What to do about Hot Water?

Homes for the Future Group Debate
Welcome and Safety Moment
‘Last month, as part of an office move, circa 100 bags of waste paper were collected for shredding.

Unbeknown to AECOM and Shred It staff, someone had put an aerosol in with the waste paper.

When the shredder in the Shred It truck started the aerosol exploded and caught fire, setting fire to everything in the back of the truck.

Fortunately the driver is okay, the fire service and police attended but this could easily have become a much more serious incident.

It goes without saying how important it is that bins are appropriately signed and staff take responsibility for appropriately segregating recyclable materials’
Introduction
Tom Lelyveld, AECOM, Chair - Homes for the Future Group
Agenda

17.30 Arrival, refreshments and networking

18:00 Welcome

18:05 Introduction, HFG Remit and Debate Context
Tom Lelyveld, AECOM, Chair of the CIBSE Homes for the Future Group

18:05 State of the Market, Where We Are Now and Where We Could Be in 2030
Becci Taylor, Associate Director at ARUP

18:15 Reducing energy use in the delivery of Domestic Hot Water
Gareth Jones, Managing Director, FairHeat

18:30 Heat Batteries – the Phase Change energy storage of heat
Bill Edrich, Global head of Commercial & Industrial, Sunamp Ltd.

18:40 Discussion and debate

19:15 Summary and Networking

20:00 Event close
Domestic Hot Water:  
State of the Market, Where We Are Now and Where We Could Be in 2030  

BECCI TAYLOR
DHW limited to:
- Storage cylinder insulation/controls
- WWHR
- DHW Heat pump COP >2

DHW NEEDS MORE CONSIDERATION IN CONSERVATION OF FUEL AND POWER?
DOMESTIC HOT WATER ENERGY

The Elephant in the Home

![Graph showing energy consumption]

- **Annual Energy MWh**
  - **Space Heating**
  - **Hot Water**

**Past** vs **Now**
Collaboration:

• CIBSE Homes for the Future Group
• Heat Networks
• SoPHE
• Domestic Building Services Panel

• Public health still primary driver
• Risk based assessment temperatures

• Reducing instantaneous hot water temperatures: easiest win to reduce carbon emissions
Combined supplies

- DHW highest temperature
- DHW drives COP of whole system
- DHW forms majority of load
**COMBUSTION FREE HEAT**

Refrigeration Cycle

- Higher efficiency when condenser temperature closer to evaporator
  - Lower hot water temperature = higher COP
- Heat pump COP increases by ~10% for every 5°C reduction in condenser water*

*For an air source heat pump operating in the range of 45-60 degC condenser water temperature*
Entropy

- It takes energy to increase order
- Mixing is irreversible, entropy goes up = waste
- Should aim to avoid where we can!
Climate Emergency

- Current instantaneous health based temperature guidance is unclear
- Combine clarity with thermodynamic opportunities to reduce carbon
- When is it ok to heat water up and then cool it down?
- Other advantages: limescale, scalding risk

**BSRIA HIU guide:**
The tendency to scaling of the heat exchanger will increase with higher hot water temperatures, so end users should be encouraged to set the hot water controls to give the lowest acceptable delivery temperature, subject to health and safety considerations. For hot water systems without storage this is 50°C.
DHW Temperatures: Heat Networks
CIBSE Homes for the Future

03 December 2019
Demonstrated model for reducing carbon from heat

Source: Werner, 2017
Global trend toward integrated low temperature heat networks (4DH)

Source: Lund et al., 2014

1G: STEAM
- Steam system, steam pipes in concrete ducts
- DH flow: 200°C
- DH return: 80°C

2G: IN SITU
- Pressurised hot-water system
- Heavy equipment
- Large "build on site" stations
- DH flow: >100°C
- DH return: <70°C

3G: PREFABRICATED
- Pre-insulated pipes
- Industrialised compact substations (also with insulation)
- Metering and monitoring
- DH flow: <100°C
- DH return: <50°C

