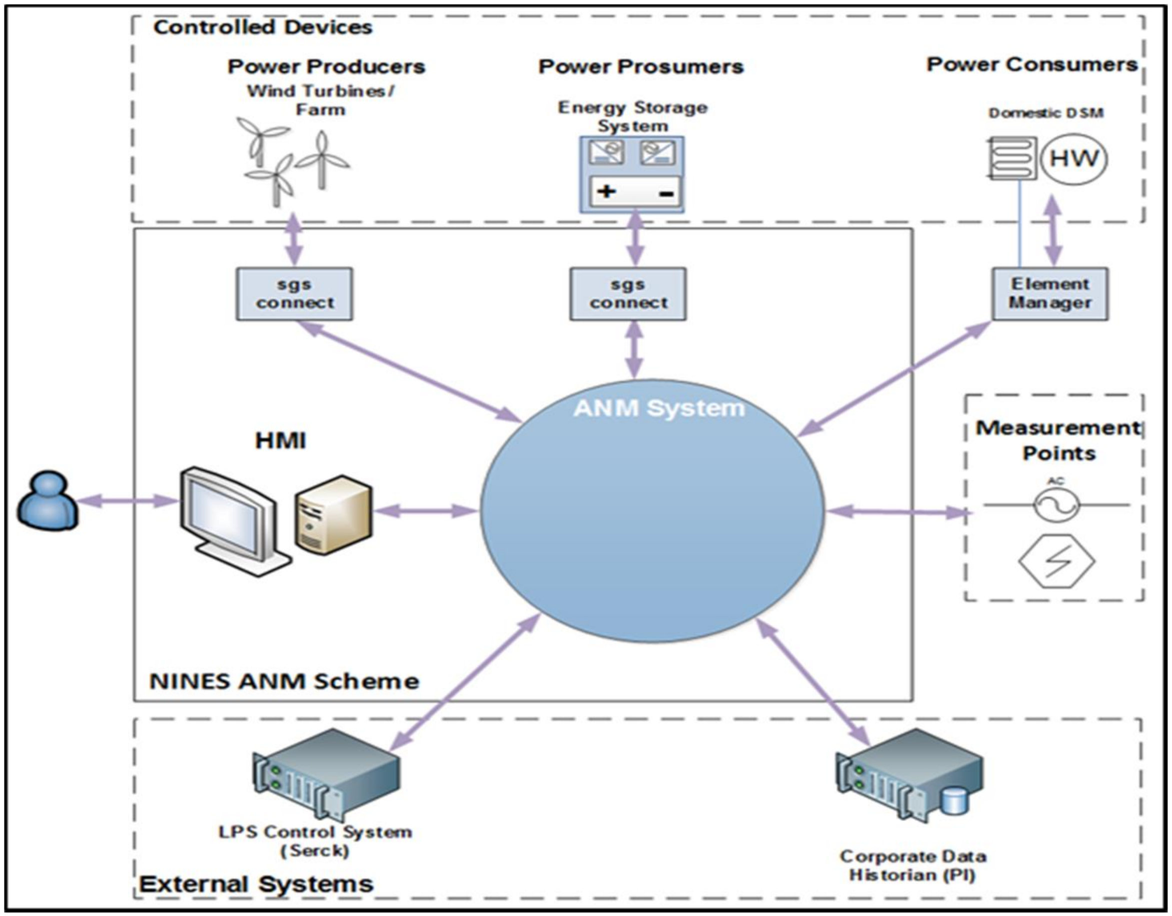

Smart Grid Case Study:
The NINES Project

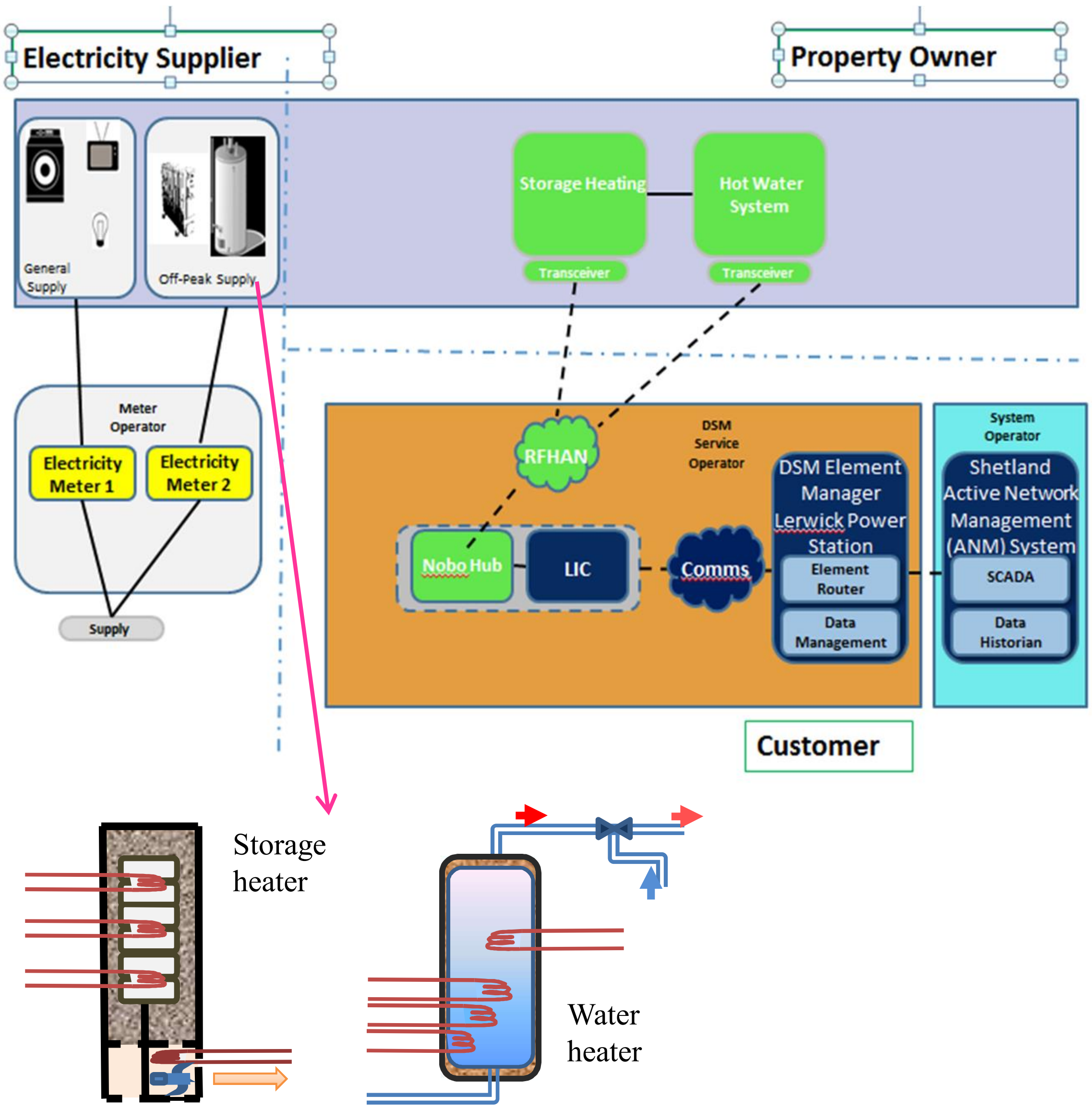
NINES infrastructure and DSM aims



Issues: equipment capability, charge scheduling, control authority, next day energy estimation,, communications, energy & comfort impacts.

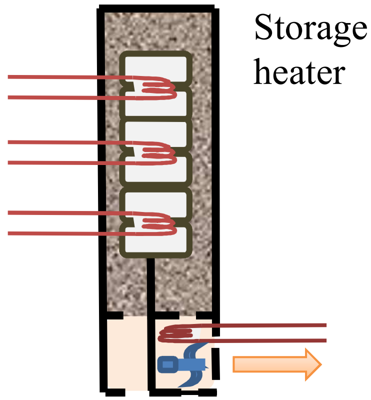
- Flexible appliance charging introduced in March 2015 (Shetland first operational smart grid in the UK incorporating DSM).
- ANM schedules generation from wind farms, and uses a 1MW battery and DSM to dynamically balance electricity demand and supply.
- Network-controlled space and water heaters shift load and store energy during periods of excess supply.
- 224 DSM homes with a total demand of 1.6 MW (= 708 installed appliances)
- Expectations that flexible charge scheduling will reduce consumption without impacting occupant comfort (provided that next day energy requirement estimation is accurate).

