Design 6: The Narrowboat Innisfree

1. Background
I bought the narrowboat Innisfree in June 2016 in order to break a long-term dependence on rented accommodation despite not having the financial means or inclination to contemplate a house purchase. My available financial resources were sufficient to purchase outright and leave a surplus for upgrades. Additionally, although at the time I felt inclined to settle in Hebden Bridge, the option of moving my home was an attractive one.

Close friends who already owned a narrowboat offered me first option when they decided to sell, which made the purchasing decision easier. An offer of a mooring arose at Redacre Growing Project in Mytholmroyd, where I had already signed up for the waiting list for an allotment plot. This design describes the boat and its integration into the wider site. It is closely related to Design 7, which describes my growing space at Redacre.

Design mostly took place during the few months immediately after I bought the boat in summer 2016. Some implementation (e.g. proper mounting of the solar panels) extended into 2017, and tweaking was ongoing over the time I lived on the boat, until I left England for Portugal in September 2020.

Design Process
SADIMET

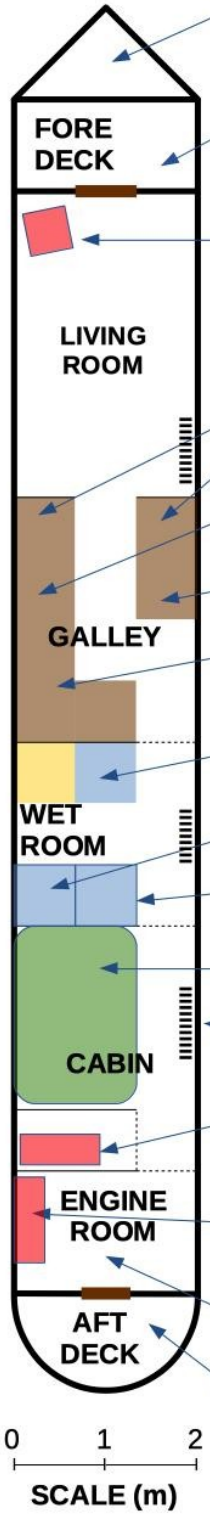
Main Design Tools Used
- Base map
- Input-output analysis
- PMI analysis

2. Design Specifications
The main purpose of the boat was to provide me with a comfortable place to live, minimising environmental impacts and unnecessary drains on my time and energy.

Buying the boat, essential maintenance on taking possession and transportation from its previous location (on the Macclesfield Canal in Cheshire) to my long-term mooring in Hebden Bridge left me with a budget for improvements and upgrades of around £5,000.

The design particularly emphasised the following **permaculture principles**:
- *Obtain a Yield*
  Each element maximally contributing to the main yield of providing me a safe, comfortable low-impact home.
- *Produce no Waste*
  I sought wherever possible to eliminate unnecessary wastes, both material and energetic. In line with the primary function of the boat - to support my rest and recuperation – this includes my personal energies (and time) as an important dimension. In financial terms, while I did not waste money I was also prepared, to some degree, to incur addition expense in order to offset unnecessary time and effort on my part.
- *Use and Value Renewable Goods and Services*
  I additionally sought as far as possible to remove fossil fuel dependency. Where I decided not to do this, I carefully examined the reasons for this decision and identified future pathways to design out usage of fossil fuels, even if these could not be implemented at the moment.
- *Use Small and Slow Solutions*
  In keeping with the emphasis on self-care, and budgetary constraints, I also took into account the trade-off between the benefits of possible changes and the costs, in both financial terms and in relation to my energy and convenience. Some ambitious changes that would have made sense in terms of other design criteria but beyond my existing capacity were filed under ‘nice to have’ and not implemented at this time.

