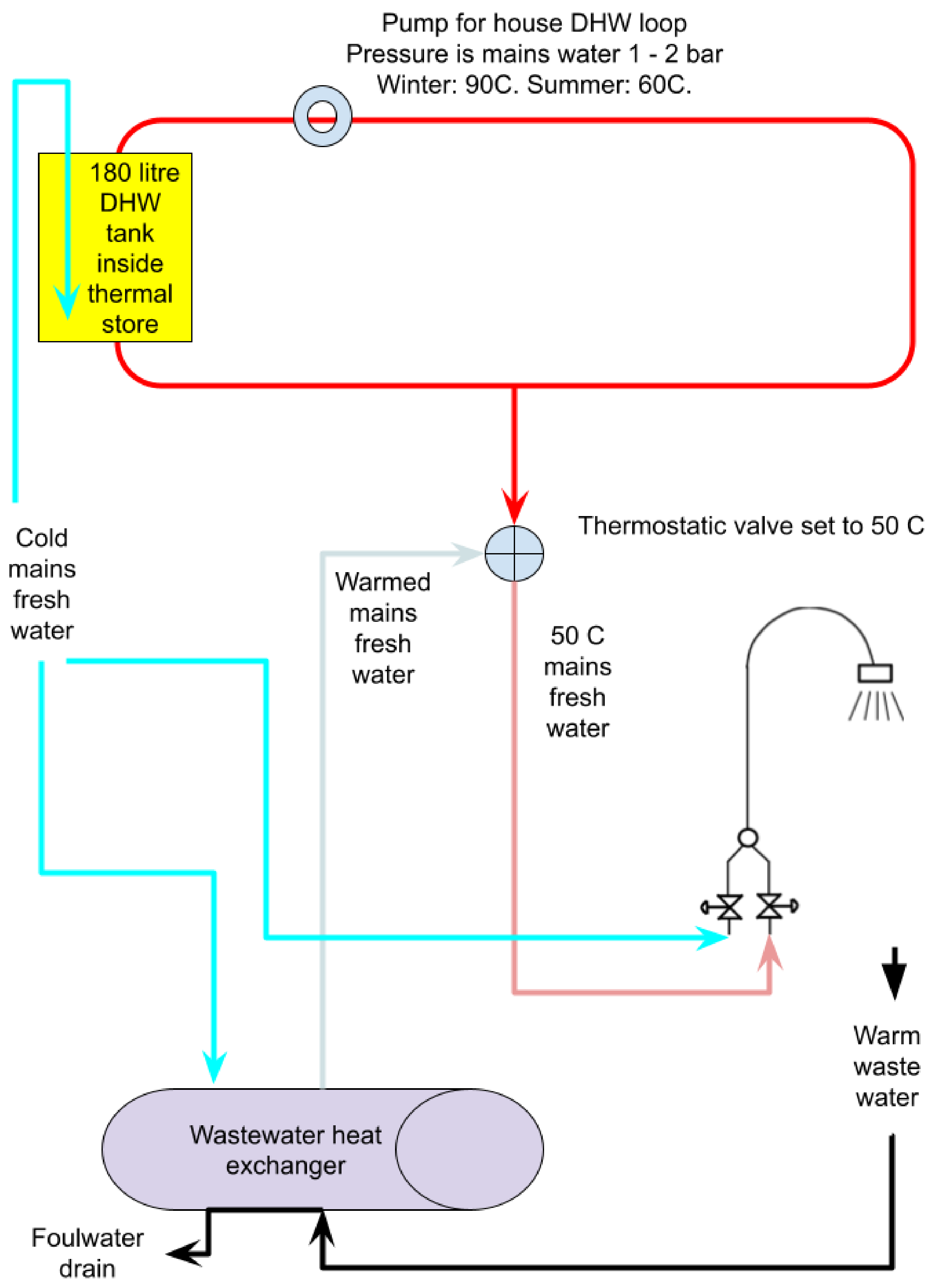
The Domestic Hot Water loop

The DHW loop is pumped constantly in the daytime hours to ensure rapid hot water from every tap, and as such it is either on or off - varying flow does not seem useful to me. I would suggest that for this a low wattage 230v AC circulating pump is the obvious choice, with a mechanical relay to turn it on and off. I would propose that the DHW loop is kept at the thermal store working temperature (90 C in winter, 60 C in summer), and is mixed down to 50 C by a local thermostatic valve just before exiting the hot water tap in question. As mentioned earlier, one can get a job lot of thermostatic mixers from Aliexpress for under €20 each, one might spend more on frequently used hot water e.g. the kitchen, but I don't mind swapping out units as they fail.

