OPTIWOOD Project Summary of Biomass Boiler Data Logging Activity and Boiler Operator Training

October 2020

Interreg France (Channel Manche) England
EUROPEAN UNION
OPTIWOOD
European Regional Development Fund

South East Wood Fuels

Vert Energy ASSOCIATES

OPTIWOOD:
Overview of Data Logging Results and Operator Training
5 UK Sites

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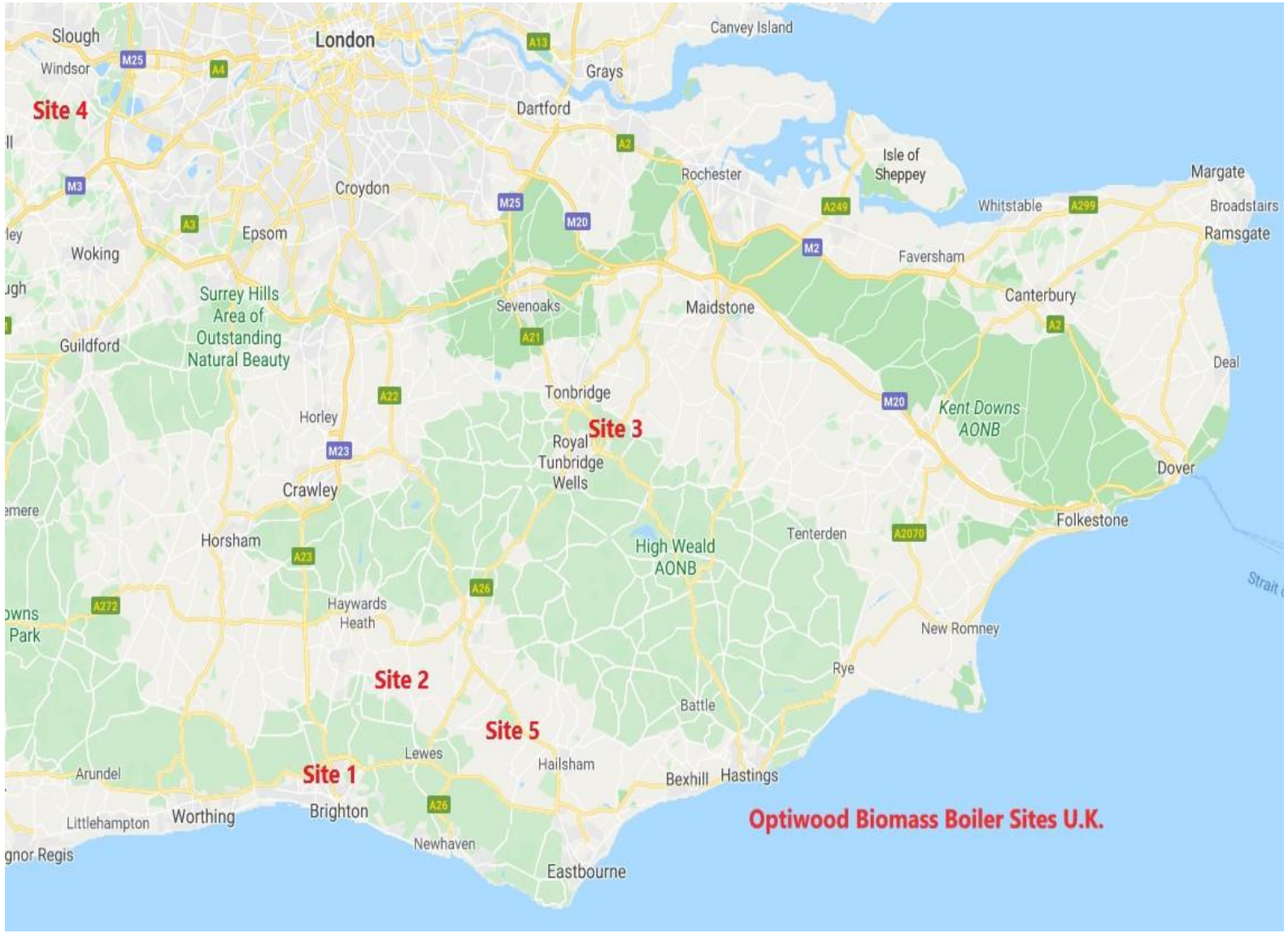
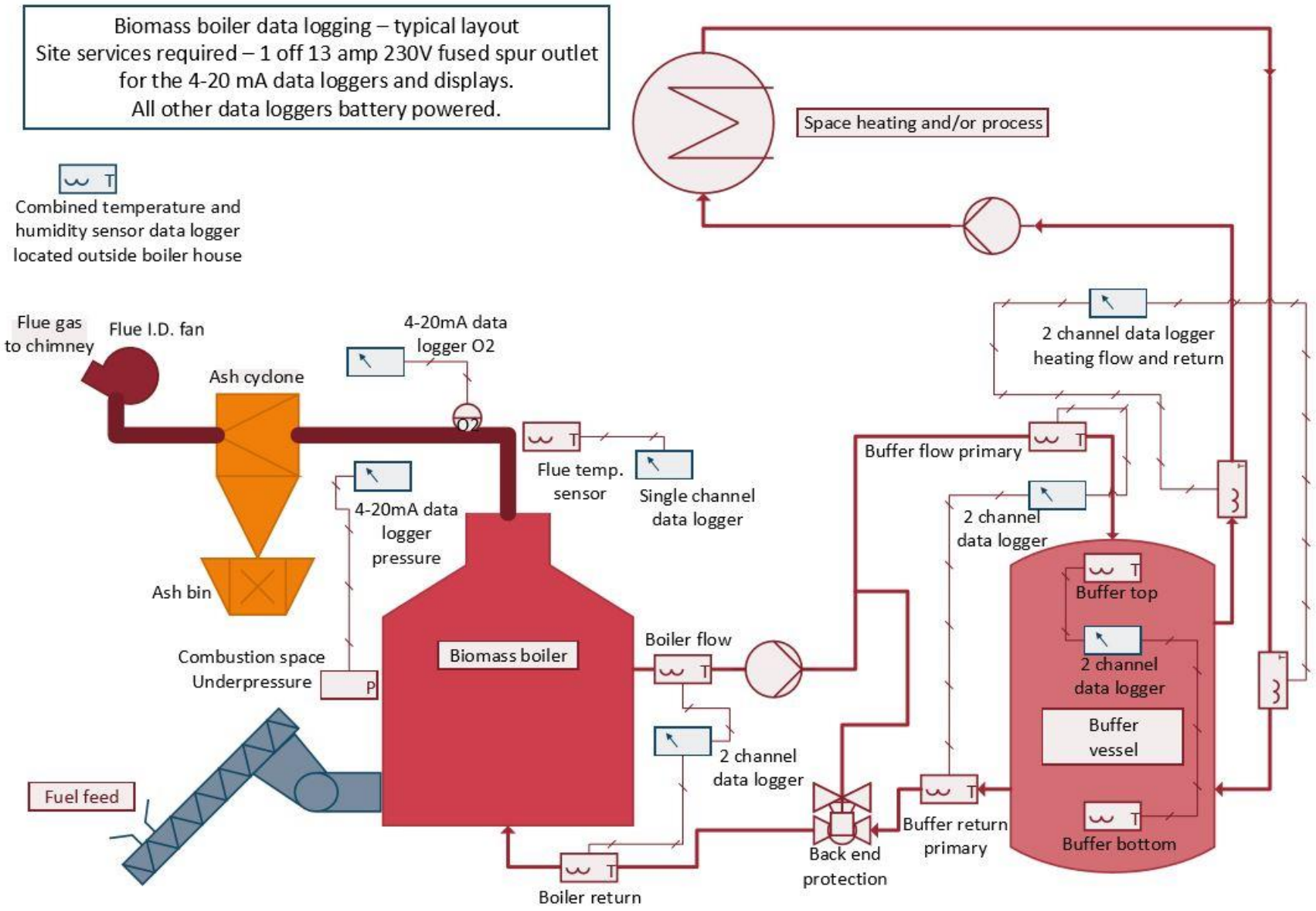
UK Pilot Sites

1. 300kW wood chip boiler:-
   - Constructed 2012 – RHI 2019
   - Archive and Library centre
2. 199kW wood chip boiler:-
   - Commissioned 2015–RHI 2011
   - Community living project
   - Series of dwellings and community spaces
3. 990kW wood chip boiler:-
   - Opened 2011 - RHI 2018
   - 512 bed NHS hospital
4. 900kW wood chip boiler:-
   - Established 1980 – RHI 2015
   - Nursery-retail space
5. 450kW wood chip boiler:-
   - Opened 1958 – RHI 2013
   - 550 pupil Academy school



Optiwood – Data Logging – Typical Site Layout



Limited budget for data logger equipment

Design was a low-impact system with minimal on site wiring

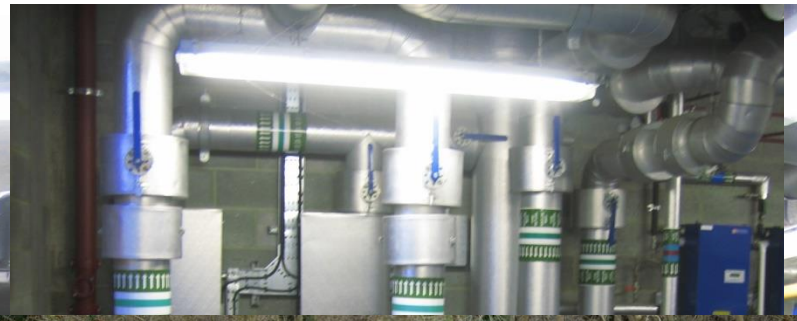
Regular site visits (4-6 weeks) were considered a bonus to liaise with the boiler operator and check ancillary site equipment

Data Logging Components Used – UK Site Installed Examples

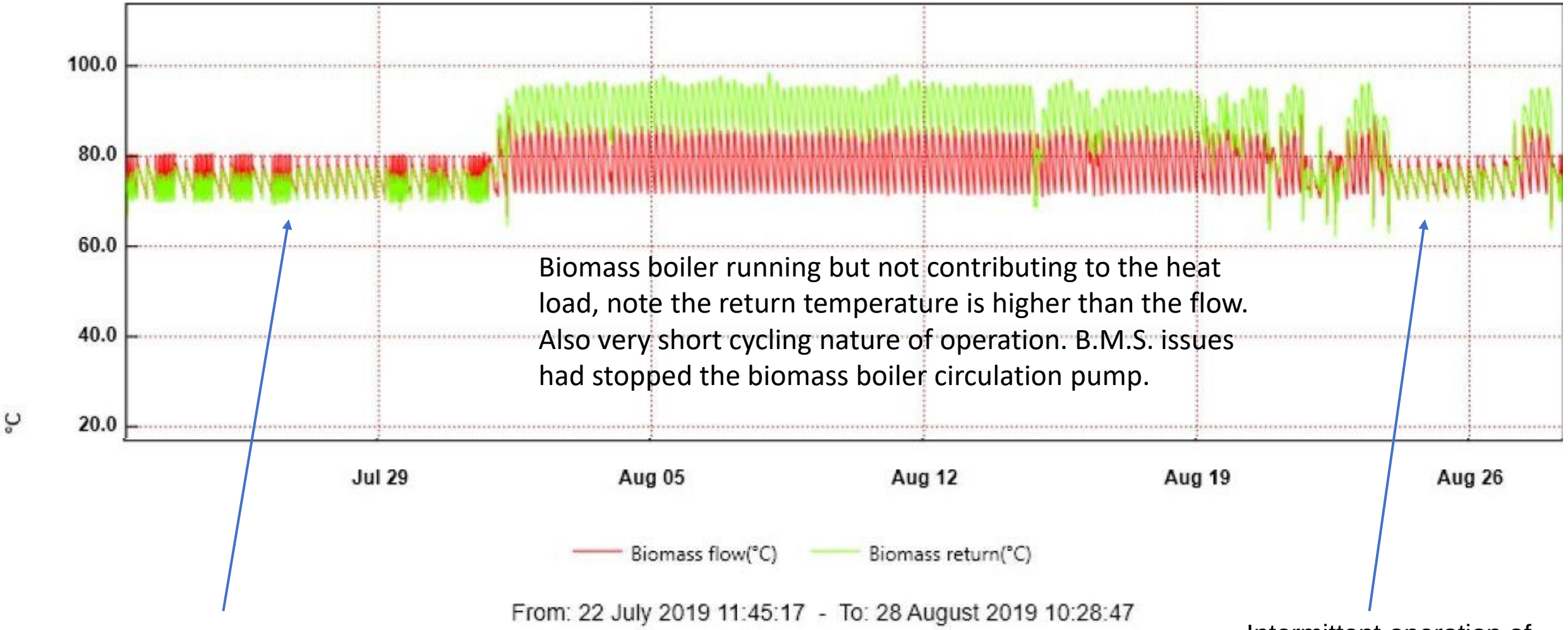
Site 1: Local Authority Archive-Offices – 300kW Wood Chip Boiler

Site 1: Local Authority Archive-Offices – 300kW Wood Chip Boiler

- Main Observations:
  - 300kW biomass boiler with buffer vessel – lead boiler with annual heat load
  - Backup modular gas boiler 3 * 100kW
  - Accredited for Renewable Heat Incentive (RHI) 2019 – existing heat meter
  - Biomass boiler off for long periods due to administrative + technical difficulties

Site 1: 300kW Biomass L. A. Offices – Flow / Return at Boiler

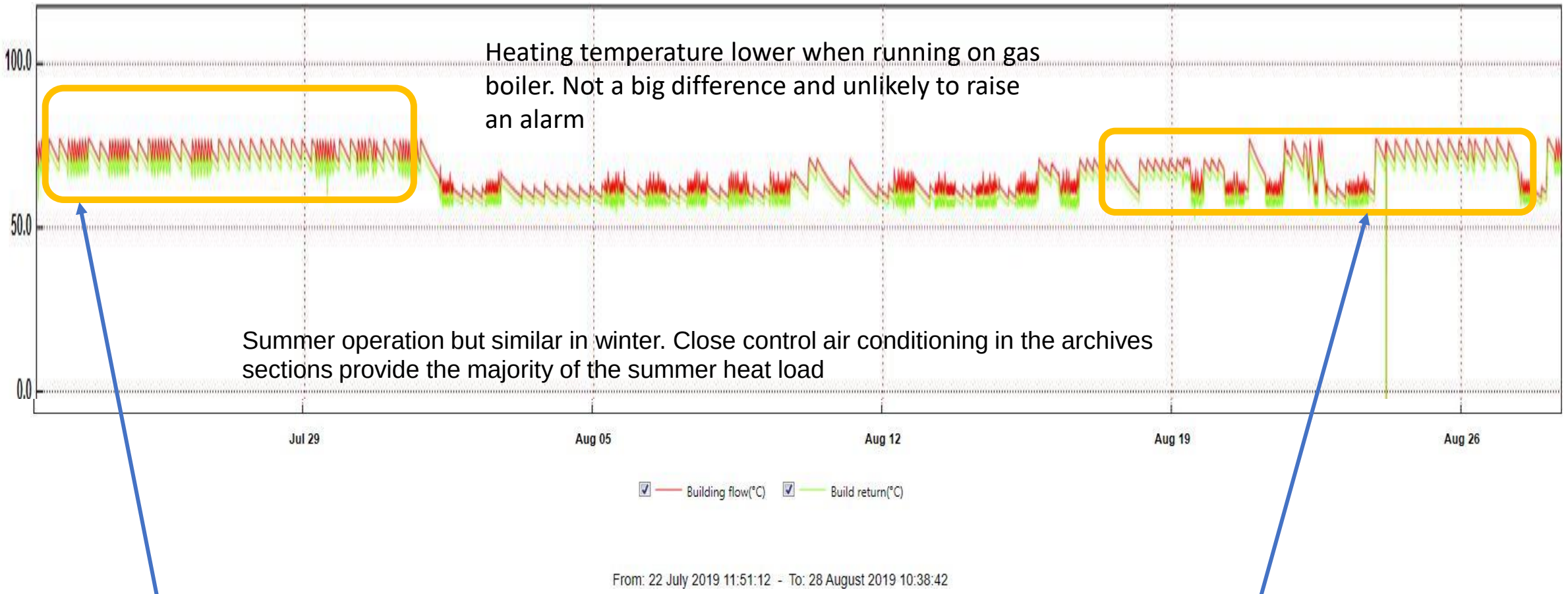


Biomass boiler running but not contributing to the heat load, note the return temperature is higher than the flow. Also very short cycling nature of operation. B.M.S. issues had stopped the biomass boiler circulation pump.