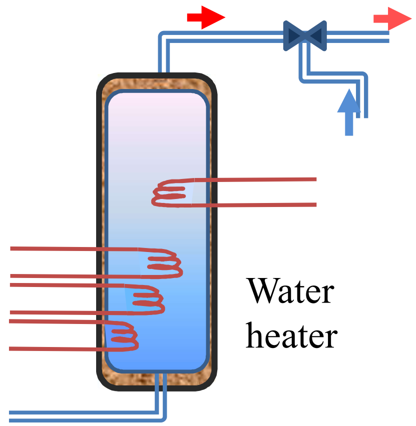
DSM equipment and control

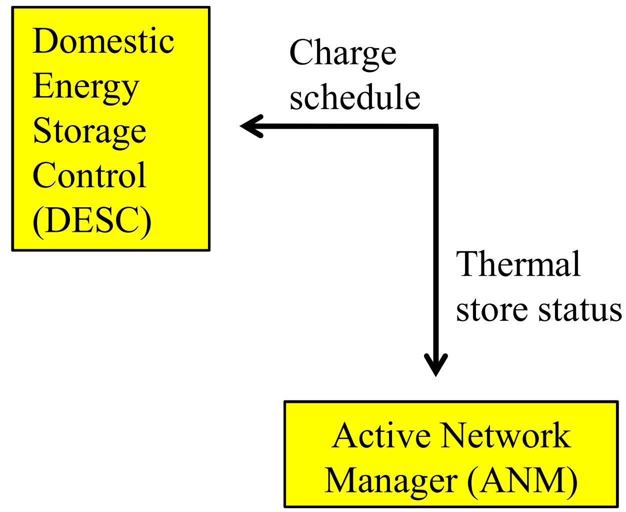


- Heaters accept instructions for input power every 15 minutes, and relay back status information to the ANM.
- Charging automatically terminates if network frequency drops and increases when it rises.
- Device controllers employ a charge control algorithm to predict the next day's Daily Energy Requirement (DER).
- For space heaters, DER depends on the next day's temperature forecast and user temperature/ time settings.
- For water heaters, DER is the average of the energy used in the previous 3 days.
- Algorithm prioritises customer requirements over network needs.
- Gives 7.2 kW/house flexible power, 42.4 kWh/house storage capacity, supports 2.4 kW/house of additional wind generation.