Base Map June 2016



Gas Locker
Beneath bow of boat; contains three standard Calor 13 kg propane cylinders supplying cooker and boiler

Water Tank
Stainless steel tank beneath foredeck, estimated capacity 150l
Filled via inlet on foredeck (*)
Automatic electric pump delivers water to taps and hot water tank

Solid Fuel Stove
4.5kW Squirrel Morso cast iron stove

WORK SURFACES

Cooker
Full cooker with four standard domestic gas hobs, grill and oven

Fridge
Half-size 12V fridge, powered from main electric ring

Kitchen Sink
Full-size stainless steel sink with mixer tap and draining board

Shower
60cm square base with curtain on two sides, shelving behind (shaded yellow)

Sink

Toilet
Pump-out system: water flush into slurry tank requiring mechanical pump to empty

Bed
Raised platform with large storage drawers beneath. 1.5 width

RADIATOR

Boiler
Wardrobe with gas boiler feeding hot water tank adjacent and radiators in cabin, shower room and living room

Batteries
Starter battery for engine and four 12V leisure batteries powering pumps and lighting. 600W inverter supplying 230V outlets in cabin and living room

Engine
Diesel onboard in bilge, beneath partially soundproofed floor

Diesel Tank
Beneath aft deck, supplying engine

3. Survey

3.1 History of the Boat

The boat's previous owners told me that it was built in 1992 by a lock-keeper and woodworker. A basic inspection gave clear indications of the benefits of this. Functionally, the boat was fitted to a very high standard, with the major components (hull, engine, solid fuel stove, boiler, pumps and other auxiliary devices) all of excellent quality, well located, and ideally suited to its previous life as a holiday boat. Aesthetically, it was decorated with simple but elegant wooden fittings that combined practicality (for the most part) with a simple beauty that ensured it was already a very pleasant environment to be in.

3.2 Condition of the Boat

The boat was already fitted with all the elements necessary for travelling and living aboard (see base map): a full kitchen with sink, hobs and cooker powered by gas bottles stored in a locker at the bow; a wet room with shower, toilet and sink; 12V and 230V electrical circuits; internal plumbing; a cabin with bed and storage; a living space at the front of the boat and dual heating system comprising a solid fuel stove and gas boiler. Detailed descriptions of each of these key functional elements are in Appendix 1.

3.3 The Mooring Site

The boat was moored at Redacre Community Growing Project, where I was also a member with a half plot, two raised beds and a polytunnel bay. The Rochdale Canal forms the southwestern border of the site. The site had occasionally hosted boaters at its wharf before. However, I was the first long-term resident boater and the first also to be a cooperative member and grower. The wharf offers about 25m^2 of hard standing and is located about 60m from the water tanks and only source of domestic quality water on site, 80m from the site entrance and 50m from the nearest point of vehicular access. The site combines privately rented plots, raised beds and polytunnel bays with communal facilities including a roundhouse, fruit trees and compost toilet, plus areas reserved for raising chickens and bees.

Redacre Growing Project and Wharf

4. Analysis
I conducted a basic input-output analysis for each of the boat's main functional components or sub-systems, and undertook a more detailed evaluation of options for those in possible need of redesign.

My overall assessment was that the overall quality of the existing design and installation were excellent, but at the same time reflected some priorities and values different from my own. In particular, it was designed more as a travelling boat than a full-time living space, in ways that assumed daily use of the engine and regular access to canal-side services (for water, sanitation, waste disposal and provision of gas and diesel). The original design also reflected conventional canal culture, which assumes ongoing diesel consumption for onsite power and heating, even on residential vessels that mostly remain moored in one place.

My own lifestyle aspirations at the time contrasted somewhat: to live as sedentary a life as possible, move the boat only when essential and minimise or avoid use of the engine at other times, and to maximise the integration with the mooring site at Redacre Growing Project. The existing configuration also conflicted in some important ways with my basic design criteria outlined above, particularly where it involved unnecessary drains on my personal energy, fossil fuel inputs, and polluting material outputs.

The following table summarises the main inputs and outputs associated with each element.