Biomass boiler running after a long period of inactivity. Note the short cycling but boiler working well.

Intermittent operation of the biomass and gas boiler circuits from the BMS output.

Site 1: 300kW Biomass L.A. Offices – Heating Flow and Return



Heating temperature lower when running on gas boiler. Not a big difference and unlikely to raise an alarm

Summer operation but similar in winter. Close control air conditioning in the archives sections provide the majority of the summer heat load

Flow and return heating temperature to the building when running on biomass boiler

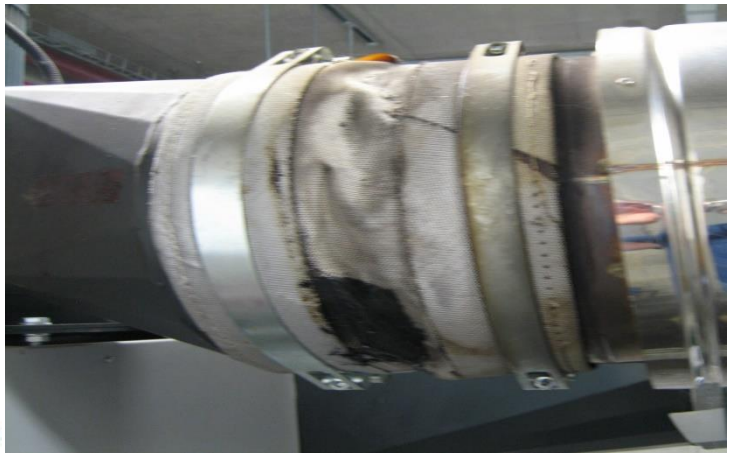
Mixed heating water temperatures during intermittent B.M.S. control condition

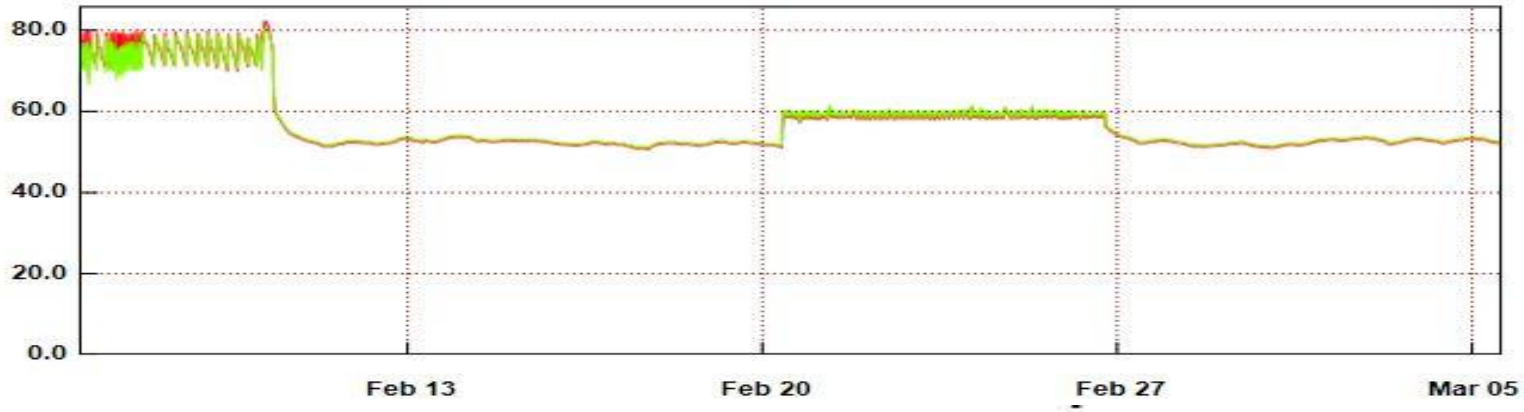
Site 1: 300kW Biomass Local Authority Records Building – Initial Summary

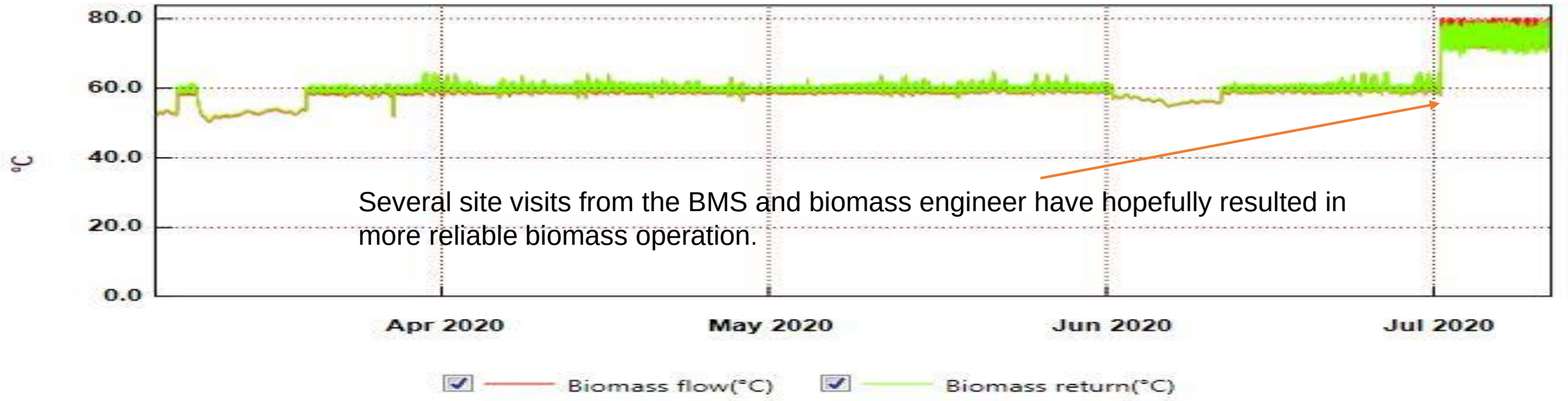
- Biomass is lead boiler:-
  - Gas backup in the event of biomass failure but BMS allowing both boilers to run
  - BMS boiler sequencing unreliable, requires manual intervention to regain biomass priority
- The biomass system can work efficiently when allowed:-
  - Site meeting arranged for all parties late 2019
  - 2 day engineering service scheduled to resolve boiler sequencing, circulation pump operation and gas boiler parameters
- Biomass short cycling:-
  - Attributed to the reduced building heat load from the initial design
  - Maximum boiler output is to be reduced when a reliable operating state is available to reduce short cycling

Site 1: 300kW Biomass L.A. Offices – UPDATE Sept 2020

- Biomass flow and return



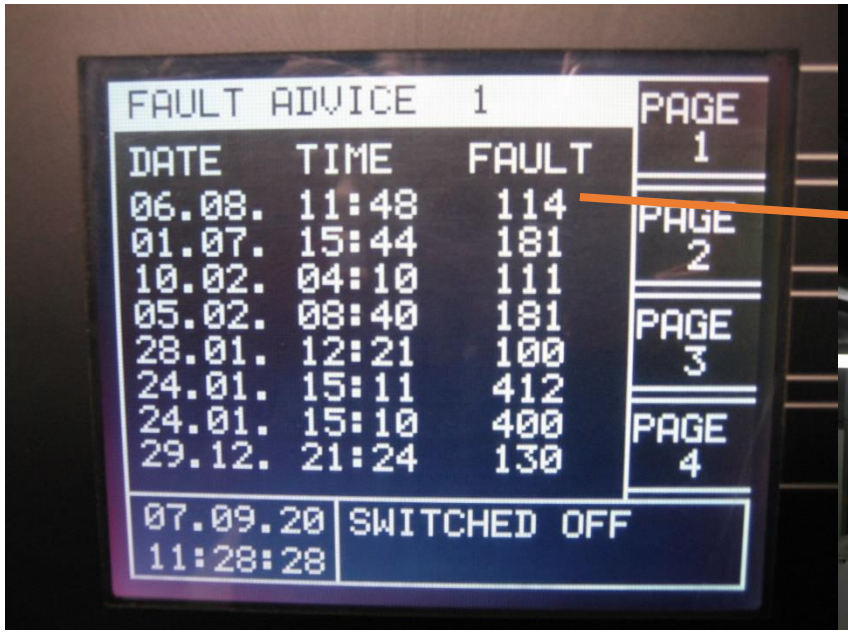




Several site visits from the BMS and biomass engineer have hopefully resulted in more reliable biomass operation.

Site 1: 300kW Biomass L.A. Offices – UPDATE Sept 2020

- Biomass boiler

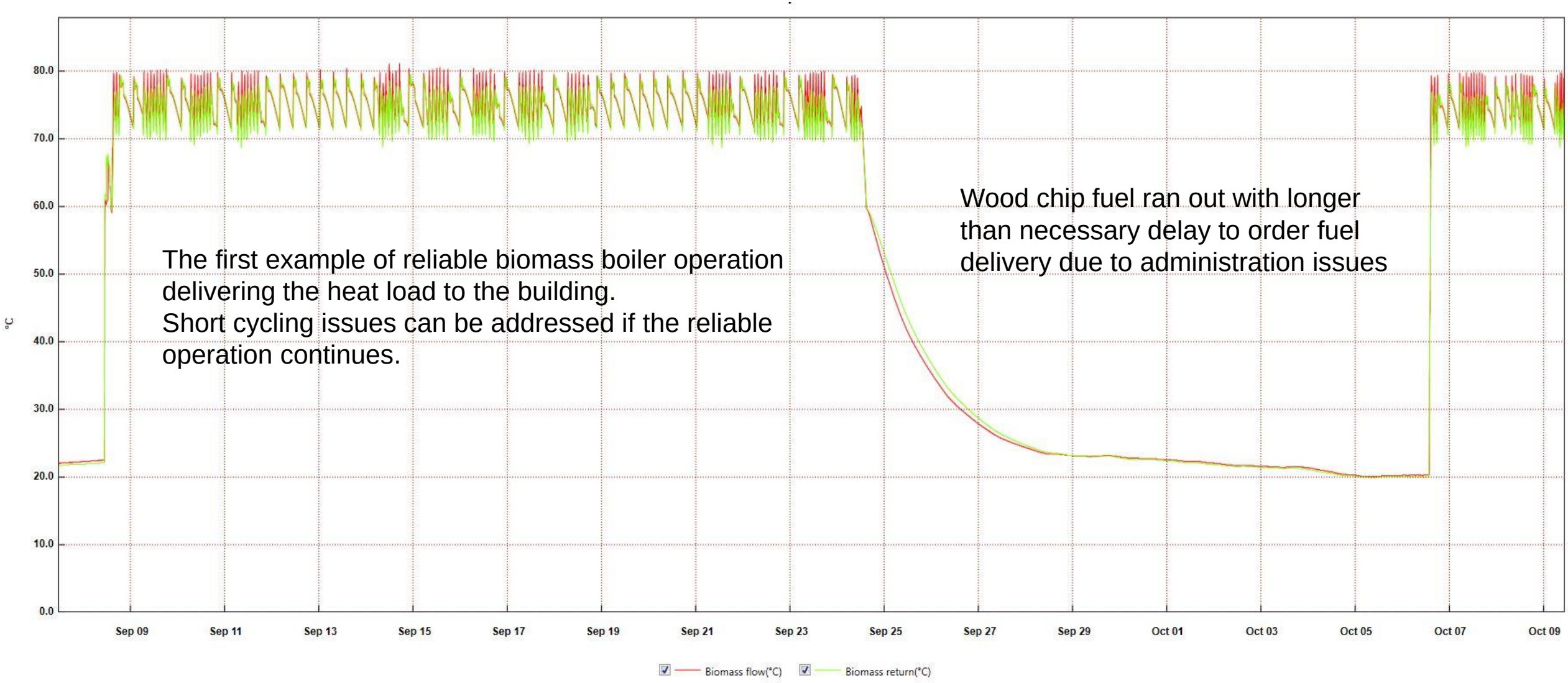


Water level dropped in stoker protection reservoir

A combination of some simple boiler faults, a power cut, BMS inconsistencies and extended repair response times result in a dirty floor and lost R.H.I. revenue.