4G: 4th GENERATION
- Low energy demands
- Smart energy (optimum interaction of energy sources, distribution and consumption)
- 2-way DH
- DH flow: 50-60°C (70°C)
- DH return: <25°C

Future energy source
- Biomass conversion
- 2-way District Heating
- e.g. supermarket
- Water, Wind surplus, Electricity
- CHP Biomass
- Geothermal
- PV, Wave

Development (District Heating generation) / Period of available technology
- Local District Heating
- District Heating

Source: Lund et al., 2014
...which we are starting to see in the UK

Example Network Flow & Return Temperatures: 18 November 2019
Low operating temperatures require low DHW temperatures

Low Flow Temperature - 55°C

HIU forward approach temperature of 5°C

• Implies a max DHW temperature of 50 °C
Two issues to review in relation to DHW temperature

1. Health & Safety risk
2. Dish washing
Two key H&S issues for a domestic DHW system

1. Legionella
2. Scalding
Advantages of low temp networks

Three stages of development for UK heat networks

Certain conditions increase risk from Legionella

a) the water temperature in all or some parts of the system may be between 20-45 °C

b) it is possible for water droplets to be produced and if so, they can be dispersed;

c) water is stored and/or re-circulated;

d) there are deposits that can support bacterial growth
Showers are an issue

a) the water temperature in all or some parts of the system may be between 20-45 °C

b) it is possible for water droplets to be produced and if so, they can be dispersed;

c) water is stored and/or re-circulated;

d) there are deposits that can support bacterial growth
Advantages of low temp networks

Three stages of development for UK heat networks

Most discussion based on traditional systems with DHW storage

a) the water temperature in all or some parts of the system may be between 20-45 °C

b) it is possible for water droplets to be produced and if so, they can be dispersed;

c) water is stored and/or re-circulated;

d) there are deposits that can support bacterial growth
...with guidance to control risk through temperature

- Set control parameters to ensure water is stored at 60°C
- Ensure DHW delivered to outlet at a minimum of 50°C within one minute
- Ensure return temperatures at least 50°C on systems with recirculation
Guidance for low storage systems (e.g. HIUs) is different

“2.68 Low storage volume heaters (ie no greater than 15 litres) such as instantaneous units and POU heaters, may be generally regarded as lower risk”
“2.68 Low storage volume heaters (ie no greater than 15 litres) such as instantaneous units and POU heaters, may be generally regarded as lower risk”

HSG 274 Part 2 Guidance for Low storage systems:

• Should be able to achieve a peak temperature of 50 °C - 60 °C
• Recommend using temperatures <50 °C only where there is high turnover (or alternative control)
Significant tangential evidence that low temps not an issue

- European Examples - e.g. Denmark
- Combi boilers

EST Study: Frequency of DHW Delivery Temperatures for Combi Boilers

Source: Energy Savings Trust, Measurement of DHW Consumption in Dwellings, 2008
Two key H&S issues for a domestic DHW system

1. Legionella
2. Scalding
Two key H&S issues for a domestic DHW system

1. Legionella
2. Scalding

HSG 274 Part 2:

- “At 50 °C, the risk of scalding is small for most people but the risk increases rapidly with higher temperatures and for longer exposure times.”
>10-fold increase in risk of scalding from 50°C to 55°C