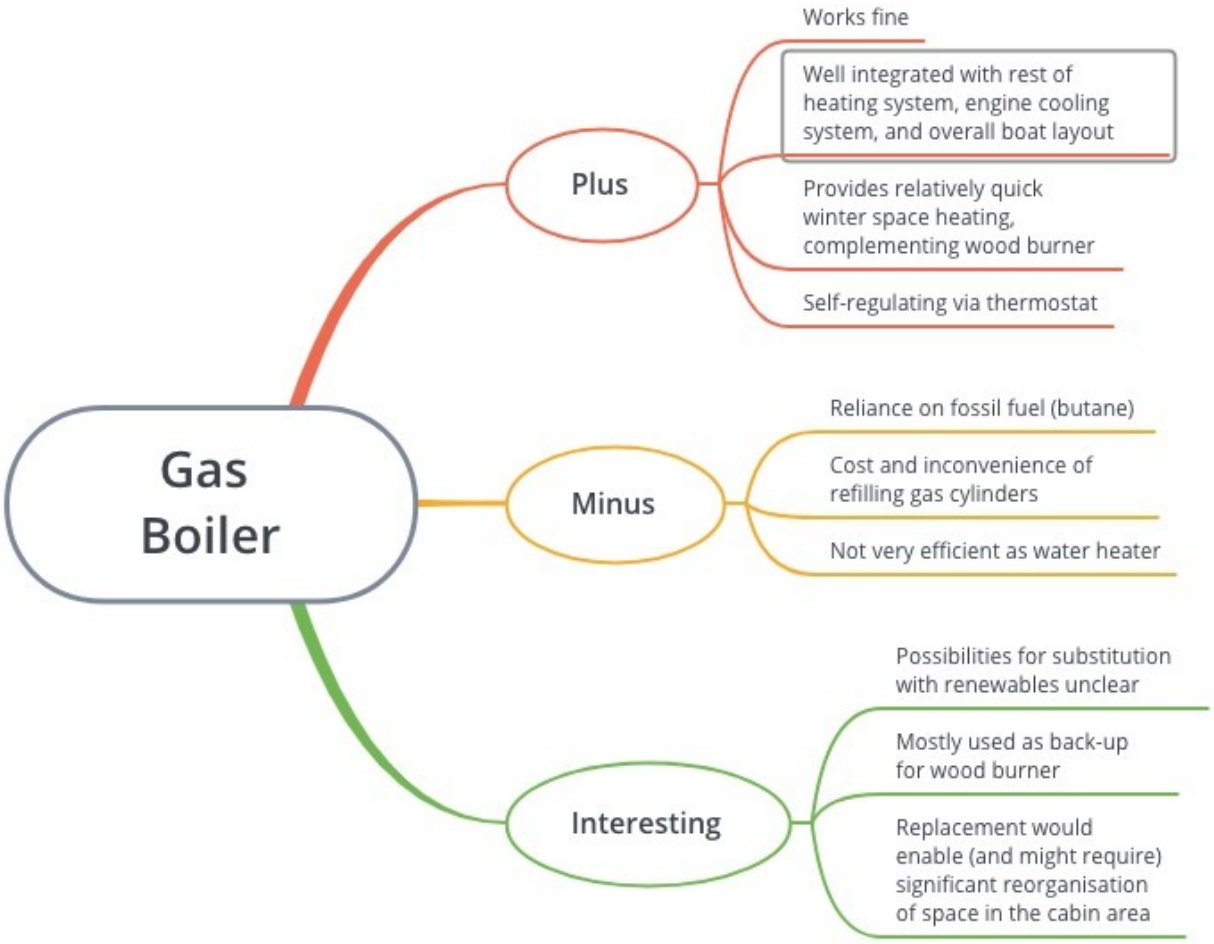
Element	Main Inputs	Useable Outputs	Waste Outputs	Comments
Solid Fuel Stove	Wood (£) Tinder & kindling Cleaning, maintenance (/£)	Space heating	Ash Smoke	Risk of carbon monoxide poisoning from smoke
Gas Boiler	Gas (£)	Space heating Hot water	Noise	Fossil fuel dependency
Electrics	Engine (Diesel, £)	Lighting Pumps (essential life support) Music Use of electrical appliances	Expired batteries Engine noise	Very low efficiency Fossil fuel dependency
Kitchen stove	Gas (£)	Cooked food, hot water		Fossil fuel dependency
Sinks and shower	Water Heat (boiler or engine)	Cleaning	Grey water	
Toilet	Water Pump-out (£)	Disposal of bodily wastes	Slurry	Need for regular travel to pump-out station
Engine	Diesel (£)	Propulsion Electricity Hot water	Noise Vibration Exhaust fumes	Fossil fuel dependency

Two sub-systems operated in ways I found particularly dysfunctional, building in unnecessary resource inputs, costs, inconvenience and pollution:

- The only source of electrical power was charging the leisure batteries via the engine, a highly energy-inefficient process that consumes diesel and creates noise, exhaust fumes, waste heat (in summer) and carbon dioxide. In addition, the batteries were of a cheap lead acid variety, highly toxic in production and disposal and requiring replacement every two to five years.
- The toilet was a pump-out system: solids, liquids and water used for flushing accumulate in a tank in the boat requiring regularly emptying at specialised facilities at a cost (around £18 a time).