Site 1: 300kW Biomass L.A. Offices – UPDATE Oct 2020

- Biomass boiler flow and return

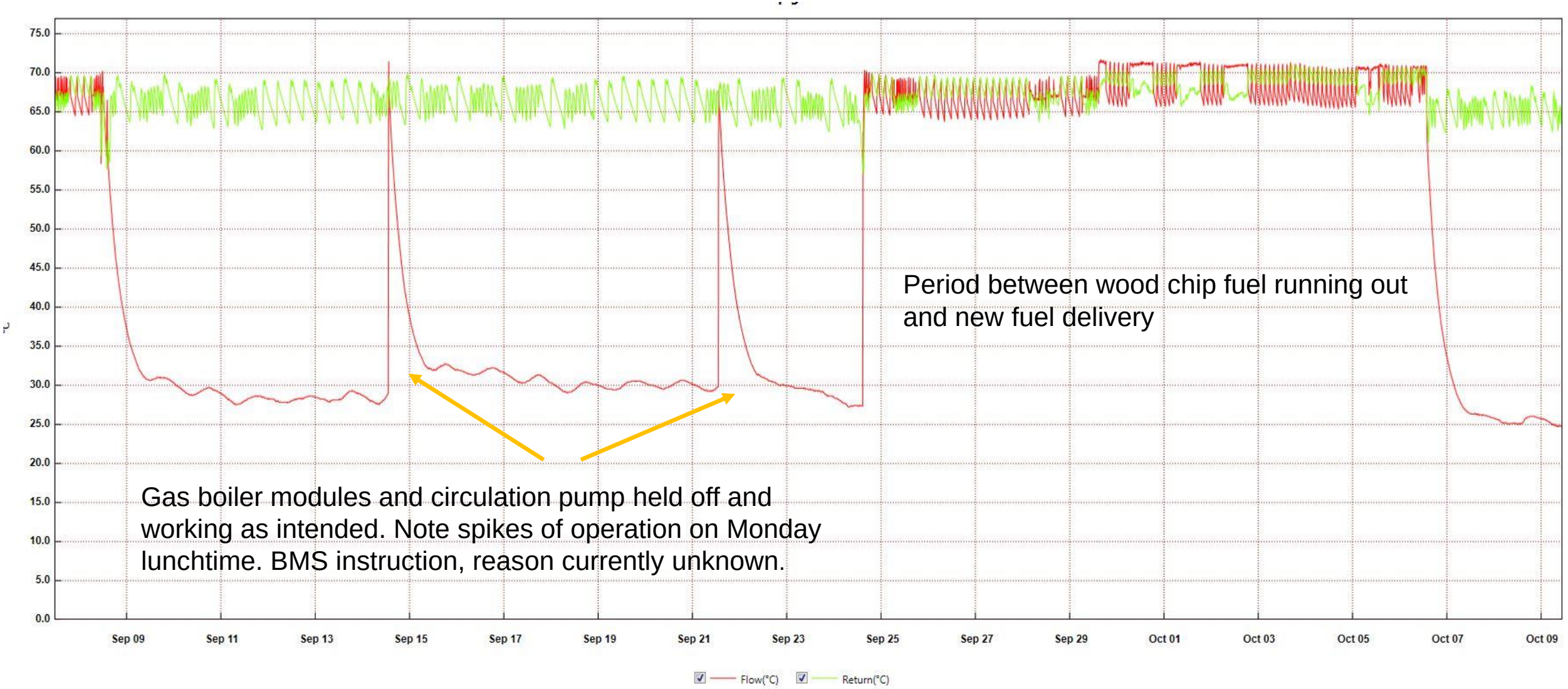


The first example of reliable biomass boiler operation delivering the heat load to the building.
Short cycling issues can be addressed if the reliable operation continues.

Wood chip fuel ran out with longer than necessary delay to order fuel delivery due to administration issues

Site 1: 300kW Biomass L.A. Offices – UPDATE Oct 2020

- Gas boiler flow and return



Site 1: 300kW Biomass L.A. Offices – Conclusions

- Biomass boiler more than capable of supplying the required heat load with good combustion characteristics.
- As the biomass boiler was recently accredited for RHI the site personnel may not be fully aware of the financial benefit to run on wood chip as much as possible and save use of fossil fuel boilers.
- Good news:- early October 2020 shows how the plant room can operate as intended.

Site 1: 300kW Biomass L.A. Offices – Efficiency 2018 – 19 - 20

Pilot Project 1 - Public Sector-Offices Storage (300kW)	Wood Fuel Consumption (tonnes at 30% MC)	Wood Fuel Coverage (% of total heat demand)	Biomass Boiler Efficiency (%)	Costs of Wood Fuel	Tonnes CO_2 Emissions saved (cf with equivalent gas)
Heating Season 2018-19	30	34%	42%	N/A	8.3
Heating Season 2019-20	35	27%	40%	N/A	9.3
Gain or Loss	+5	-7	-2%	N/A	+1
Estimated Additional Gains if Recommendations Carried out	+25	+35%	+30% (72%)	N/A	+5

Footnote 1: Boiler not operating for long periods due to control issues

Footnote2: Based on evidence of correct running operations

Footnote3: Based on short period of correct operations by biomass and conservative efficiency calcs

Footnote 4: Based on higher boiler efficiency levels and much longer running periods

(Conversion factors used from DEFRA:- UK Govt GHG Conversion Factors for Company Reporting. Version 1.00 Year 2020)

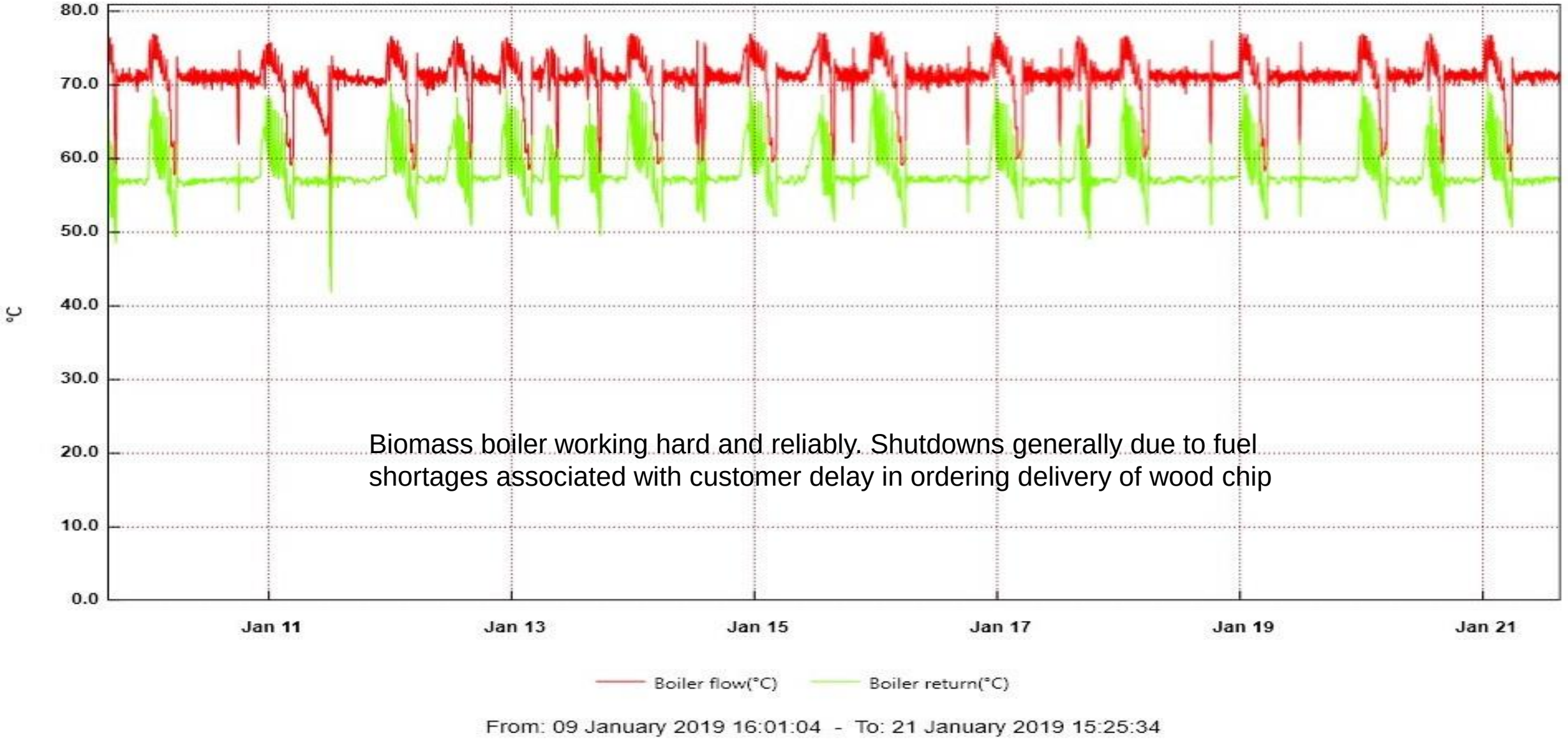
Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- Main Observations:
  - 199kW biomass boiler with two buffer vessels serving underground heat main (>1.2km)
  - Annual heat load without backup heat source
  - Accredited for Renewable Heat Incentive (RHI) c.2013 – existing heat meter
  - Current boiler replaced original five year old 300kW biomass boiler
  - Many residents complaining of inadequate heating and hot water

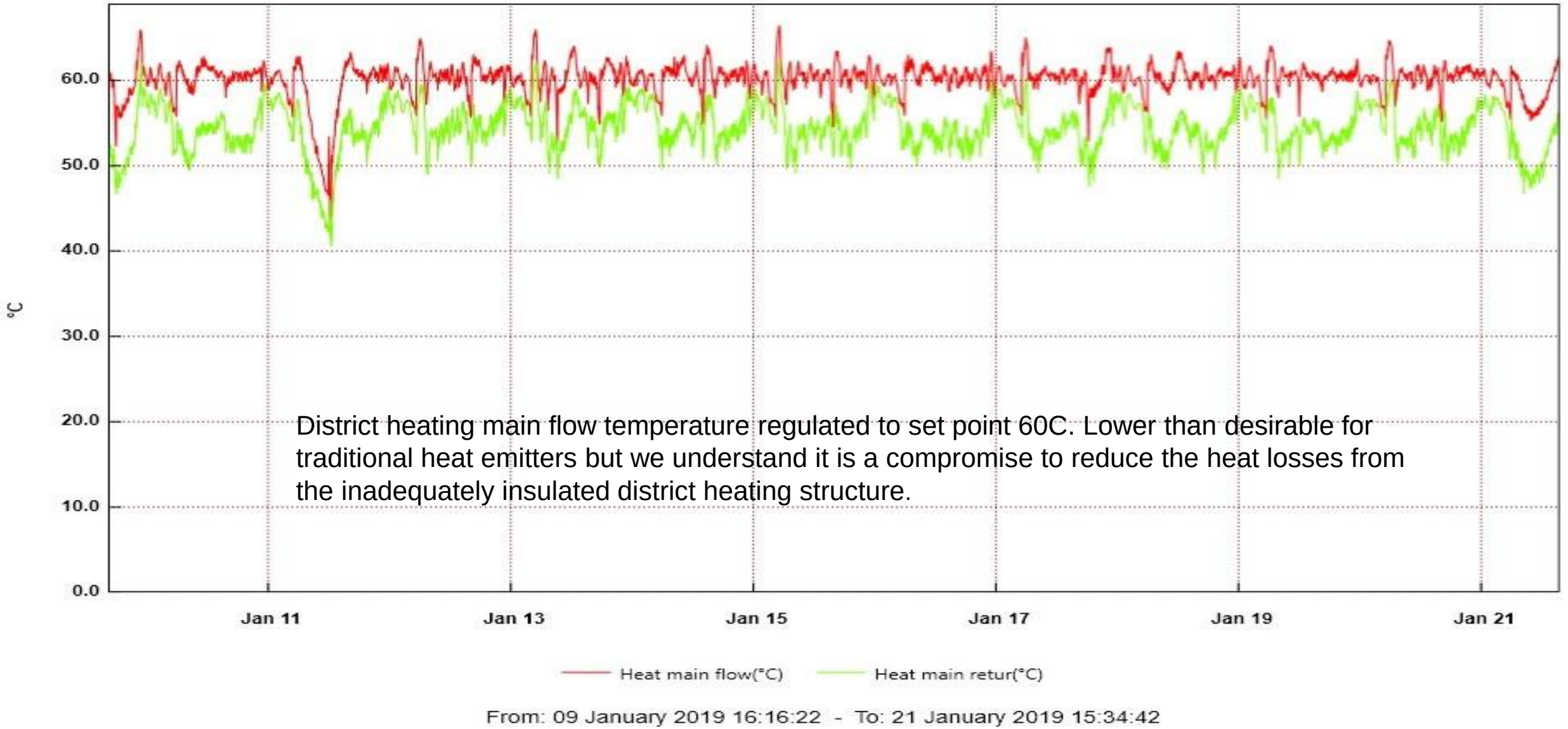
Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- Boiler Flow and Return



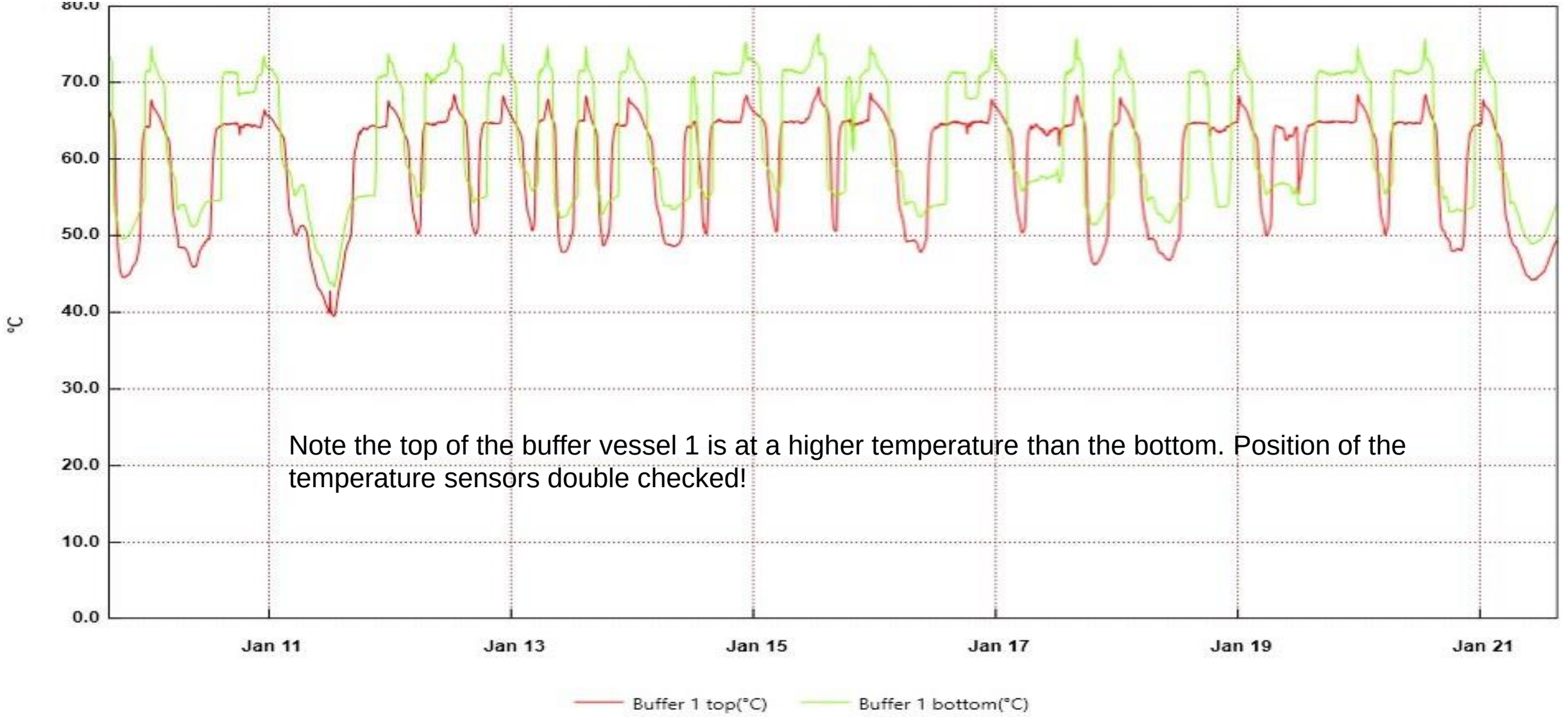
Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- District Heat main Flow and Return



Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

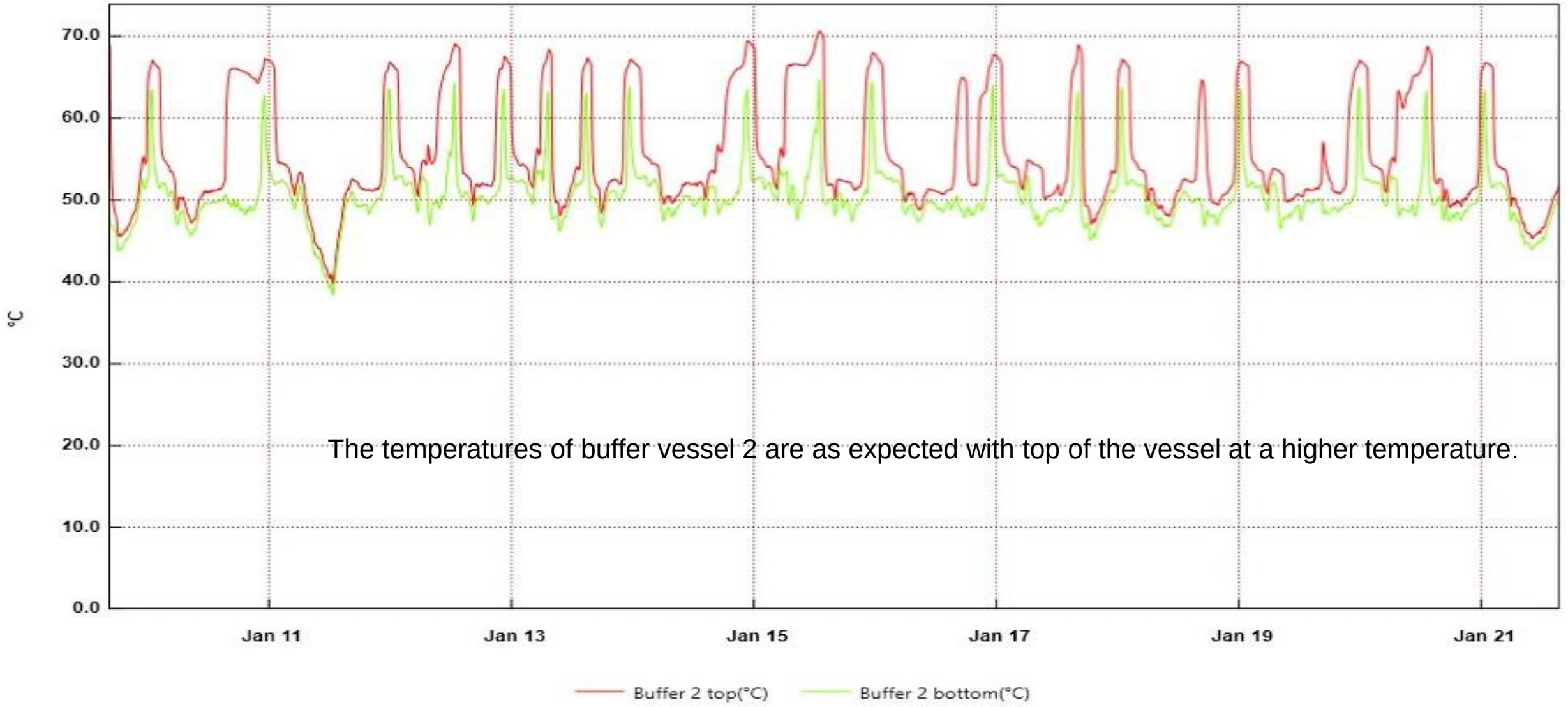
- Buffer Vessel 1



Note the top of the buffer vessel 1 is at a higher temperature than the bottom. Position of the temperature sensors double checked!

Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- Buffer Vessel 2

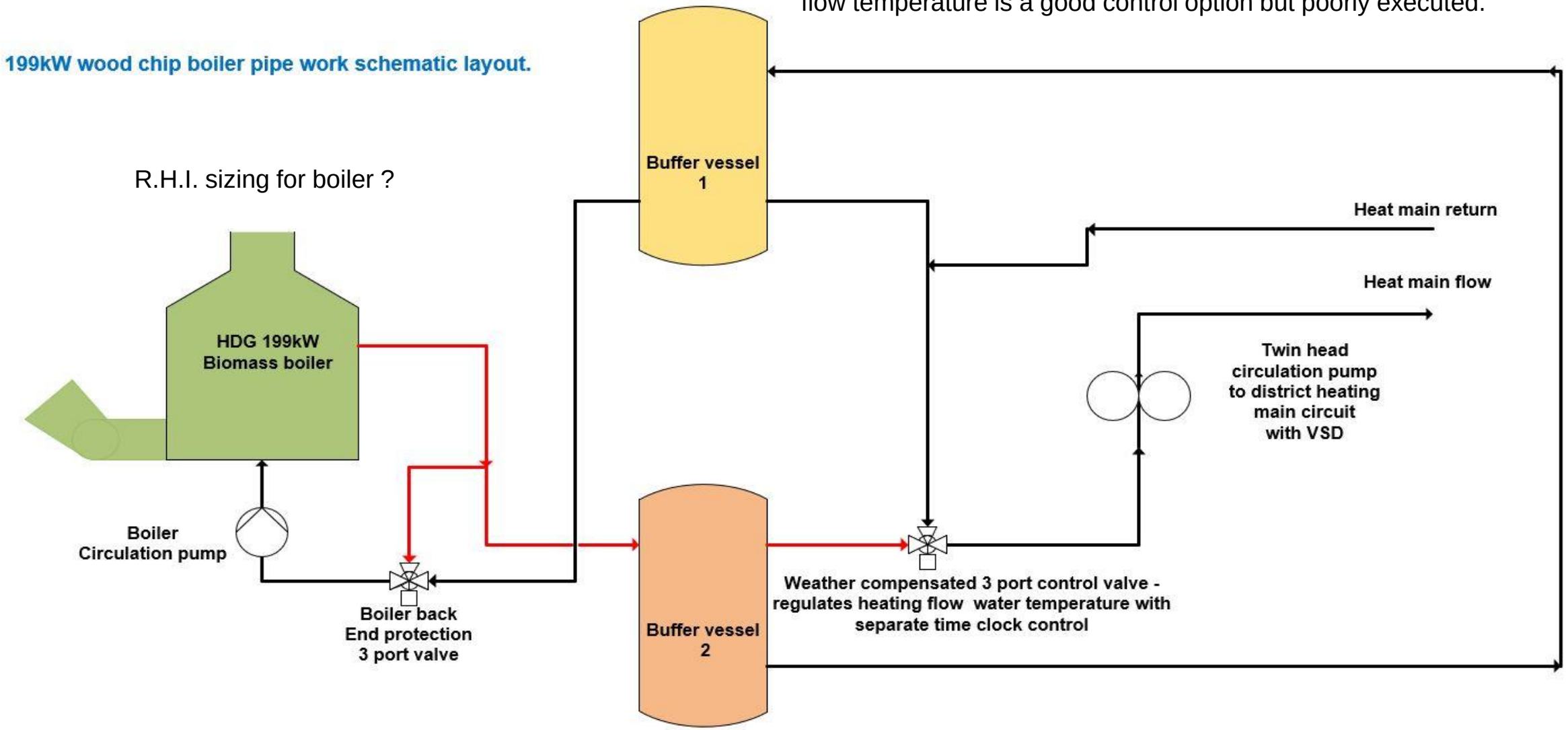


The temperatures of buffer vessel 2 are as expected with top of the vessel at a higher temperature.

Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

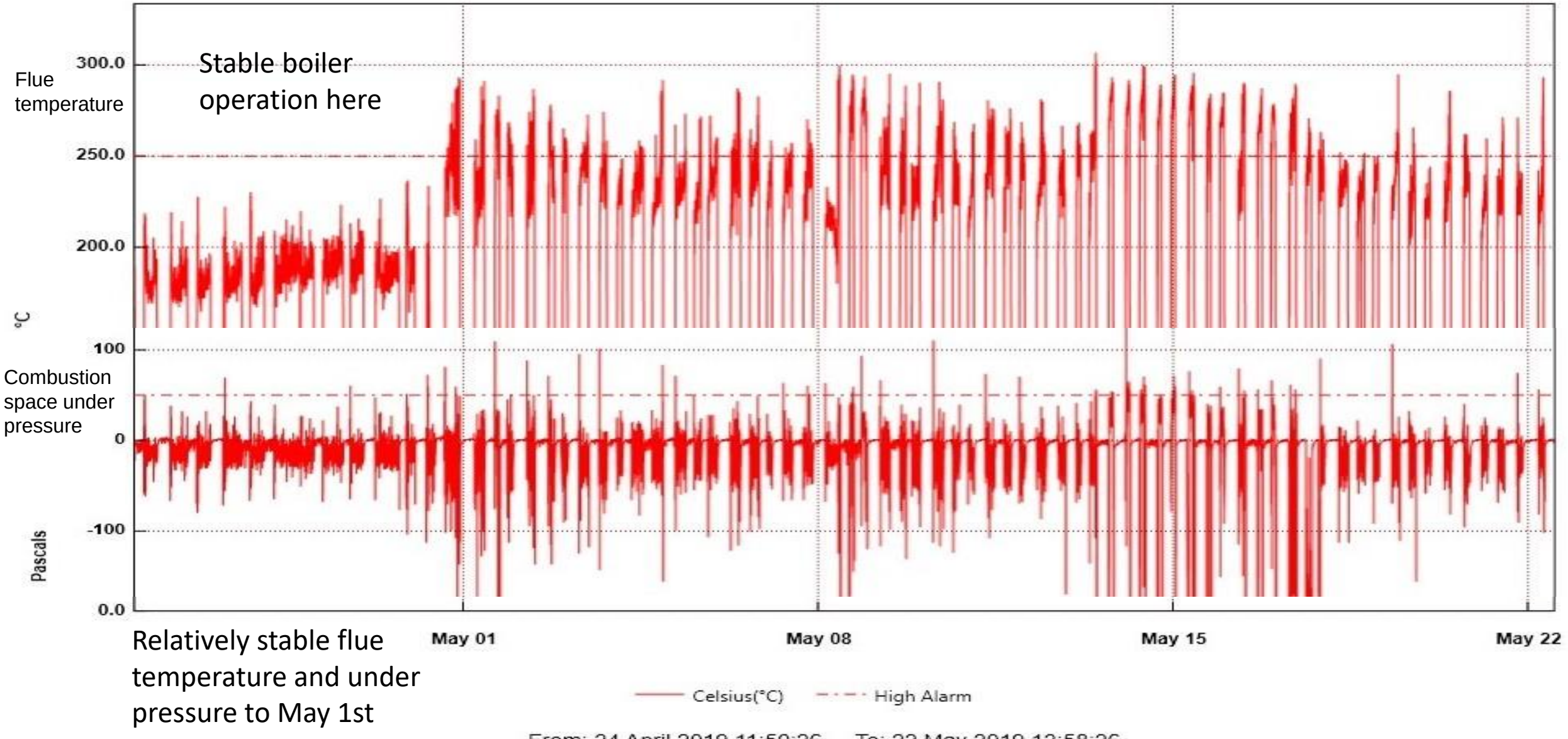
- Pipework layout

Convoluted pipe layout could be simplified and make better use of the buffer vessel storage capacity. Weather compensated heat main flow temperature is a good control option but poorly executed.



Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- Erratic boiler combustion condition indication – flue temperature and underpressure



Relatively stable flue temperature and under pressure to May 1st

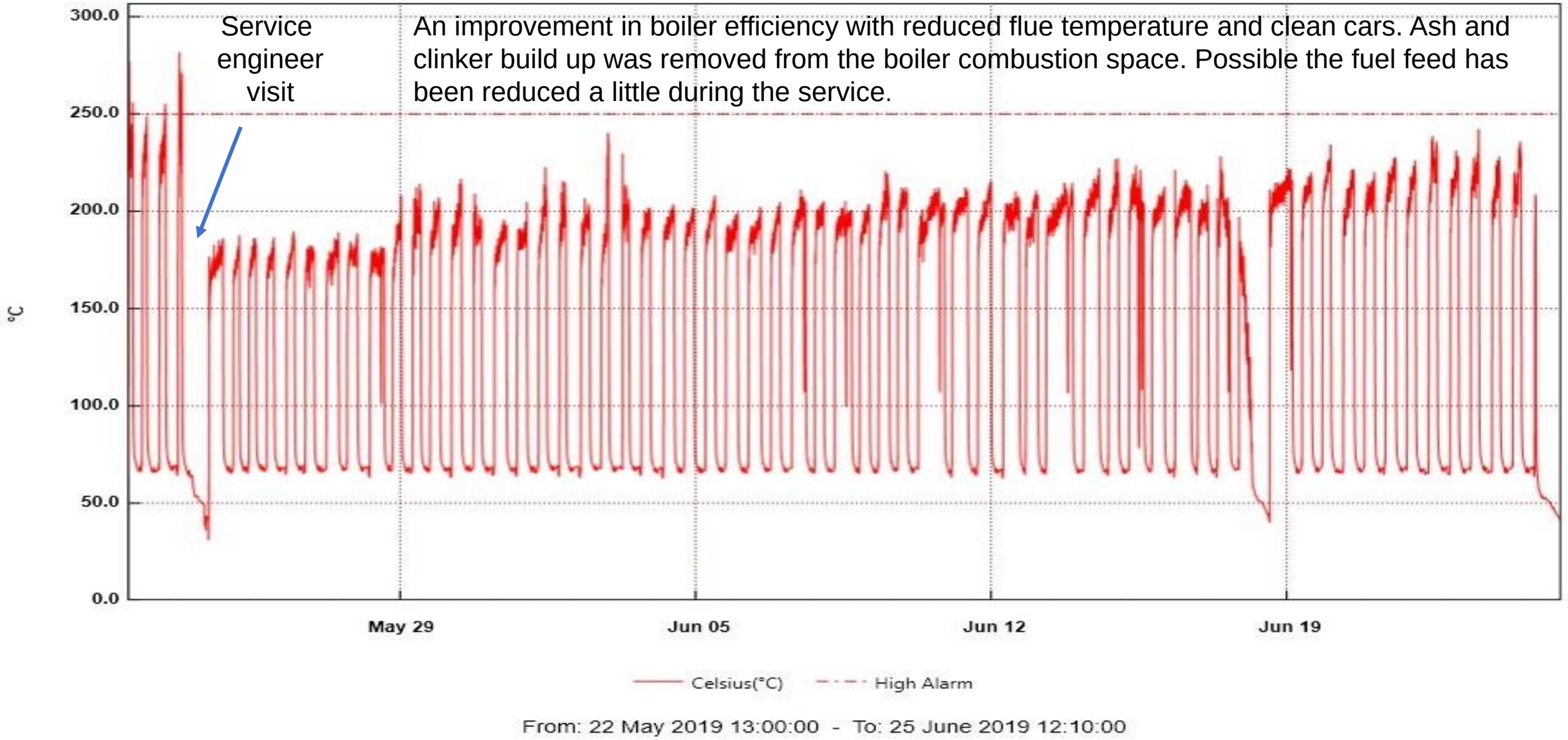
Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- Boiler combustion condition indication – car park

While collecting boiler data from site the accumulation of fine ash on the vehicles in the adjacent car park was evident. This and the erratic combustion parameters suggested urgent service visit required.