NINES technologies

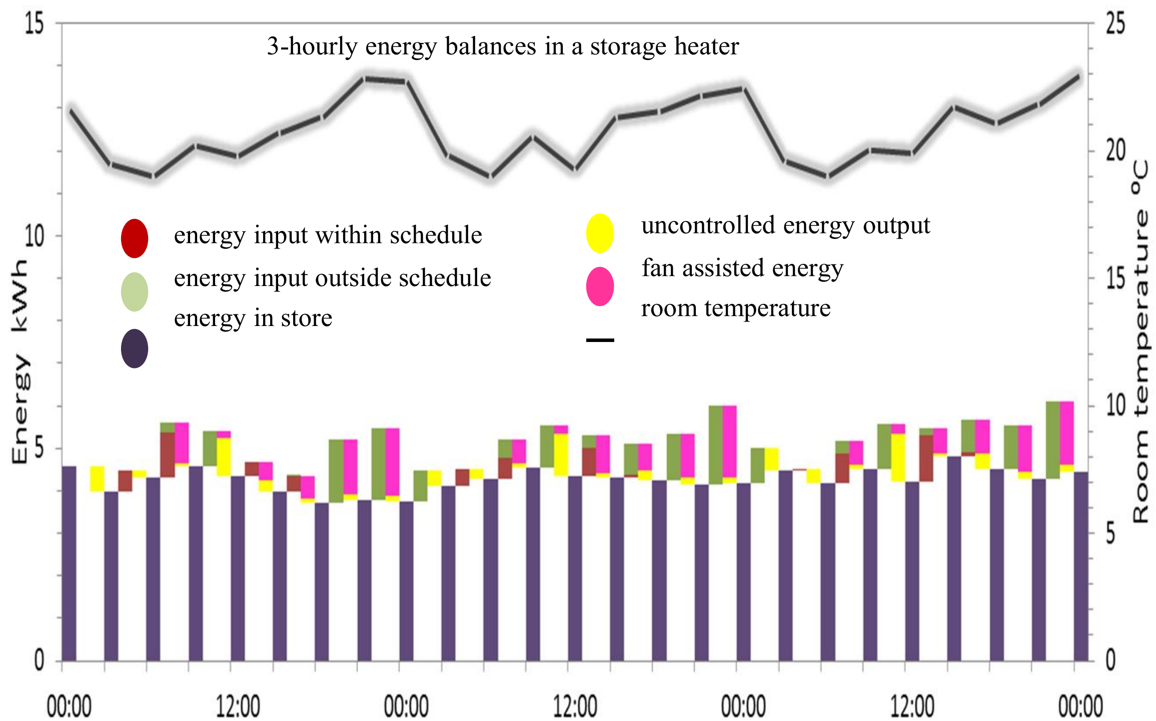






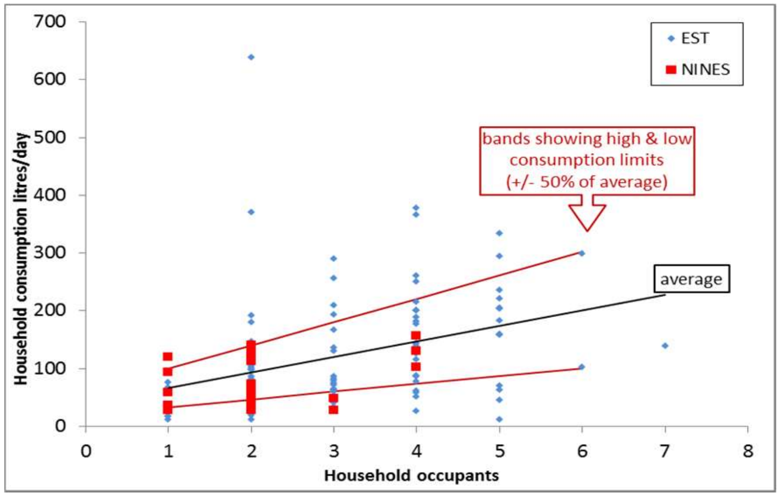
- ANM controls power station units and switches wind generators in response to demand.
- Energy storage devices are controlled centrally: 1 MW battery, 4 MW district heating store, and domestic energy storage with total capacity of 2.1 MW distributed across 235 dwellings.
- DESC uses space and water heaters to store energy to level out demand; heaters respond to external charge schedule and grid frequency.
- Basic instruction is a power input schedule by ¼ hour for the upcoming 24 hour period based on anticipated supply, demand and network status.

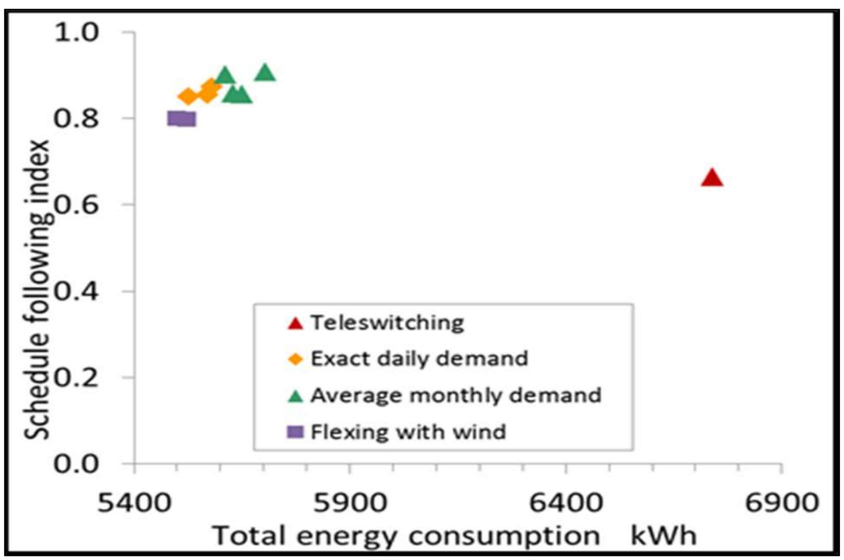
Control authority and standing losses



- Main issue is device controllability and standing loss avoidance.
- Space heaters have 3 heating coils allowing them to be charged at discrete power levels, and incorporate a maximum temperature cut-off for safety and a minimum temperature switch-on to ensure occupant comfort. Fan-assisted output is via user-controlled temperature/time settings.
- Water heaters have 3 heating coils of different sizes to allow variable level charging.
- Local control prioritises customer requirements over network needs.