The most straightforward way to eliminate the fossil fuel dependency associated with the engine would be a biodiesel conversion. Removing the engine's function as a main power source means it is used insufficiently often to justify the cost, uncertainty and risk of a conversion.

I also gave strong consideration to replacing the gas boiler. I concluded its replacement to be desirable rather than essential: it would involve significant cost and uncertainty, with no obvious renewably-powered alternative for water heating and as complement and back-up to the solid fuel stove. As the boiler and hot water tank take up significant space in the wardrobe and bedroom, which could be reallocated, I concluded replacing this was not a priority and would be best undertaken in the context of a complete reconfiguration of that space. A detailed assessment, in PMI format, is presented below.



PMI analysis of implications of keeping the existing gas boiler

The most important remaining fossil fuel dependency was the gas stove. The absence of workable renewable alternatives to gas as a cooking fuel and convenience of the current configuration, along with relatively low levels of consumption made designing this out a very low priority.

5. Design

Based on the analysis, I made the following decisions in relation to each functional component:

- Wet-room: replace the pump-out toilet with a composting toilet and integrate processing of human bodily wastes into onsite nutrient cycling processes
- Electrical system: install a new primary power source that allows renewable generation throughout the year, with the engine needed only as emergency back-up (if at all)
- Heating system: retain the current system, with the solid fuel stove as main form of space heating and gas boiler as back-up, complement and water heater. Installation of renewable alternative to the gas boiler a possible future option, likely linked with full redesign of the cabin space.
- Kitchen: retain cooking system as is.
- Water: fill water tank from onsite source, collect drinking and cooking water separately from same source to ensure hygiene.
- Engine: No change for now. Conversion to biodiesel is a possible future option, but need more information about possibilities, costs and likely technical implications, as well as availability of fuel sources.

For the toilet, following some online research I bought a commercial Separette separating toilet from a specialised online supplier, along with an optional 25l fluids tank. I also took advantage of the opportunity to completely gut and rebuild the bathroom in order to accommodate the new toilet, make better use of the

available space, repair some ongoing damage, line the floor with a single sheet of marmoluem (a natural alternative to synthetic floor coverings) and install a larger and more comfortable shower.

For the electric power system, having assessed alternative options, including a hybrid system including a small wind turbine (for which the wind resource locally is reputed to be insufficiently reliable), and given the possibility to use the engine as a back-up generator, I decided to design for year-round use of solar electricity, I acquired locally two new ex-trade 230Wp photovoltaic panels, which precisely fitted the two available spaces of this size on the roof of my boat. I bought the remaining components from an online supplier (Bimble Solar): a 30A MPPT charge controller (optimised for maximum capture of available solar energy under low light conditions), a 200Ah Nickel Iron battery (non-toxic in production and disposal, with a working life of up to 40 years, in ten replaceable modular units and with higher discharge depth, effective capacity and durability than conventional lead acids). I also replaced the existing incandescent lighting with LEDs throughout, greatly improving illumination quality and reducing electricity consumption.

6. Implementation

I did the initial installation of the solar power system myself, then brought in a local professional installer to mount the panels properly (on a hinged system allowing inclination towards the sun whichever direction the boat is facing) and add various components (switches, fuses, etc.) necessary for safety purposes.