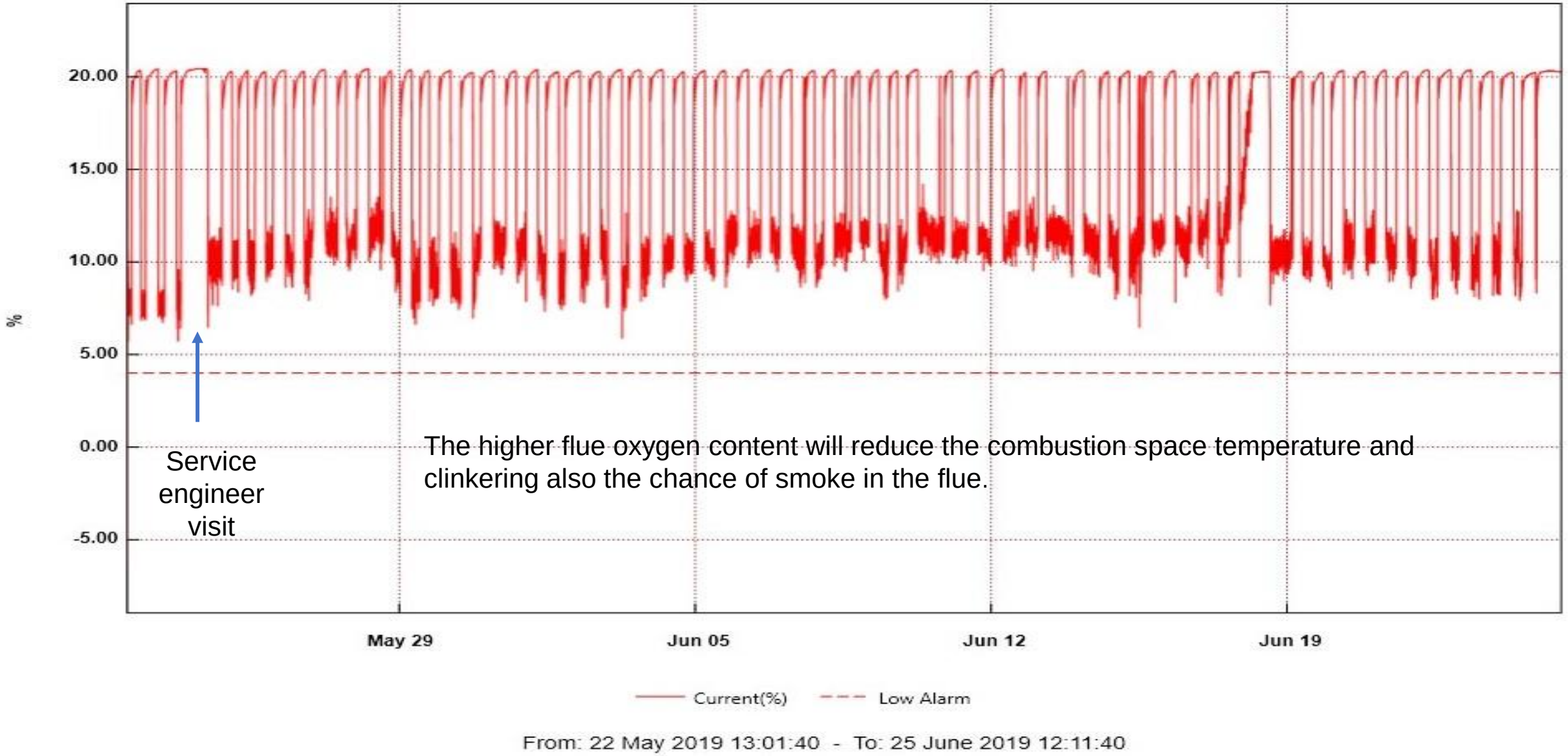
Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- Boiler combustion condition after service engineer visit – flue temperature reduced



Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- Boiler combustion condition after service engineer visit – flue oxygen content increase

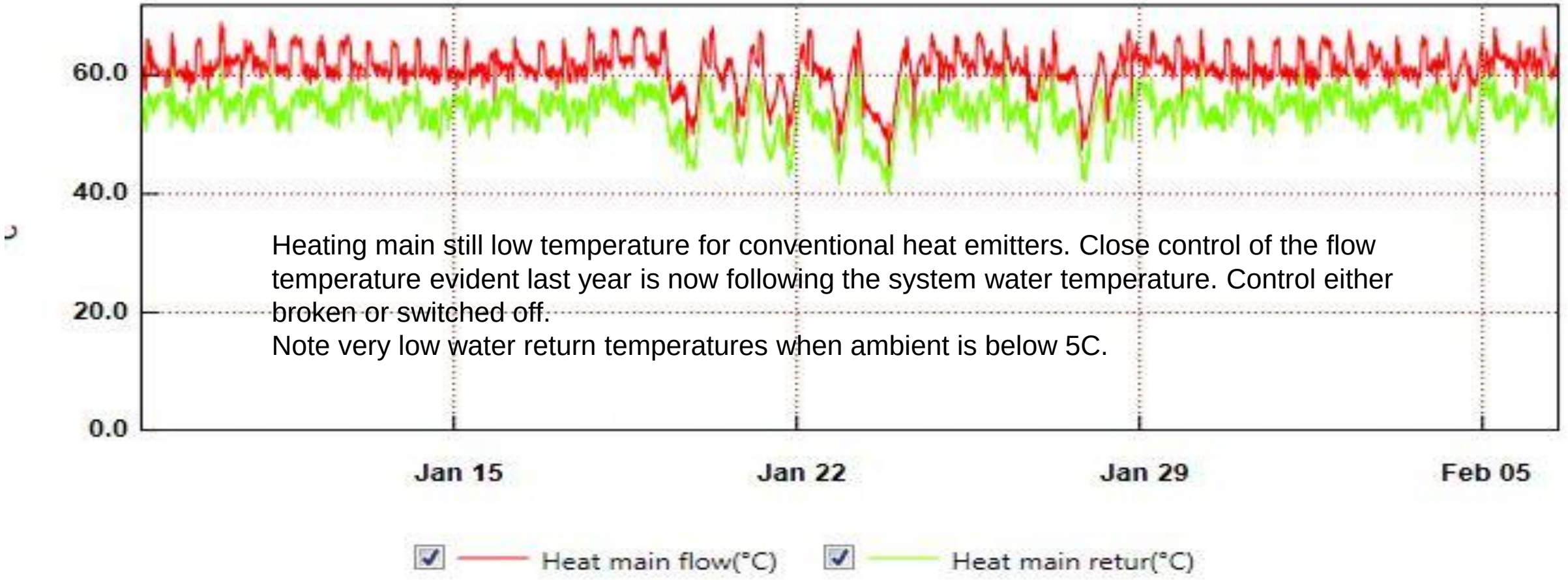


Site 2: 199kW Biomass Community Project - Initial Summary

- Biomass boiler sole source of heating to small district heating community.
- Marginal boiler sizing coupled with the poorly insulated district heating system contributes to many residents having insufficient heating and / or hot water.
- The flow temperature for the heating main has been adjusted down to reduce heat losses from heat main.
- The two buffer vessels do not contribute as effectively as possible to the system capacity.
- The site managers have been informed but to date have not taken up the offer to consider the options for improvement.

Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

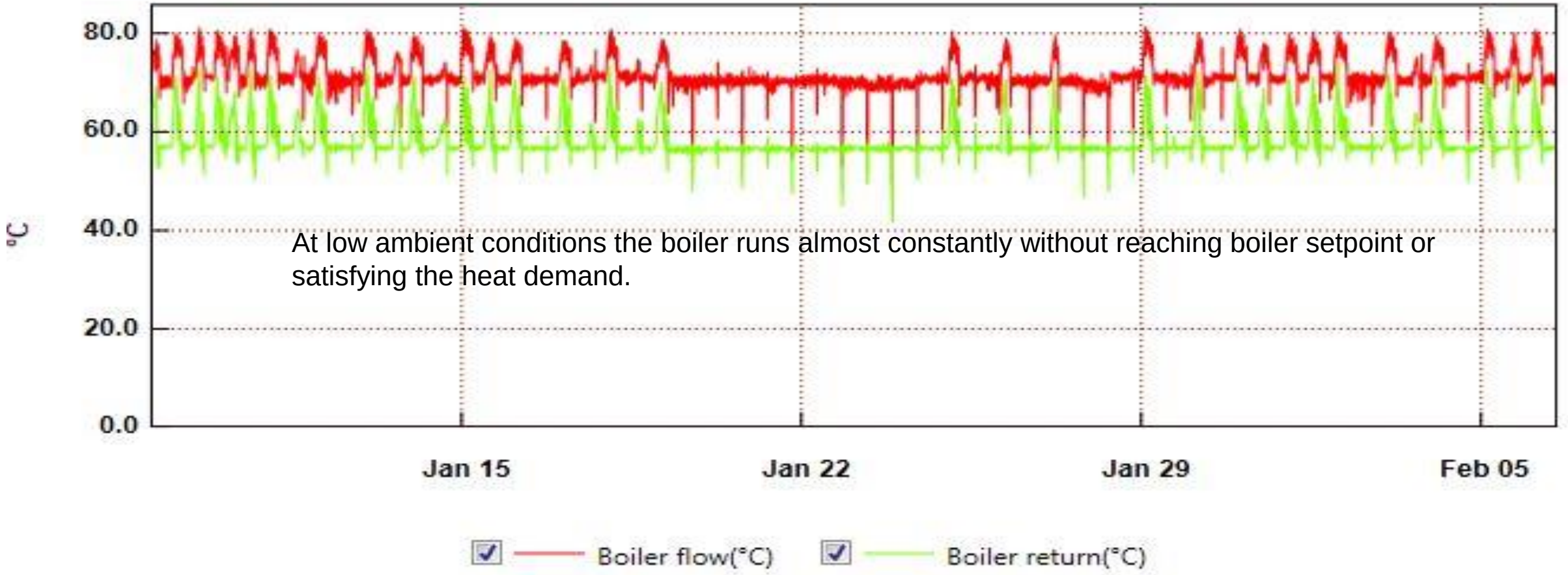
- UPDATE Feb 2020 Heat main – flow and return



Heating main still low temperature for conventional heat emitters. Close control of the flow temperature evident last year is now following the system water temperature. Control either broken or switched off.
Note very low water return temperatures when ambient is below 5C.

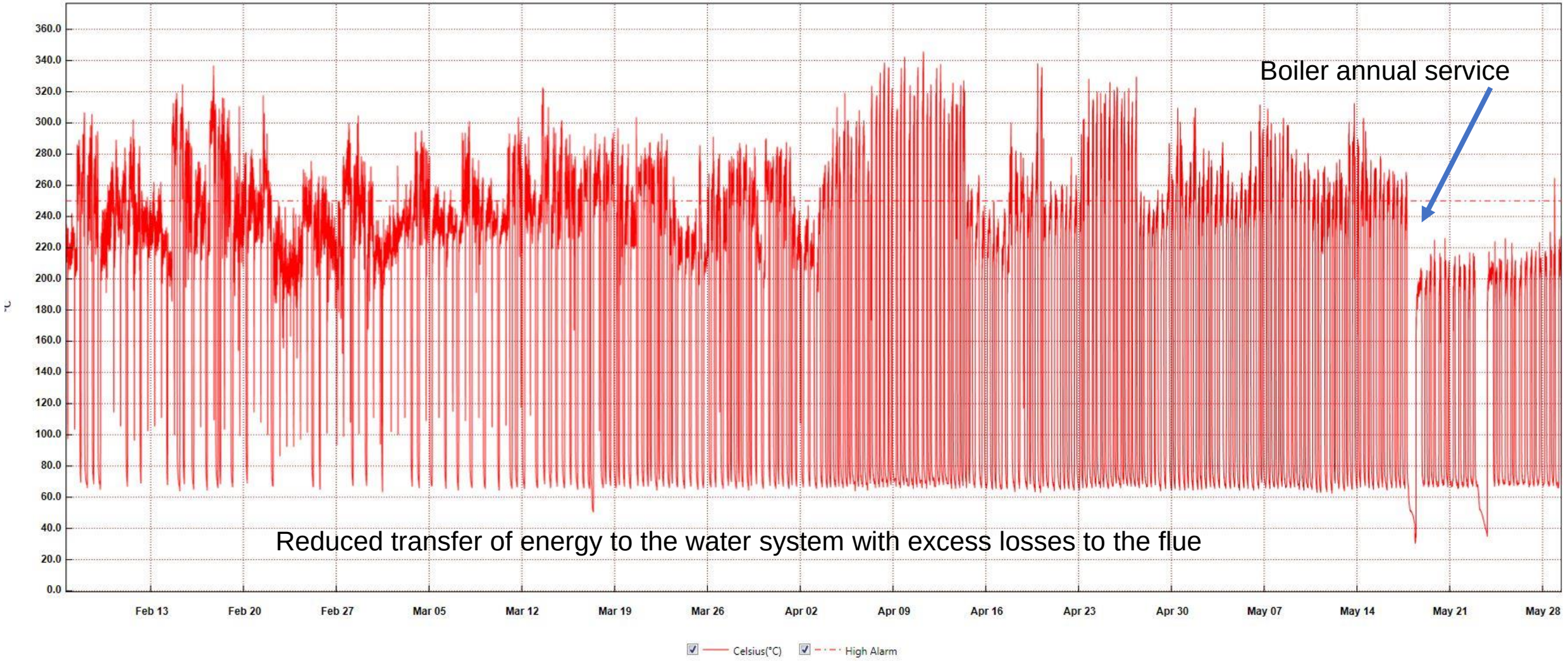
Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- UPDATE Feb 2020 Biomass boiler flow and return