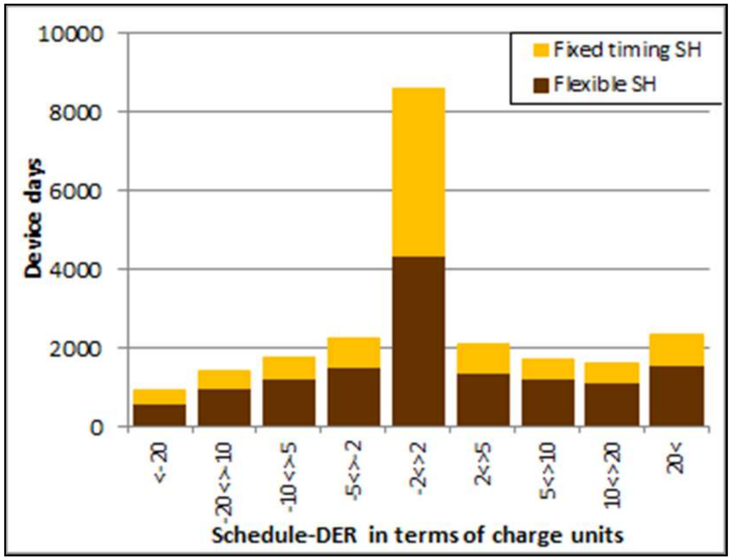
Impact on energy consumption

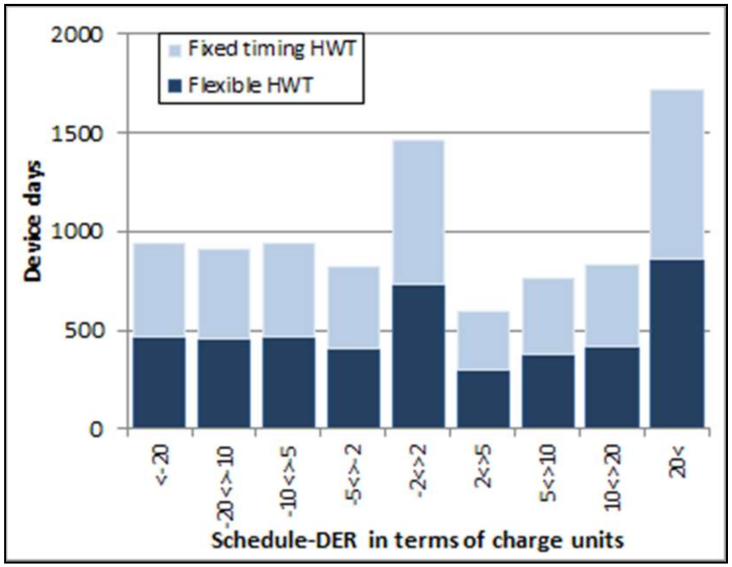


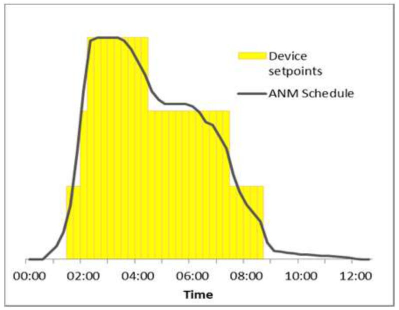


- Hot water use is within the normal range.
- Water tanks consistently averaged between 55 C and 60 C with standing losses between 1 kWh/d (small tanks) and 1.5 kWh/d (large tanks).
- Space heater uncontrolled output comprises a significant proportion of the total energy delivered: larger units 4-8 kWh/d, smaller units 2-6 kWh/d.
- Different charging schedules were investigated: old tele-switching regime; fixed time, variable power schedules that deliver the DER either exactly or approximately; and flexible schedules generated by the ANM.
- Little variation observed between active schedules, with the maximum energy consumption 2-7% higher than the minimum.
- Active scheduling uses 10-18% less energy compared to tele-switching mode (where heaters are charged to a set level irrespective of demand and then lock heat).