As the house is so energy efficient, energy losses from DHW going down the drain consume a large proportion of total house energy unless a heat exchanger is used to recover heat from waste water. These are expensive and are prone to getting clogged with gunk (especially the smaller ones), so I propose fitting one large central unit which is easily removable so it can be cleaned. From the Passive Certified Components Database, the largest available unit is the Showersave QB1-21D (https://database.passivehouse.com/en/components/details/heat_recovery/q-blue-bv-showersave-qb1-21d-20-lmin-1047sr03). It recovers 66% of the heat at 20 litres/min, 75% of the heat at 8 litres/min. Costs €1015 ex VAT. My proposal is that the cold water input into the thermostatic mixer taking the DHW loop down to 50 C comes from the Showersave unit.

Note that the Showersave unit places a 20 ltr/min maximum flow limit on all the DHW usage combined. Rather than reduce each shower to a hardcoded low maximum flow which equals a piddling flow shower, I would suggest placing a valve switched in flow limiter on every DHW consumer to prevent unpleasant temperature shocks caused by oscillating low flow pressure, and have Home Assistant switch those on as needed. Then each shower remains capable of maximum flow if used individually.

Here is a diagram explaining my proposal for DHW implementation:



The Sauna

It is not common for a Passive House this far south to have a Sauna, as these thermally dump into the house, causing overheating. However I believe that if we pump heat out of the Sauna after use back into the Thermal Store instead of letting it dump into the house, this can work.

To this end I propose that the Sauna (which measures 2.3 m x 1.3 m = 3 m^2 in the planning permission) gain a false open vented wall behind which there are two large radiators top and bottom. Note that this false wall may require slightly expanding the size of the Sauna from the existing plans. When the Sauna is activated, the thermal store pumps 90 C or 60 C rapidly into those radiators, quickly heating the Sauna. Then the Sauna's traditional Finnish 3 kW stone heater (https://narvi.fi/en/product/narvi-minex/, costing €450 inc VAT) is switched on to provide the traditional dry Sauna experience at 80 C.

When the Sauna is deactivated, the stone heater is turned off and cold water is pumped through the radiators, rapidly reducing the temperature of the Sauna. This should reduce thermal dumping by the Sauna into the house to an acceptable level. Obviously this will produce condensate; however, as Saunas are tanked with drain this won't be an issue.

Cold Water

There are three sources of cold fresh water in the house:

1. Roof harvested rainwater (non-potable).
2. Softened mains supply (potable).
3. Treated mains supply (potable).

Be aware that the mains supply into the house is a half inch pipe, and I can't see it supplying more than 12 Ltr/min. It may be wise to utilise both mains supply pipes into the site, and then we get 24 Ltr/min.

Roof Harvested Rainwater

This comes from a suspended tank mounted on the west of the house. The tank should hold up to 10 m^3 of rainwater, which is 10,000 litres, and it supplies a wide diameter pipe (probably 25 mm diameter to accommodate the very low 0.1 bar pressure = 11 ltrs/min after 20 metres) running along the top wall of the greenhouse in order to water the plants. At the end of that pipe, it reenters the building, where it supplies the ground floor toilet next to the greenhouse. On the other side of the house, it also enters the house to supply the master bedroom en suite toilet.

It is important that there is a fallback ability to supply both pipes from mains water, firstly if the tank ever ran out or failed, but secondly because almost certainly we won't initially install the tank as it costs at least €5,000, and that is cash flow better spent elsewhere in the early days. Regulations require separation of potable water from contamination by non-potable, I don't know exactly what those are but I assume some hand turned valve would do it. We would need some mechanism to reduce pressure from mains (1 - 2 bar) to 0.1 bar.