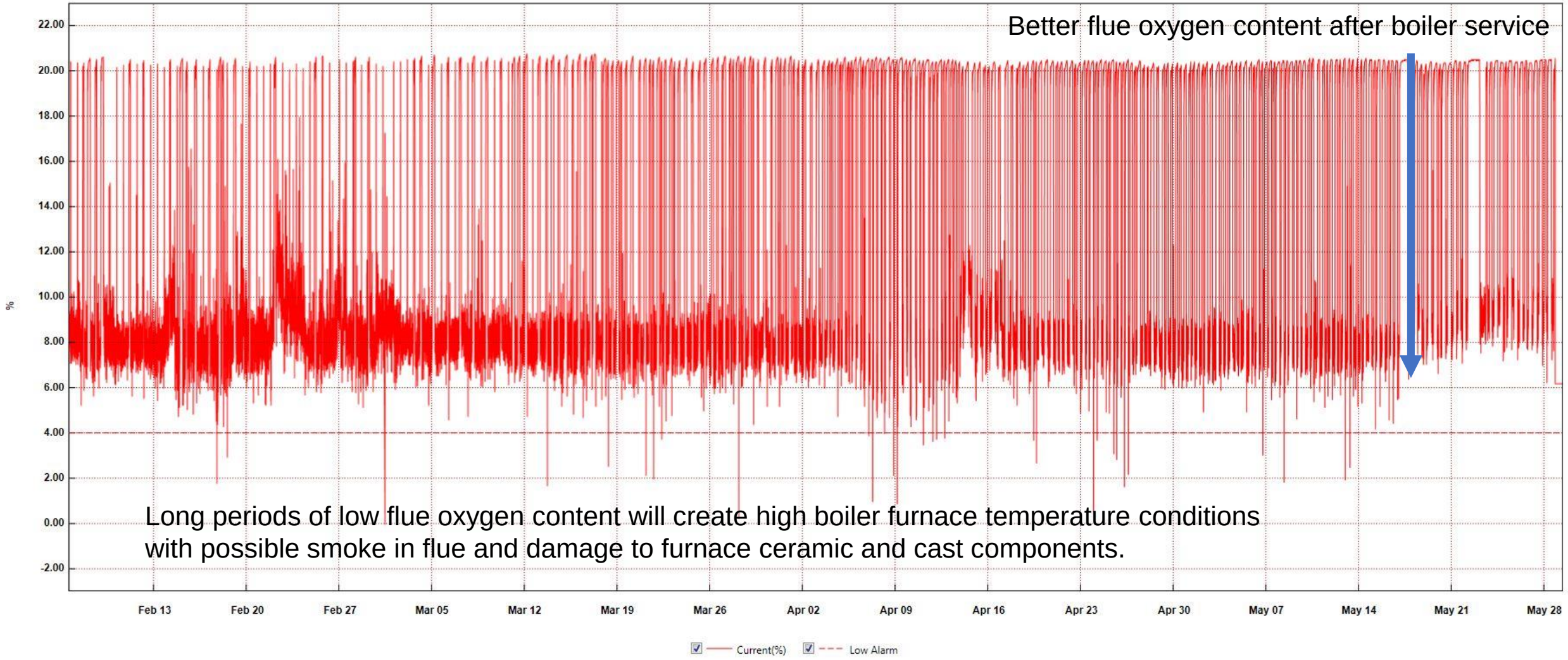
Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- UPDATE Sept 2020 Flue temperature over extended period



Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- UPDATE Sept 2020 Flue oxygen content



Site 2: Community Project, District Heating – 199kW Wood Chip Boiler

- UPDATE Sept 2020 Boiler House - recurring issues

Site 2: Community Project, District Heating – 199kW Wood Chip Boiler Conclusion

- Biomass boiler generally working well with good combustion characteristics.
- Poor installation and specification of the district heating scheme has resulted in huge heat losses.
- Boiler house pipe work modifications could make better use of the 2 buffer vessels
- A proposal to turn off the boiler in the summer months (reduce the very lowest efficiency periods of operation) and use alternative forms of energy to heat the residents hot water demand has not been considered a viable option.
- Biomass boilers working at high output and all year round should have a minimum of two major services to help keep them operating to their optimum and also increase their life span. If in doubt the run hours per annum should be recorded and get advice from the boiler supplier as to the service visits recommended.
- Attention to detail required e.g. maintain the correct system water pressure.

Site 2: Community Project, District Heating – 199kW Wood Chip Boiler Efficiency 2018 – 19 - 20

Pilot Project 2 - Community D Heating (200kW)	Wood Fuel Consumption (tonnes at 30% Moisture Content)	Wood Fuel Coverage (% of total heat demand)	Biomass Boiler Efficiency (%)	Costs of Wood Fuel	Tonnes CO_2 Emissions saved (cf with equivalent heating oil)
Heating Season 2018-19	178	100%	57%	N/A	87
Heating Season 2019-20	164	100%	60%	N/A	86
Gain or Loss	-14	-	+3%	N/A	-1
Estimated Additional Gains if Recommendations Carried out	-30	-	+15-20% (75-80%)	N/A	N/A

Footnote1: Based on boiler room hydraulic hanges and not running system over summer

Footnote2: No other heating system on site except for some individual electric water heaters

Footnote 3: Mods to hydraulic system in boiler room and switching biomass system off in summer

Footnote4: Lower use of biomass in summer but electic water heating with higher CO2 emissions (not possible to calculate)

(Conversion factors used from DEFRA:- UK Govt GHG Conversion Factors for Company Reporting. Version 1.00 Year 2020)

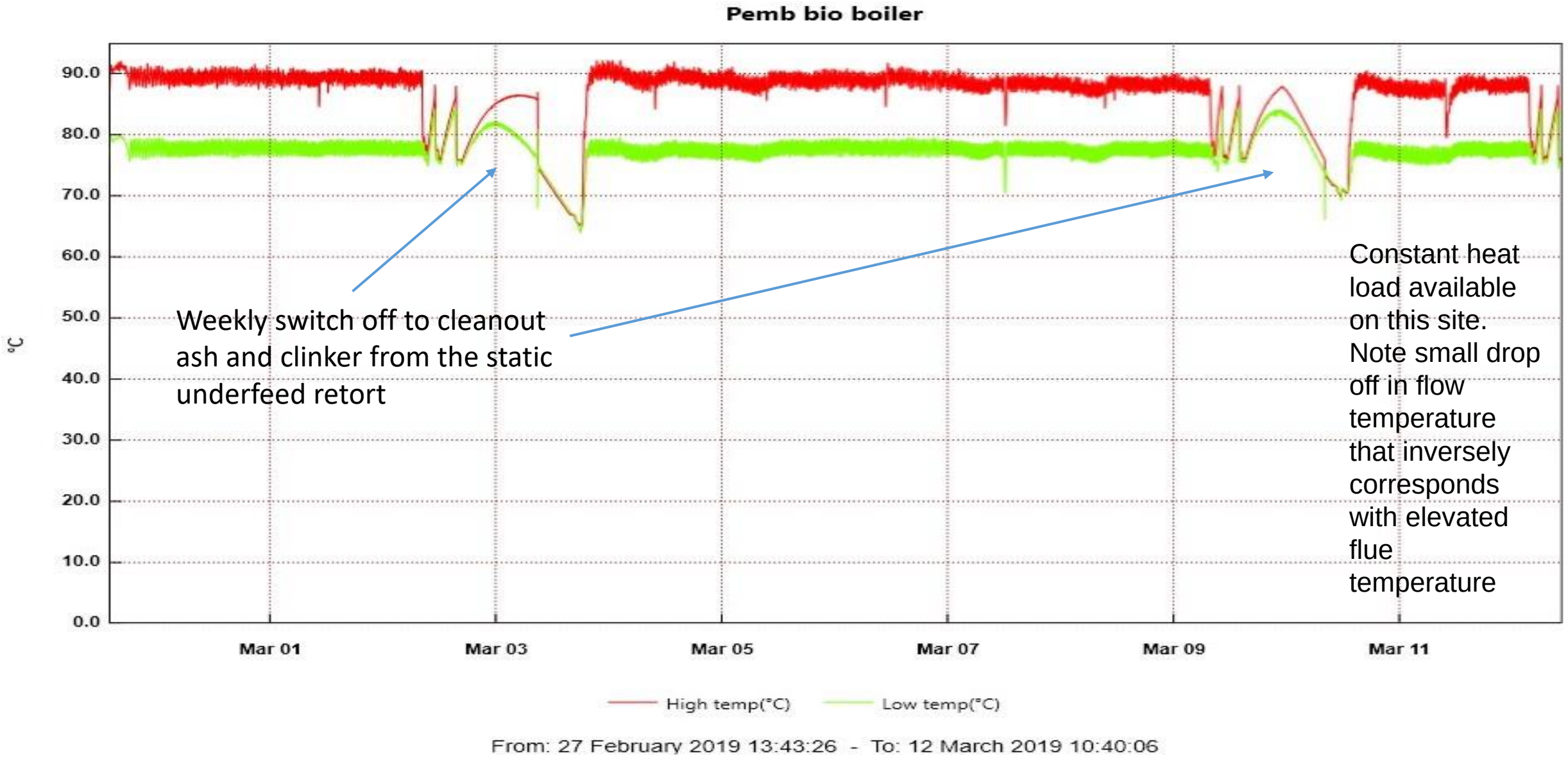
Site 3: NHS Hospital 990kW Wood Chip Boiler

Site 3: NHS Hospital 990kW Wood Chip Boiler

- Main Observations:
  - 990kW biomass lead boiler with 10,000l buffer vessel
  - Four backup multi fuel boilers
  - Accredited Renewable Heat Incentive (RHI) 2018 – existing heat meter
  - Designed to provide up to 20% annual heating load

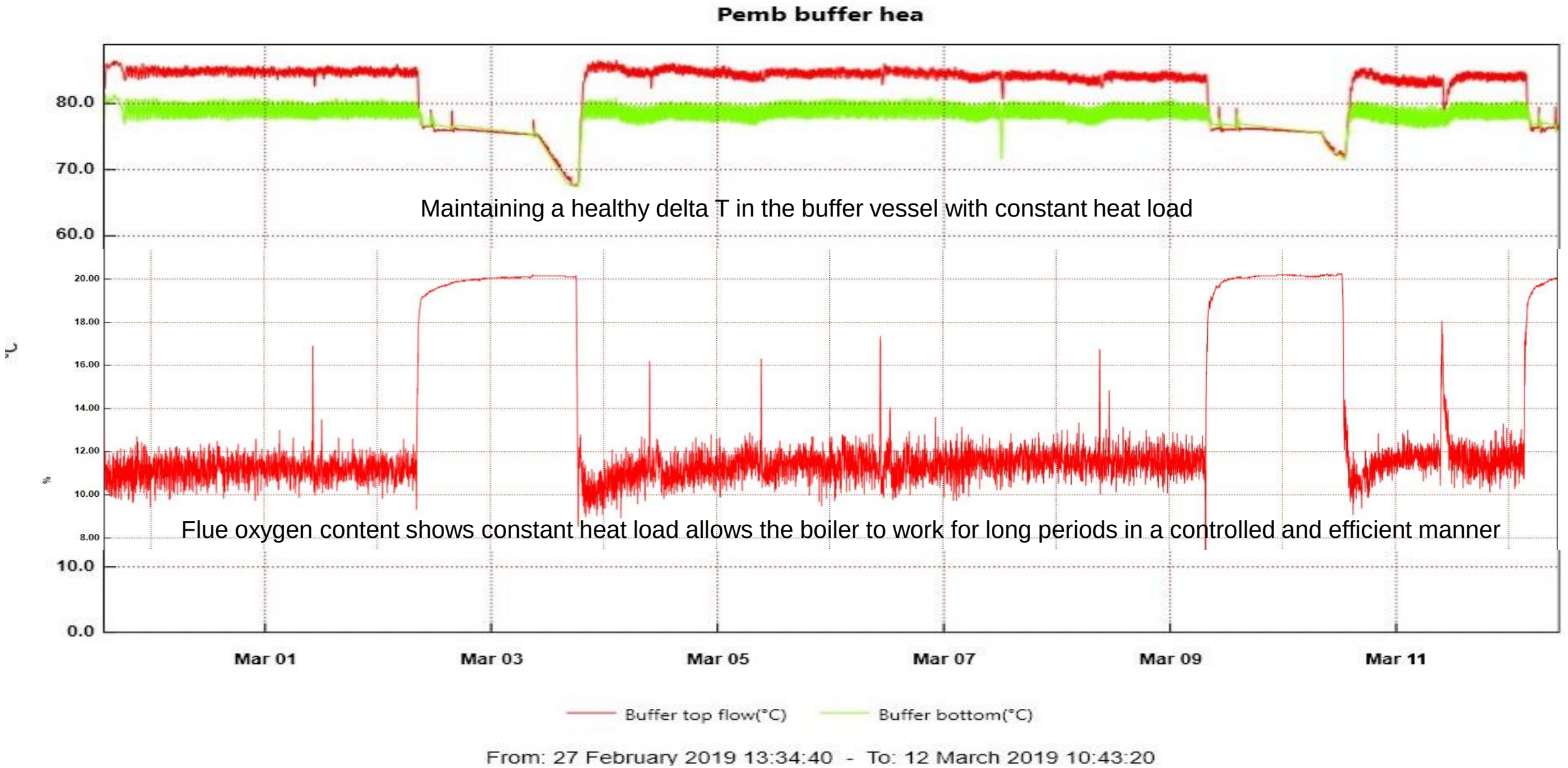
Site 3: NHS Hospital 990kW Wood Chip Boiler