Scheduled/ delivered energy compared to DER



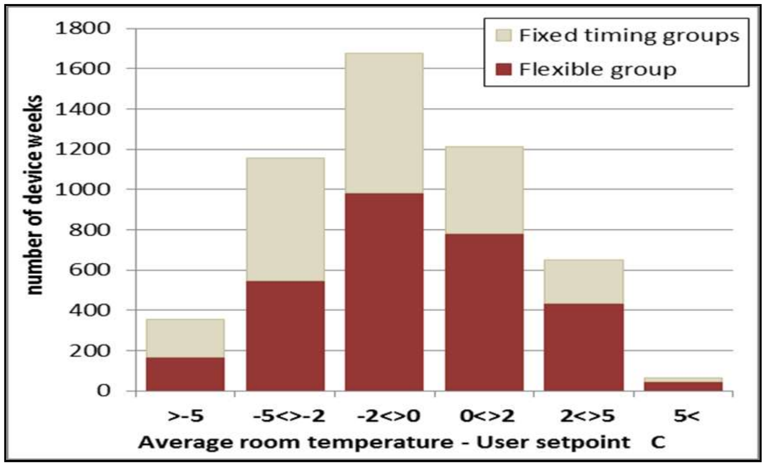


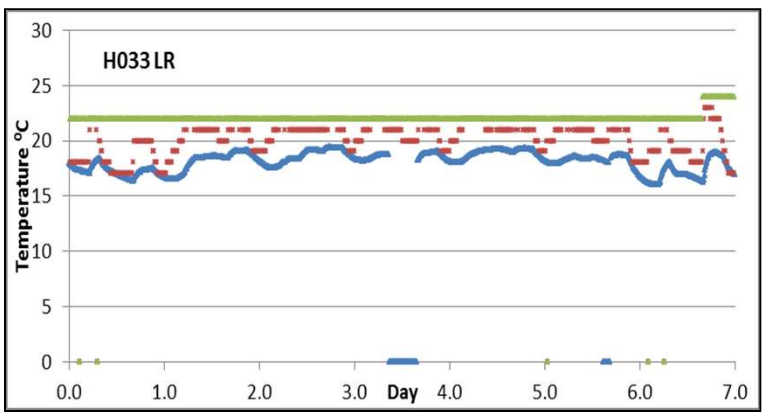


- LIC maps target power profile to a set of instructions that each heater with its discrete power settings can follow.
- Because heaters operate at fixed charge values, the smallest unit for scheduling is the minimum power for 15 minutes, the 'charge unit' (CU). For space heaters this varies between 0.10 and 0.28 kWh, for water heating 0.09 kWh.
- The target energy delivery can be either higher or lower than DER by several charge units each day (more over- than under-delivery observed).
- With space heaters:
  - 38% of target profiles were within ±2 CUs of DER each day, and 57% within ±5 CUs;
  - 10% of target profiles would deliver more than 20 CUs in excess of DER and 4% would under-supply by the same amount.
- With water heaters:
  - 18% of device days are within ±2 CUs;
  - tanks have to be cycled through 60 C once a day for health and safety reasons;
  - required several iterations of the firmware to achieve the present state.

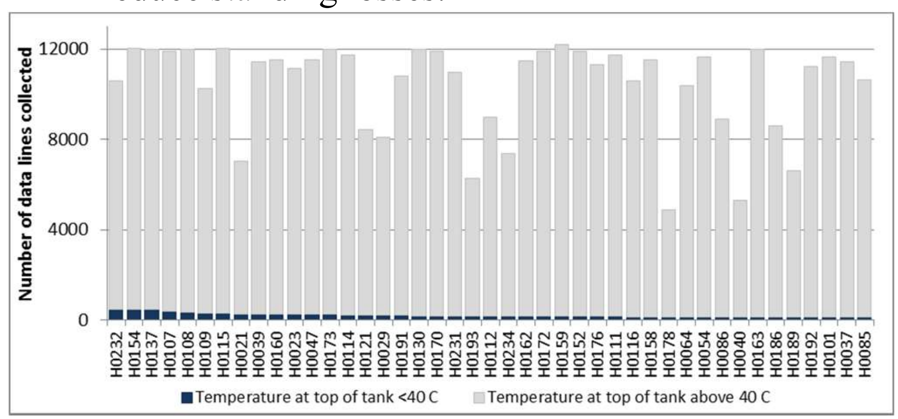
Customer impact

Preference	Proportion	England & Wales
Cool (<20 C)	26%	30%
Average (20-22 C)	54%	30%
Warm (>22 C)	20%	40%