Innisfree moored at Redacre Community Growing Project, summer 2018

The Separette toilet came with an electric-powered fan unit to dry solids. As installing this properly would have involved making a large hole in the hull, I decided instead to use sawdust to dry and cover wastes and create a suitable balance of carbon and nitrogen, adapting the method in Joseph Jenkins' book humanure. Sawdust was obtained from a local joiner who uses only untreated woods, supportive of Redacre and of the principle of composts toilets, and glad to find a use for this waste product. Solids were collected in bulk in wheelie bins, combined with solid wastes from the onsite compost toilet, with the intention that each would contain sufficient mass to allow hot composting. Composted humanure was spread around the communal fruit trees following apple harvest each autumn or winter after between one and two years in the wheelie-bin. For the sake of appearance and hygiene, and to accelerate integration into the soil, it was covered with a layer of cardboard, usually collected from the recycling area of a local supermarket. Liquids were added to the communal compost bays onsite, and in smaller quantities to a personal compost bin that I used for kitchen and allotment wastes. I initially set up the Separette myself

Separating toilet (fluids tank on floor at right of picture)

The upgrades to the wet-room and power system together took most of my available budget, which restricted me to minor changes elsewhere.

Solid fuel stove with Ekko fan

I purchased an Ekko thermoelectric fan for the wood burner, which breaks up vertical stratification and improves and accelerates dispersal of heat along the length of the boat. I added ash to compost, both my own and in the communal bays, as a nutrient supplement, or spread it around the fruit bushes in my allotment.
I acquired sufficient length of drinking-safe hose (from specialist suppliers) to reach between the water tank and boat, and installed new taps to allow connection of the hoses to the existing water supply and filling of bottles for drinking and cooking.

7. Maintenance

Learning the routines of boat life and getting used to its rhythms took some time. By my second winter I found I had settled comfortably into the lifestyle and location.

7.1 Electricity Generation

The size of the solar power system and batteries proved exactly adequate to my needs. With frugal use over the winter I had sufficient electricity available for vital services (lighting and pumps) at all times without reliance on the engine (although running an engine every two weeks is considered good practice in relation to engine maintenance, and could be combined with topping up batteries). Excess summer production could have been used to power a fridge or heat water via a dump load. In practice, I found a fridge noisy and unnecessary. While

I sourced the components to install a dump load in the water tank, concerns over safety and performance meant I didn't actually do so.

7.2 Humanure Disposal

Occasional visual inspection of humanure in the wheelie bins suggested active composting to last up to six months, depending on the time of year. after which time it appeared inert. When spreading the first batch (gathered from the onsite toilet before my arrival) I saw that the contents the bottom half of the container had become anaerobic. On future occasions, I put a foot-high layer of woodchip in the bottom of the wheelie bin before filling with humanure to ensure complete aeration, and avoided filling them to more than two-thirds of their capacity. Humanure spread around fruit trees was integrated into the soil and left no visible trace by the end of the following summer. It had no discernible effect on the quantity or quality of fruit produced. As an unexpected yield for local wildlife, these areas were often dug up by the badgers that sometimes visit the site, presumably because they are rich in earthworms.

Solar charge regulator and monitor

7.3 Heating

During the winters I developed a balance between using the gas boiler for short periods for rapid heating on waking and returning to the boat at night, and to heat water for showers, and the wood burner for general heating over longer periods. Later I developed the skill of keeping the wood burner smouldering slowly to maintain an acceptable level of warmth over the course of the night or a working day away from the boat.

During my first winter I found I needed an annual supply of two cubic metres of hardwoods. I sourced firewood from a local supplier committed to regenerative woodland management and harvested newspaper and cardboard from recycling bins for tinder. For the second winter, I build a wood store with a capacity of one cubic metre from waste pallets, located on the wharf, close to the boat and directly between the site of delivery and that of use, to minimise the labour involved in handling it.

I located a source of gas cylinder refills at an agricultural supplier around 20 minutes' walk away. Communal wheelbarrows available for use onsite were just big enough to transport a full bottle, and allowed me to resupply without relying on vehicular transportation. A bottle usually lasted two to three weeks during the winter, around two months in the summer.

7.4 Water

The water tank tended to need refilling every 7-10 days in regular use (one shower and one bowl of washing up daily). Connecting and reconnecting the hoses every time was fairly laborious. During extremely cold weather the hoses would get blocked with frozen water, making it impossible for me to top up: I learnt to anticipate these times or wait them out. I discussed with the Redacre directors the possibility of burying the hoses permanently in order to feed a new tap at the wharf, but finances and human capacity did not permit this at the time. As containers for drinking and cooking water I bought three 5l bottles of mineral water from the supermarket and refilled them in pairs as necessary. In order to avoid excessive deterioration of the plastic, whenever the handle gave out on one of these bottles I replaced it and cut off its bottom to convert it into a cloche for use on my allotment.