- Boiler Flow and Return Temperature



Site 3: NHS Hospital 990kW Wood Chip Boiler

- Buffer Vessel Temperature and Flue Oxygen Content

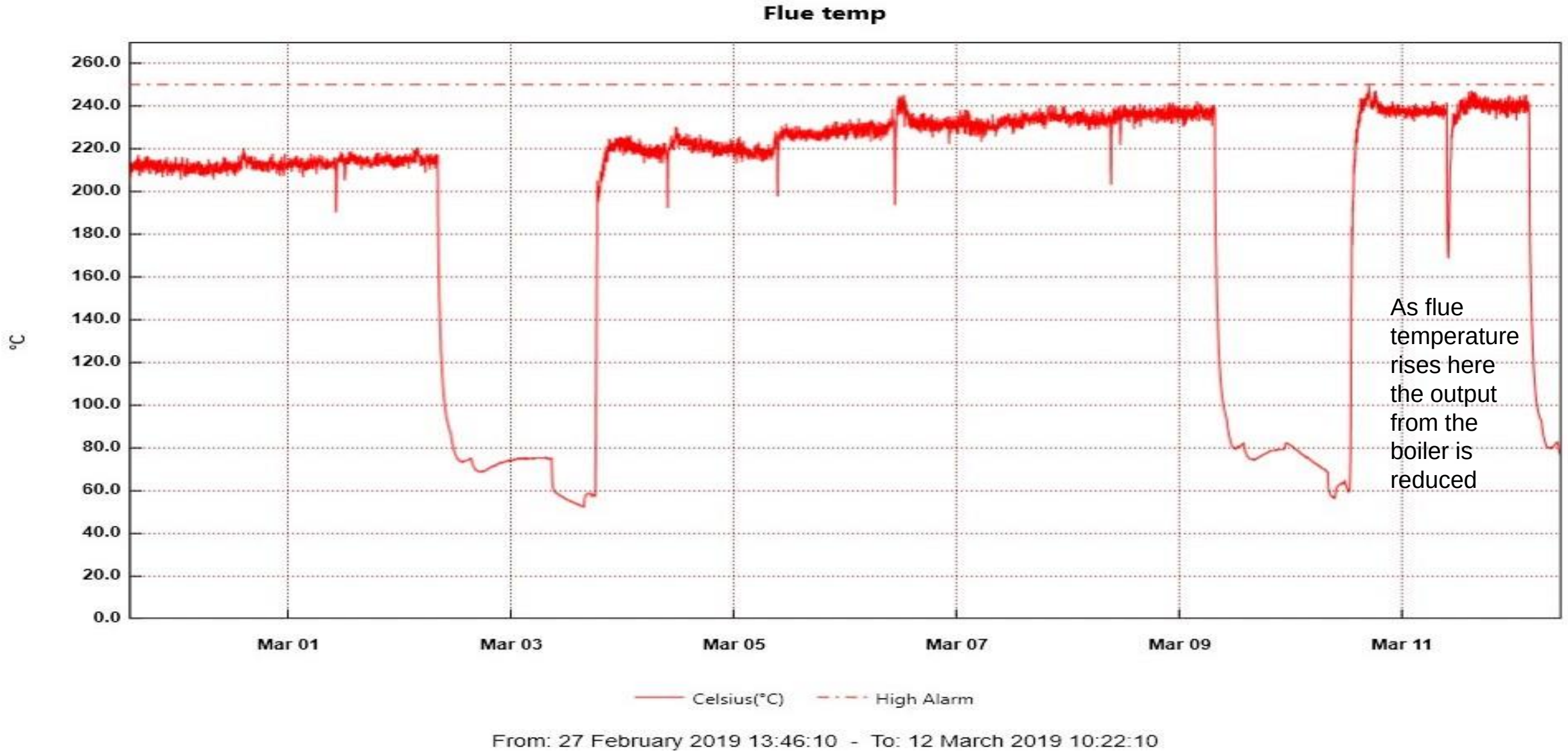


Maintaining a healthy delta T in the buffer vessel with constant heat load

Flue oxygen content shows constant heat load allows the boiler to work for long periods in a controlled and efficient manner

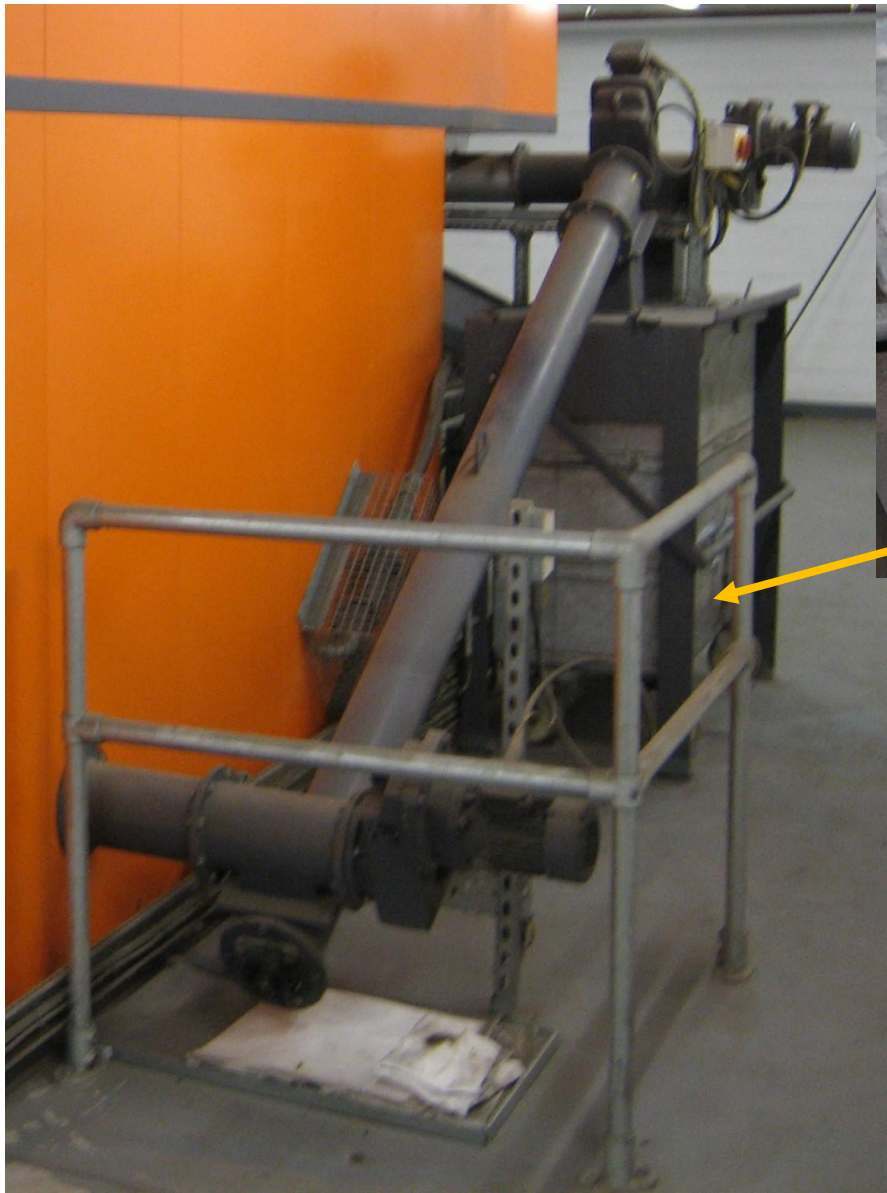
Site 3: NHS Hospital 990kW Wood Chip Boiler

- Flue temperature

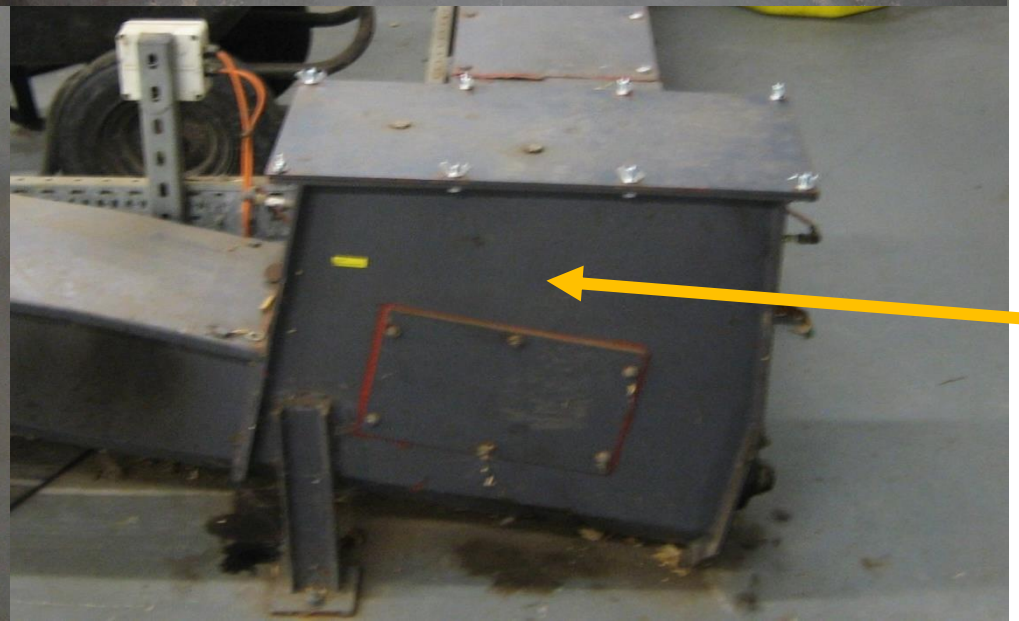


Site 3: NHS Hospital 990kW Wood Chip Boiler

- Site issues



Ash bin doors modification can allow false air into the boiler



Metering bin fuel blockage point when oversize wood chips are present in the fuel supply

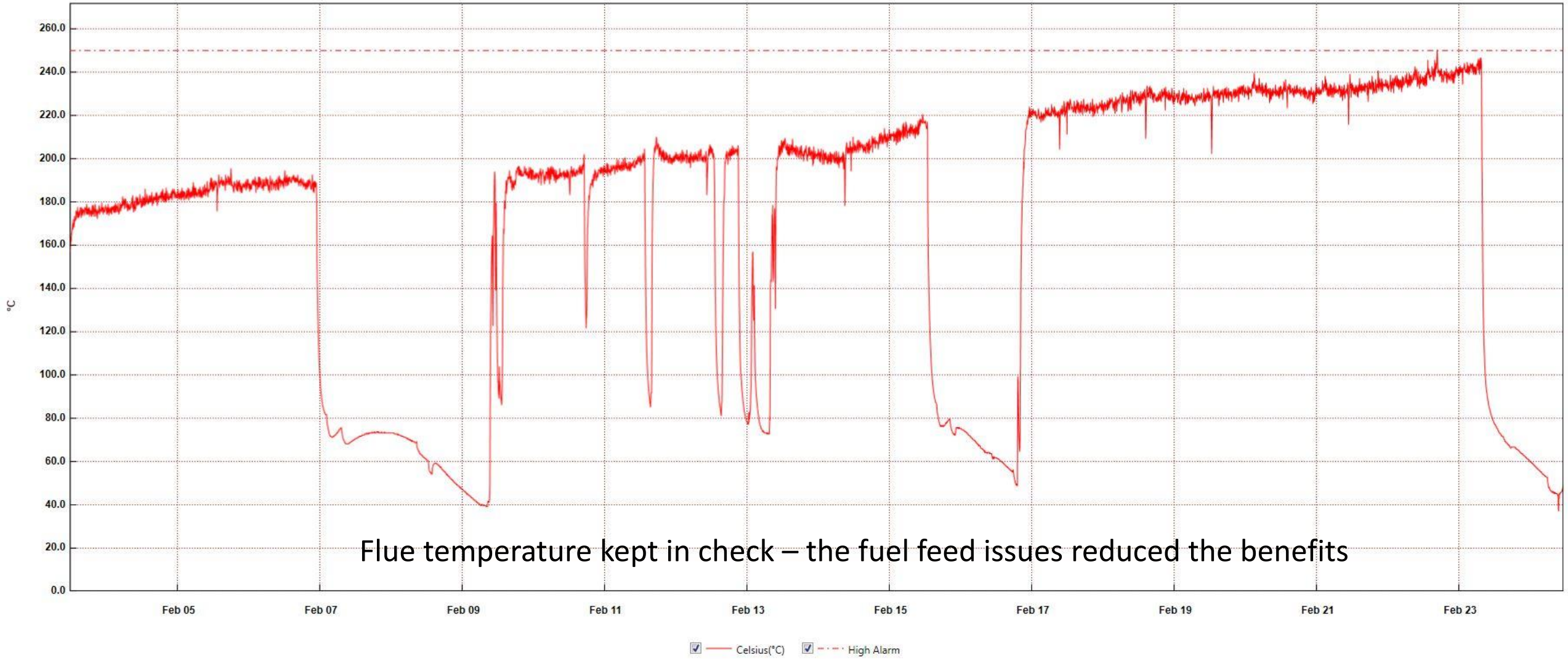
Site 3: NHS Hospital 990kW Wood Chip Boiler – Initial Summary

- Biomass boiler contributes full output when operating
  - Weekly shut down necessary to clean ash and clinker
  - Four weekly manual heat exchanger clean

- Arrange three weekly cycle for the heat exchanger clean and monitor the temperature increase over the period
- Consider reducing down time for the weekly ash clean
- Obtained order for replacing the ash bin doors to reduce air leaks

Site 3: NHS Hospital 990kW Wood Chip Boiler

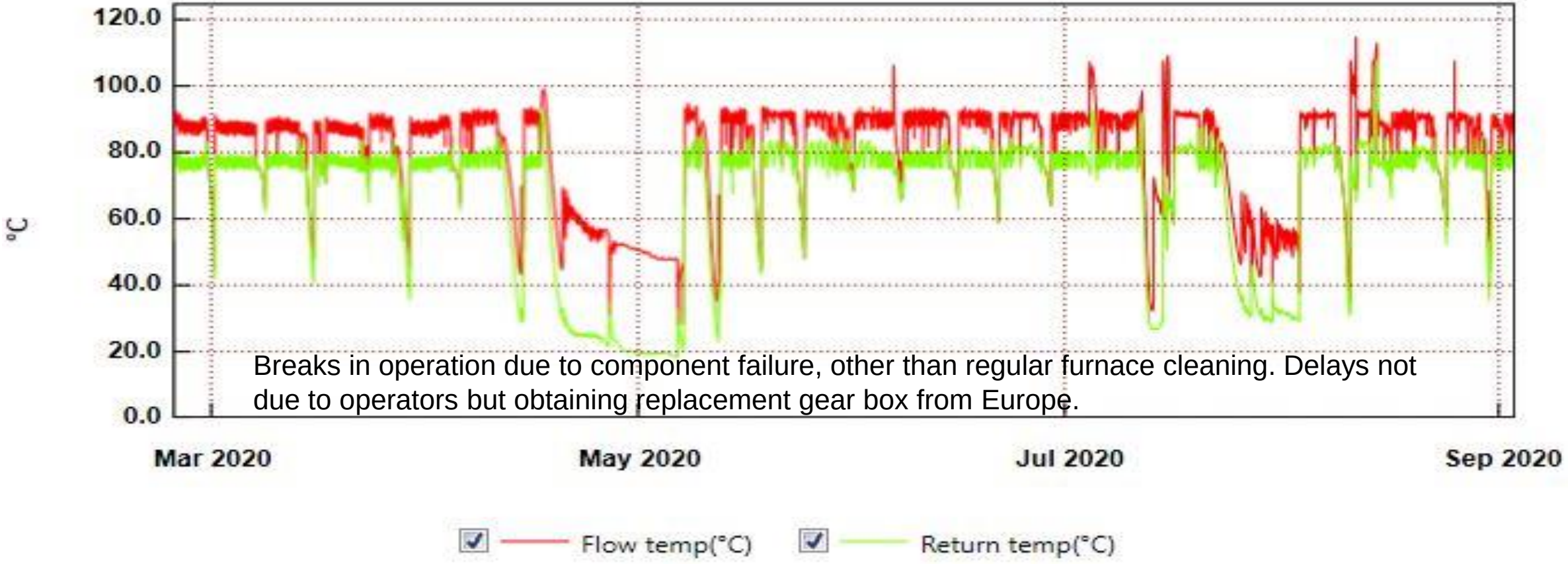
- Update following 3 weekly heat exchange cleaning – flue temperature



Flue temperature kept in check – the fuel feed issues reduced the benefits

Site 3: NHS Hospital 990kW Wood Chip Boiler

- Update Sept 2020 – Boiler flow and return



Breaks in operation due to component failure, other than regular furnace cleaning. Delays not due to operators but obtaining replacement gear box from Europe.