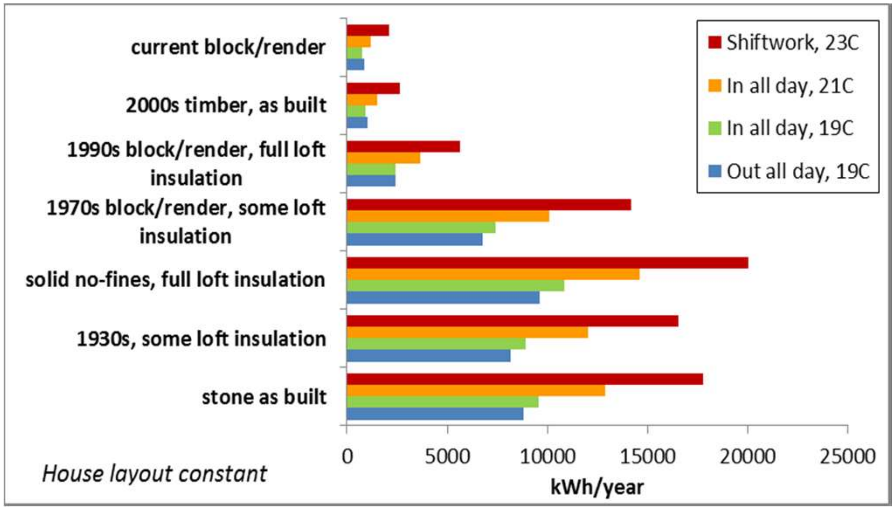




- Higher proportion of households fall into the 'average' temperature band and a lower proportion into the 'warm' preference band.
- Space heaters are capable of consistently maintaining the user set-point temperature.
- Device sensor (red) is higher than an independent room sensor (blue) because the heater is less exposed. (heater reports that the set-point is met even though occupants experience a low temperature: at the end of the week the set-point (green) is increased to compensate.
- Tank temperature is set to a minimum of 40 C in the top half; charging commences irrespective of the imposed schedule to ensure this => hot water available most of the time. Relaxing this minimum setting and the need to cycle the tanks through 60 C daily would reduce standing losses.



Future rollouts



- Occupants of low rated houses have more to gain from DSM: need more heat; uncontrolled output makes a valuable contribution.
- These attributes also make them more attractive to the DSM Service Provider as each house provides larger controllable capacity.
- Suitable types of property are:
  - pre-1945 houses, with solid or hard to insulate cavity walls, large rooms, high ceilings - estimated 1,200 private dwellings in Shetland;
  - houses built between 1945-93, typically timber frame, block & render cladding, and no or moderate retrofit insulation - estimated 3,100 private dwellings.
- NINES market model has two financial elements:
  - annual payment of £50 to encourage customers to join DSM: customer purchases DSM-ready heaters; Service Operator provides the upgrade kit (LIC, Home Hub, transceivers, home energy monitoring kit, and hot water controller);
  - customers advised to change to a single rate tariff - such as general domestic – but receive a levelisation payment to compensate for not running the heating at a lower off-peak rate;
  - most new tenants opted in even though the incentive payment was not available

Lessons learned

- DSM can operate only with meters that are capable of providing a 24 hour low rate supply.
- Best to move vulnerable customers and those on prepayment to DSM in stages after it has been demonstrated that they are not at risk of using up their prepayments to facilitate storage.
- In some houses RF communication between the devices and Home Hub have proved problematic: future installations should be agreed only after communications have been fully tested on site.
- Schedule timing in itself has minimal impact on cost or customer comfort provided that roughly the correct amount of energy is delivered.
- The technology does not suit modern, well-insulated houses, where demand may be less than the uncontrolled output of these heaters.
- Two (not uncommon) issues caused some customers to use more energy than needed:
  - under a power outage, the DER is retained in memory but the calculation of the energy delivered against that requirement is re-set; and
  - the manual boost heating circuit does not switch off automatically until the next heating period.
- DSM space heating does not result in higher energy ; DSM water heating has slightly increased energy consumption.