8. Evaluation

The design fulfilled the permaculture ethics in the following ways:

- Earth Care: lower impact living through use of renewable energy for all electricity and most space heating and onsite composting of human waste, along with having the degree of control over my own living space necessary to support freedom of lifestyle choice.

- People Care: supporting my self-care and autonomy of lifestyle choice.
- Fair Share: private ownership only over the space necessarily for my basic living, combined with use of communal outside space held by a cooperative; access to my own home within my limited financial means and free from mortgage debt, rent and other forms of financial exploitation.

Overall, I considered it a successful design, in that it struck a realistic balance between desirability and practicality. Two key limiting factors - my energy and available budget - led to compromises in key areas, specifically replacement of the gas boiler with a simpler, renewably powered alternative that took up less space and the associated redesign of the bedroom area, along with other useful possibilities such as installing a dump load from the PV system in the water tank, creating a zero-power cool-box in the bilge of the boat, and installing filters to allow safe use of water from the taps. While to some degree I regretted not being able to undertake all of these, realistically they would have been at the expense of the key design aim, of providing a comfortable living space able to support me at a time in my life when my energies were best focussed on growing professional challenges.

9. **Reflection**
I learnt a lot from the process of choosing, buying, redesigning and living on the boat, on various levels.

My key learning in terms of design was about the need to balance different factors, particular environmental and personal sustainability. This design also involved navigating numerous trade-offs: of sustainability, practicality, financial costs and relationship to my personal energies. For example, replacing the gas boiler with a renewable alternative made sense from a sustainability point of view – and such an alternative might well have been cheaper and easier to operate, as well as reducing the time and effort needed to refill gas bottles - and would have provided an opportunity to redesign the cabin area for greater overall comfort. However, doing all this was beyond both my financial resources and personal energy to design and implement such a change. Instead, the most appropriate course of action was to accept the existing set-up as 'good enough for now' and concentrate on the changes that were most needed and most effective.

I also learnt that the design process was as much about adapting myself to the boat as adapting the boat to fit my needs. In a mundane sense, I needed to understand how a boat works, acquire the skills and knowledge necessary to manage the boat and live aboard, and develop the habits, routines and practices that integrated this new knowledge into my everyday life. On a deeper level, it involved finding a whole new way of being: of relating to the place I was living, the surrounding environment, and myself, in ways very different from those I was used to. In this way, the boat itself and the fact of living on it became important parts of my inner landscape (see Design 10).

The write-up could have emphasised more the roles of the ethics and principles in the design. The ethics were clearly in my mind from the start: how can I find a comfortable home (people care), that supports my wish to live sustainably (earth care), within limited means (fair shares), and ideally making a positive contribution to all three ethics. The principles were again present throughout. In addition to those listed at the outset, others that were important include: Design from Pattern to Detail (the patterns of boat, mooring and the standard features of a houseboat, and the specific ways I adapted these to my wishes and constraints), Use Edges and Value the Marginal (the canal is a classic edge habitat between land and water, canal residents are a marginal population, and key solutions like solar panels and a composting are relative novelties in the canal world), and Capture and Store Energy (solar panels and batteries, wood store, water deposits, compost toilet). This is in addition to the role of the principles in the integration with the wider site at Redacre Allotment described in Design 7.

Appendix 1: Description of key functional systems at time of purchase

Heating System

This consists of a solid fuel stove located at the front of the boat, and a gas-powered boiler at the back of the boat supplying a central heating system (radiators in the cabin, wet room and living space) and hot water tank.

The solid fuel heater is a 4.5kW cast-iron Squirrel Morso stove (a well-known brand reputed for its high quality and durability), and presumably of the same age as the boat. It can run off wood or coal, and also requires kindling, tinder and a source of ignition. While in use, it needs ongoing removal of ash every few days and ideally a clean of the flue about once a month. Its age means it needs occasional renovation and maintenance/replacement of parts (firebrick, glass, etc.). It is ideally sized to be able to heat the entire boat when in ongoing use. Being located right at the front of the boat means it takes 2-3 hours of constant use before the cabin gets warm. It has high thermal lag, which means it takes longer to warm the space when starting from cold. However, once hot it can be left burning slowly and still sustain a comfortable temperature, so can keep the boat warm overnight or while unoccupied during the day.