Type of burn by time of exposure by DHW temperature*

<table>
<thead>
<tr>
<th>Type of Burn</th>
<th>Temp</th>
<th>45°C</th>
<th>50°C</th>
<th>55°C</th>
<th>60°C</th>
<th>65°C</th>
<th>70°C</th>
<th>75°C</th>
<th>80°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult 3rd</td>
<td>&gt;60 m (e)</td>
<td>300 s</td>
<td>28 s</td>
<td>5.4 s</td>
<td>2.0 s</td>
<td>1.0 s</td>
<td>0.7 s</td>
<td>0.6 s (e)</td>
<td></td>
</tr>
<tr>
<td>Adult 2nd</td>
<td>&gt;60 m (e)</td>
<td>165 s</td>
<td>15 s</td>
<td>2.8 s</td>
<td>1.0 s</td>
<td>0.5 s</td>
<td>0.36 s</td>
<td>0.3 s (e)</td>
<td></td>
</tr>
<tr>
<td>Child 3rd</td>
<td>50 m (e)</td>
<td>105 s</td>
<td>8 s</td>
<td>1.5 s</td>
<td>0.52 s</td>
<td>0.27 s</td>
<td>0.18 s</td>
<td>0.1 s (e)</td>
<td></td>
</tr>
<tr>
<td>Child 2nd</td>
<td>30 m (e)</td>
<td>45 s</td>
<td>3.2 s</td>
<td>0.7 s</td>
<td>0.27 s</td>
<td>0.14 s</td>
<td>&lt;0.1 s</td>
<td>&lt;0.1 s (e)</td>
<td></td>
</tr>
</tbody>
</table>

(e) = estimated

c. 2,500 cases of scalding per annum (400 hospital admissions from hot water scalding for children)
c. 400 cases of Legionnaires’ disease per annum (includes cooling towers, travel)

*Source: Children’s Burns Trust campaign’s HotWaterBurns website
On balance, good case for limiting HIU DHW temp to 50°C

- HSG 274 Part 2: low volume instantaneous DHW systems “low risk”, with guidance for 50°C at outlet
- Conversely >10-fold increase in risk of scalding from 50°C to 55°C
Two issues to review in relation to DHW temperature

1. Health & Safety risk
2. Dish washing
Four sources of comfort on 50°C for manual dish washing

1. Testing of dishwashing detergents
2. Confirmation from manufacturer
3. Empirical feedback from residents
4. Testing of hot water decay
All dishwashing detergents in EU tested at 45°C

1. All dishwashing detergents in Europe tested for effectiveness
2. Tests conducted at starting temperature of 45°C, able to drop to 35°C during test
3. >500 products tested
4. Conclusion: demonstratable that 50°C sufficient for cleaning dishes
Response from Proctor & Gamble’s R&D department:

"We test Fairy across a range of temperatures. However, 38-41 °C is in the normal temperature range that a consumer would use for this product."
Empirical evidence from developments

- FairHeat working extensively with sites delivering DHW at 50°C, both new build and legacy
- Role includes resident engagement on in home systems
- Complaints tend to be:
  - Time to deliver hot water
  - Delivery temperature in bath, where lower temperature policy
- Lack of complaints about output temperature at kitchen sink
- Side note: combi boiler temperatures in UK
Advantages of low temp networks
Three stages of development for UK heat networks

Tested hot water decay in typical sink
DHW temperature decay much longer than typical wash
Advantages of low temp networks

Three stages of development for UK heat networks

Summary: 50°C sufficient for manual dish washing

1. Dishwashing detergents proven to be effective at temperatures of 45°C and below

2. Confirmation from manufacturer that product expected to be used at 38°C - 41°C

3. Testing of hot water decay shows that temperatures above recommended operating temperatures maintained for a long period (1.5 - 2 hours)

4. No complaints from residents at sites where 50°C being delivered to the kitchen sink
In summary, strong support for reducing DHW temps with HIUs

1. Health & Safety:
   - Low storage systems (HIUs) = low risk systems
   - No evidence supporting >50°C
   - Potential for 45°C - 50°C? (Further studies required)

2. Dish washing:
   - 45°C sufficient
UK HIU Test Standard
Sunamp

Introduction to company and technology
The Heat Opportunity

World energy consumption

- 17.5% Electricity
- 27.5% Transport
- Others 9%
- 46% Heat

- Space Heat
- Hot Water
- Process Heat
- Cooling

Electrical storage:
- Over invested
- Overcrowded
- High entry barriers
- Materials questions