The upstairs toilet is always mains water filled, incidentally, and that is immediately adjacent to the roof harvested tank if that is useful.

Softened Mains Supply

I expect to fit a Clack 30L water softener to the mains water supply just after it enters the house (costing €492 inc VAT at https://waterpartsdirect.com/product/10l-clack-water-softener/?c=d9703a36dec2) before it goes into anything else. This will remove calcium salts from the hard water area which is Banteer. This unit can sustain 23 ltrs/min of mains water supply, enough for two showers (see below). Supposedly €7/person/yr for salt, so for five adults, €35 per year for salt.

The drain from the water softener ought to go foulwater, as the increased salt content is not good for growing plants. I expect to fit this in the upstairs toilet room.

Treated Mains Supply

I intend to further treat the softened mains water supply to remove chlorine, fluoride and other components to produce an especially pure water pleasant to drink. This would present as a drinking water tap in the home office and in the living space downstairs.

The cheapest decent reverse osmosis system that I can find including lifetime running costs appears to be the Pallas 5T-BP incl booster pump costing €302 inc VAT (https://waterpartsdirect.com/product/pallas-5t-bp-reverse-osmosis/?c=d9703a36dec2), which is a five stage unit with booster pump (2x carbon, 2x sediment, 1x membrane).

In the UK it is cheaper: a Pallas Viva five stage with booster pump (i.e. identical) costs about €234 inc VAT (https://www.fountainsofteners.co.uk/pallas-viva-5-stage-reverse-osmosis-with-pump-c2x11546492). 12 months of four replacement filters costs about €47 inc VAT (https://www.fountainsofteners.co.uk/pallas-5-stage-ro-replacement-filters-12-month-c2x14576513). New membrane (2-3 years) costs about €43 inc VAT.

If at all possible, we should not drain the considerable dirty water disposal from the reverse osmosis tap to foulwater, which is wasteful. Ideally send it to the external roof rainwater collection tank. If we do do this, therefore the reverse osmosis unit needs to be placed upstairs (I suggest also the upstairs toilet room), so it can drain into the rainwater tank, and its outlet needs to drop down from the ceiling into the kitchen (and possibly with another tap upstairs in the office). The Pallas unit requires an input pressure of 1 to 3 bar, which ought to be about right for mains water. I would suggest locating this in the home office.

Other things to be aware of

- There is a whole site rainwater harvesting solution in addition to the roof rainwater harvesting solution. The vertical levels to achieve gravity only water flow are particularly tight, but we hope to achieve it. After the site rainwater has been polished by a reed bed, it is stored in an underground tank which is later pumped into an aboveground tank when there is spare solar electricity. If that underground tank overflows, it does so into a buried soakaway cage located near the rear ditch. I would propose that the ground air heat exchanger be located between the soakaway cage and the ditch, though the 42 metres of heat exchanger pipe seems to me to be not quite long enough (depends on angle exiting the house!).
- Solenoid valves consume a fair bit of energy when actuated, and that can quickly add up, which is a problem in an especially energy efficient house. Motorised ball valves don't have this problem, but cost a lot more. Be aware you can get five 12v motorised ball valves from Aliexpress for the price of a 'proper' 12v motorised ball valve, and I'm not sure if they last one fifth the time. I'm not opposed to swapping out the cheap ones as they fail from a job lot.
- One would normally not fit flow meters wherever there is a valve as they're overkill, however for the price of them off Aliexpress I'm minded that we should (unlike pumps, there is little to go wrong in a cheap flow meter). Home Assistant can record historical flow rates over time and that can be used to detect things like build up of sludge. It also obviously quickly identifies which valve has failed.

- A hall effect current sensor can be bought for around €0.50 and wired very easily into the ESP32 to implement a cheap ‘flow meter’ for wires carrying AC and DC current. I expect to fit a lot of those as they greatly help with determining where energy consumption is going.

Nice to haves

Stuff nice to have but don’t worry if it’s not practical:

1. Cooling of the larder from the thermal store. Not worth fitting a special pump, piping and a radiator just for this. If one did do so, condensation would need to be dealt with.