The boiler is an old (discontinued) model made by Alde, a specialist in heating for boats and other mobile homes, and fuelled by the gas bottles. It heats the radiators in order of proximity (cabin, wet room and living room), both in sequence and in terms of temperature. Its thermal lag is lower than the solid fuel stove: during the winter, both the cabin and shower room reach a comfortable temperature within about 30 minutes. The two thus balance and complement each other well.

The boiler has a pilot light that requires manual switching on and off. The heating system is regulated by a thermostat located in the cabin, but this can only operate when the pilot light is on, which requires a low but constant consumption of propane. Gas consumption is high: with daily use, I found gas bottles required replacement around every two weeks.

For reasons I was never able to discern, the boiler remains lit only for short periods unless the heating is on. It thus takes over an hour to heat sufficient hot water for a shower, which is presumably very inefficient in terms of gas use. The hot water tank is also linked to the engine's cooling system, which means it heats very effectively when the engine is running.

Electrics

A 12V circuit supplies essential systems: lighting throughout the boat, and several pumps necessary for water supply and drainage, as well as the central heating pump, fridge, sound systems in the cabin and living room, and a single socket of the type commonly found in cars. It is supplied by four deep discharge lead acid batteries, which at the time I moved onto the boat were charged only from the engine and were due for replacement, holding little charge. A 600W pure sine wave inverter supplies 230V power to three-pin sockets in the cabin and living room. Lights are incandescents, very inefficient in terms of electricity use and providing low quality illumination.

Kitchen

Excellently appointed, with full-size gas cooker (hobs and oven, supplied by the gas bottles) and sink unit, plus excellent layout of workspaces and storage. The fridge creates a constant hum and consumes largely quantities of electricity, but can be switched on and off manually via a wall switch. In regular use (during summer, without use of the water heater), gas bottles lasted around two months.

Water Consumption

Water is stored in a stainless steel tank under the foredeck, filled using a hose via a capped hole in the deck. The internal piping is of alimentary standard, but does not include any filtration or other purification between the tank and point of consumption. The system is pressurised with a pressure-sensitive pump that automatically turns itself on and off as needed. Points of usage are the kitchen sink and the toilet, sink and shower in the wet-room. The system also includes a hot water tank in the bedroom cupboard, heated by the gas boiler and engine, which supplies hot water to the sinks and shower. Between kitchen and wet room use for my own personal consumption, a full water tank typically last a little over a week.

Wet Room

The overall layout used space very poorly and the specific elements are all poorly suited to their purpose. The toilet is a ‘pump-out’: water-flushed, with solids and liquids collected together in a tank that needs regular emptying at specialised stations, at a cost of around £18 per time. The shower was small, uncomfortable and bounded on two sides by a curtain. The sink was far larger than necessary and a

hemispherical shape, impracticable both to use and clean. A substantial amount of space (almost equal to that occupied by the shower) is taken up by shelving; the shelves are not very accessible and items stored there tend simply to be forgotten.

Cabin

Use of space is compromised somewhat by also acting as a passageway between the engine room and rest of the boat, which uses about a third of the available width. The bed is full length and around 115cm in width, which is fine for sleeping alone but quite cramped with two. The boiler and hot water tank occupy a wardrobe at the end of the cabin, which takes up significant space.

Engine Room

The engine is diesel-powered, of very high quality manufacture and in excellent condition. In addition to propulsion, it provides back-up water heating (the hot water tank is connected with the engine's cooling system), and charges the batteries. At the time of purchase, the engine was the only way to charge the leisure batteries: this makes sense for a holiday boat, which is usually on the move during the day, leaving the batteries fully charged during the evening. However, it makes less sense for a home: the charging process is very inefficient, and the engine produces noise and vibrations in addition to consuming diesel.

The engine room also contains the battery units: a starter battery for the engine and separate leisure batteries – four deep-discharge lead acid batteries, which at the time of purchase had reached the end of their useable life and need replacing. Replacement of batteries is an ongoing cost, and a source of toxic pollutants (lead and sulphuric acid) requiring specialised disposal.