Heat storage:
- Has not changed in centuries
- Ripe for improvement
- More heat storage needed
- Low cost, sustainable materials

Highlights

- Advanced thermal energy storage
- Founded in 2005 in Edinburgh
- Key R&D partnership with University of Edinburgh
- UK R&D and manufacturing
- Products now launched and in serial production
- >60 people directly employed (100% increase 2019)
- >2,500 homes impacted including:
  - >800 homes in social housing
  - >700 sold via OEMs
- Hundreds of direct customers & other resellers
- Factory scaling up to 20,000 per year capacity
- Two OEMs signed for Global Markets
Business Units

Residential
- UK focussed
- Social housing – retrofit and new build, electrification of heat and heat networks
- Housebuilders inc. modular
- Owner occupied
- Distributors & resellers

Automotive
- Global Tier 1 automotive OEM
- Commercial vehicles e.g. rapid warm up, cold storage
- Last mile delivery vans range extension & cold storage
- Electric range extension

OEM
- Global OEM
- Global expansion
- Global and country distributors
- Global Integrated heat and cooling products

C&I
- Global Industrial process applications
- Global Commercial applications
- Global X as a service including Demand Side Response and flexibility
- Global cooling
- Global Agriculture
- Global heat & cool networks
Thermal storage battery

**High Energy Density**

Melting and freezing a PCM (Phase Change Material) stores 3-4 times as much energy in latent heat as the sensible heat of water in a hot water cylinder. **Required** a material breakthrough to stabilize a well-known, non-toxic, low-cost but unstable PCM. **Achieved (40,000 cycles proven)**

**High thermal power**

High power charge and discharge for rapid recovery and high flow rate hot water is key user requirement. But the PCM has very low thermal conductivity. **Required** a mechanical design with high-power, low-cost heat exchanger inside, so heat can be rapidly charged into the PCM in the heat battery and equally quickly extracted. **Achieved**
Temperature Range

Materials

<table>
<thead>
<tr>
<th>Cooling</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available by special order to early adoption customers</td>
<td>R&amp;D stopped</td>
</tr>
<tr>
<td>Current full commercial volume products</td>
<td>R&amp;D active, material may enter market</td>
</tr>
<tr>
<td></td>
<td>Accelerated commercialisation</td>
</tr>
</tbody>
</table>

R&D Status

- Sunamp Cool Batteries and Heat Batteries can be filled with different PCMs to optimise each application

Sunamp’s Phase Change Materials (PCMs) are internally developed, and generally inorganic, non-flammable materials. Values indicate phase change temperature.

Note: PCMs at different level of development and not all commercially available today.

Non-confidential
Flexible Applications

- Free Heat (Air, Ground, Recycled)
- Solar Energy
- Grid AC Electricity
- Time-of-Use or Demand Side Management
- District Heat Networks
- Cool, Heat and/or Hot Water
- Cool, Heat and/or Hot Water
- Chiller/Air Con
- Fossil Fuel or Biomass
- PV Self-Consumption
- Boiler/CHP

- PV
- PVT
- ST
Better than unvented hot water cylinder.

Benefits:
- Mains pressure hot water
- Rapid reheat
- High discharge flow rate
- Compact Size
- Low heat losses, ERP A+
- No Pressure & Temperature safety valve
- No risk of explosion
- No discharge pipework
- Flexible Siting, lower cost and easy install
- No need to comply with G3 regs*
- No official maintenance requirements

*UK regulation for unvented cylinders requiring mandatory yearly inspection
Compact - Low heat loss

-71% in volume

Equal energy stored

<table>
<thead>
<tr>
<th>Equiv Cylinder</th>
<th>Daily heat loss</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed base</td>
<td>2.5 to 3.5 kWh</td>
<td>1,095 kWh</td>
</tr>
<tr>
<td>(10 years old)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brand new, top quality</td>
<td>1.3 kWh</td>
<td>475 kWh</td>
</tr>
<tr>
<td>Sunamp UniQ HW 9</td>
<td>0.74 kWh</td>
<td>270 kWh</td>
</tr>
</tbody>
</table>

Albin Trotter ATI E-305L

UniQ eHW 12

½ in both height and depth

2.140mm → ½ → 1.057mm

570mm → ½ → 365mm

570mm → ½ → 365mm
Key benefit:
- Highest efficiency on the market, nearest competitor offers water tank with B rating
- Space saving (70%)
- Price similar to water storage

Product Line

Most commonly sold size.
Replaces 210L water tank

Model Example | Measured kWh | Equivalent cylinder (L) | Heat Loss (kWh/24h) | Comments | ErP Rating
--- | --- | --- | --- | --- | ---
UniQ HW 3 | 3.5 | 70 | 0.449 |  | A+
UniQ Heat 6 | 7 | 140 | 0.649 | Stackable two high for larger storage | A+
UniQ HW 9 | 10.5 | 210 | 0.738 |  | A+
UniQ Dual 12 | 14 | 280 | 0.809 | Palletised, 1.5 Tonnes | A+
UniQ Heat 80 | 90 | 1800 | 2.2 (provisional) |  | No / Non ErP

*height for models including stand-by electric heaters

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Published Worldwide PCT Applications:
Thousands of Installations of Products Completed

Small district heating with Heat Battery

Village Hall with PV, 2x heat pumps and PV

In a prestige Passivhaus project as seen on Grand Designs

150 electric hot water tanks replaced by Heat Battery

Our customers innovating new siting locations
Hot Water with solar PV and Combis (>400 home trial)

- Enhanced behind-the-meter utilisation of on-site PV.
- Unique link between PV and combi boiler
- Side-steps feed-in tariff or net-metering complexities.
- Flexible: Can also be a primary hot water supply
- Displaces fossil-fuels (gas, oil, propane, LPG)
- Subsequently tested in >400 homes in EastHeat trial

Early adopter testing at Colin Pulham’s house!
Installation solar PV and Combis

Solar PV, combi boilers and Sunamp Storage

- Electricity consumption reduced due to PV on roof £101 SAVED
- Gas consumption reduced as a result of SunampPV £74 SAVED
Customers – Happy experience

The Lynne Family
“Our hot water is plentiful, comes out of the taps quickly and is an excellent temperature”

Alec & Joan
“In comparison to the old system, the new system performs to a much higher standard, providing a larger quantity of hot water for a much cheaper price.”

John and Jayne
“It gets a bit to getting used to, switching on the hot tap normally you would hear the sound of the gas boiler that doesn’t happen any more”
District heating - Hot water peak load shaving

**Network benefits**

- Distributed storage to reduce peak loads
- Distributed storage to reduce pumping
- Improved operational running of the heat generator whether gas CHP or heat pump
- Reduced capital expenditure because you have reduced your peak load i.e. the pipes are smaller
- Reduce on-going O&M costs less wear and tear on pumps
- Elimination of a separate Heat Interface Unit our batteries operate as the interface unit
- Elimination of legionaries as the batteries are heated to over 60°C and have no volume hot water storage
- Mains pressure for showers without complex pressure release configurations and pipework
- Small to fit into modern apartments
- Quick to install and easy to handle
- Can be wired to electricity to provide Demand Side Response heat as a service solution

Reducing the capital cost of district heating network infrastructure, AECOM & ETI 2017
Sunamp **Thermal Batteries** are the world's most energy efficient Thermal Stores

- Disruptive to hot water tanks (~43m of 107m water heaters sold/year globally, ~$50Bn market)
- Performance superiority (compactness, energy density, efficiency, flow rate, power, reliability, safety, weight)
- Cost parity today versus hot water; significant cost advantage by end 2019
- Complementary to HVAC equipment, electric batteries, renewable energy & intermittent grids
- Unique applications in high temperature, cooling and automotive
Questions and Debate