Site 3: NHS Hospital 995kW Wood Chip Boiler - Conclusions

- Biomass boiler working well with good combustion characteristics.
- The biomass boiler operation is compromised by the static underfeed retort and manual heat exchanger cleaning choices made at the time of purchase.
- Any perceived purchase cost savings have been lost many times over in terms of increased maintenance times and loss of boiler operating time.
- Retro fitting of a moving grate and automatic heat exchanger cleaning (compressed air system) costs are prohibitive.
- This site is now considered to be operating with the optimum biomass boiler usage

Site 3: NHS Hospital 990kW Wood Chip Boiler – Efficiency 2018 – 19 - 20

Pilot Project 3 - Hospital (900kW)	Wood Fuel Consumption (tonnes at 32% MC - kWh)	Wood Fuel Coverage (% of total heat demand)	Biomass Boiler Efficiency (%)	Costs of Wood Fuel £	Tonnes CO_2 Emissions saved (cf with equivalent gas)
Heating Season 2018-19	992	31%	72.00%	£157,000	437
Heating Season 2019-20	822	25%	75.00%	£140,000	389
Gain or Loss	-170	-6%	3.00%	-£17000	-48
Estimated Additional Gain/Loss if Recommendations Carried out	-30	0%	3% (78%)	-£5000	-13

Footnote: 1. Boiler in Season 2 offline for longer period due to technical failures

Footnote2; Savings when compared to Season 1

Conversion factors used from DEFRA:- UK Govt GHG Conversion Factors for Company Reporting. Version 1.00 Year 2020)

Site 4: Nursery / Retail Space – 900kW Wood Chip Boiler

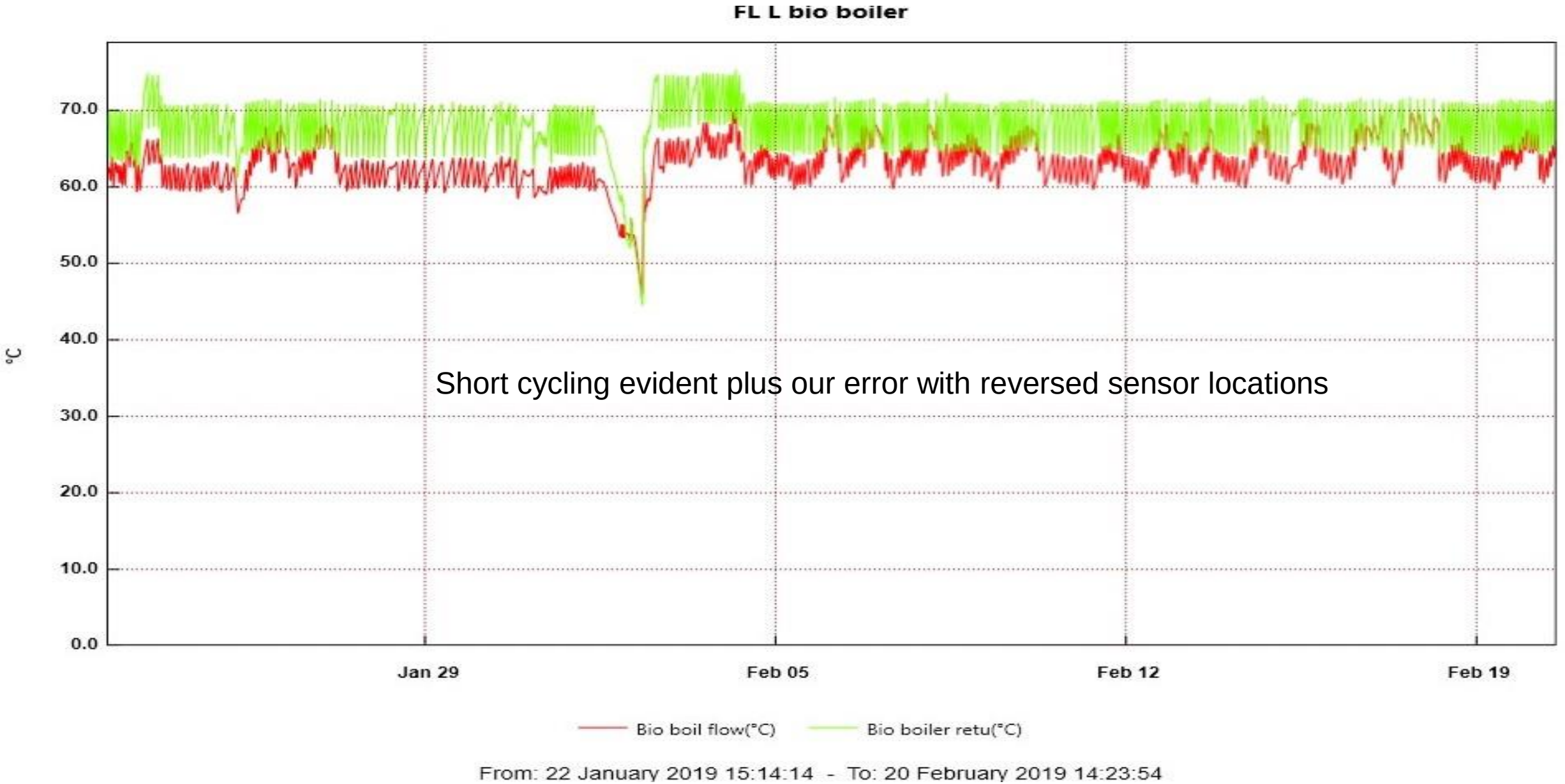
Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

- Main Observations:-
  - 900kW biomass boiler with 10,000l buffer. Heating season heat load
  - Accredited Renewable Heat Incentive (RHI) existing heat meter
  - Buffer vessel located outside
  - Large gas boilers looking unlikely to operate



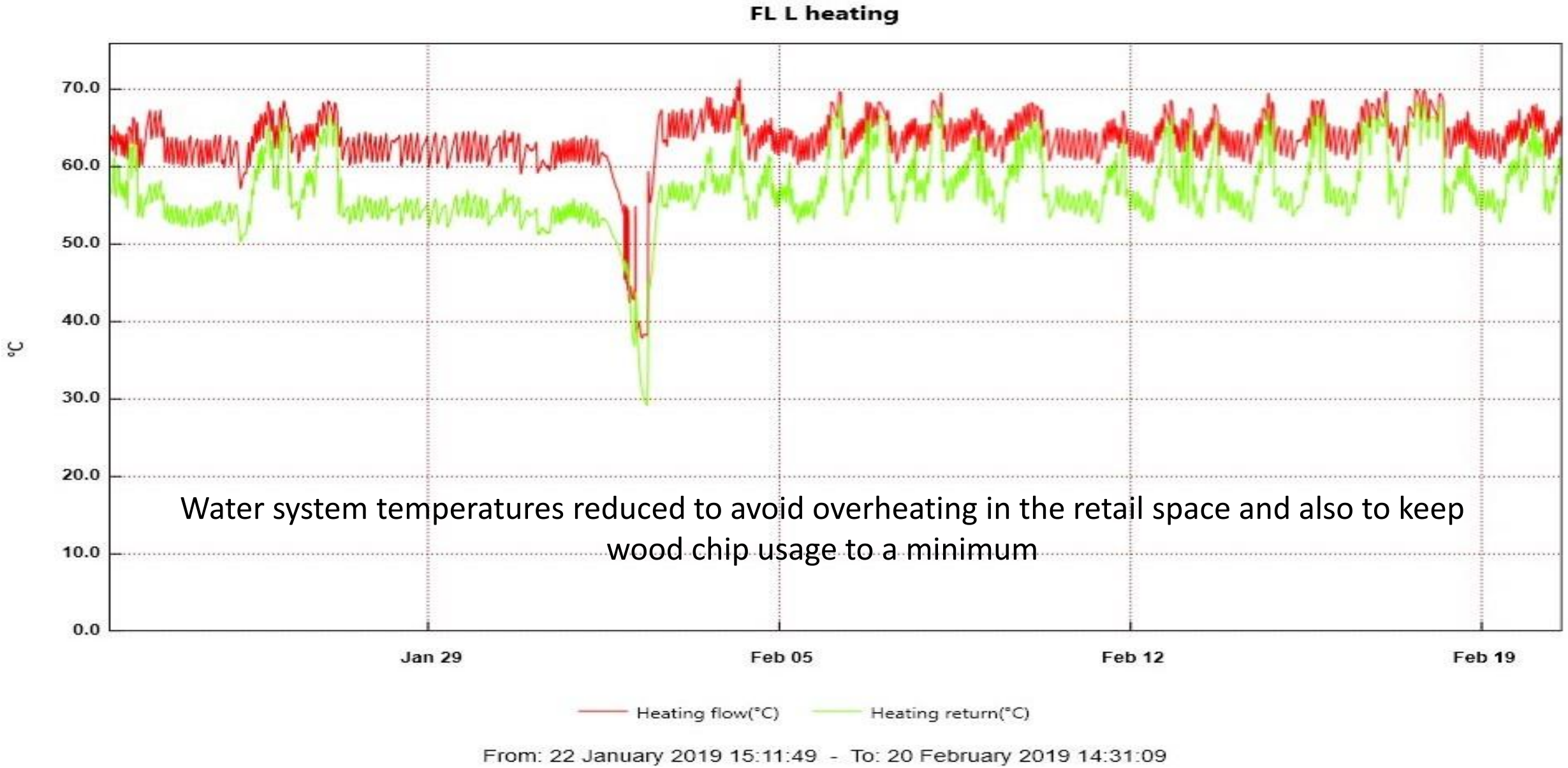
Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

- Boiler water flow and return temperatures:-



Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

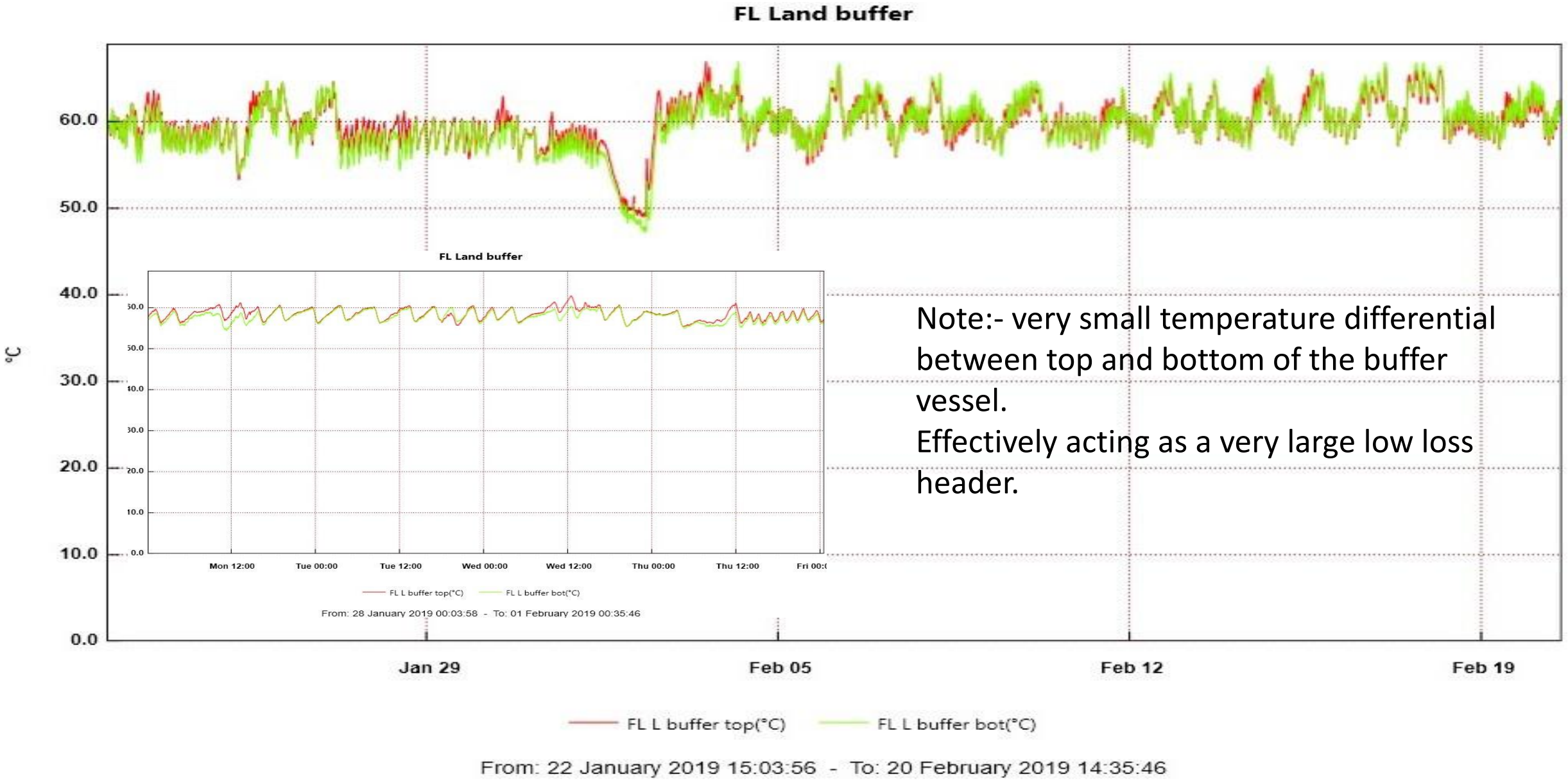
- Heating circuit temperatures:-



Water system temperatures reduced to avoid overheating in the retail space and also to keep wood chip usage to a minimum

Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

- Buffer vessel temperatures:-



Note:- very small temperature differential between top and bottom of the buffer vessel.
Effectively acting as a very large low loss header.

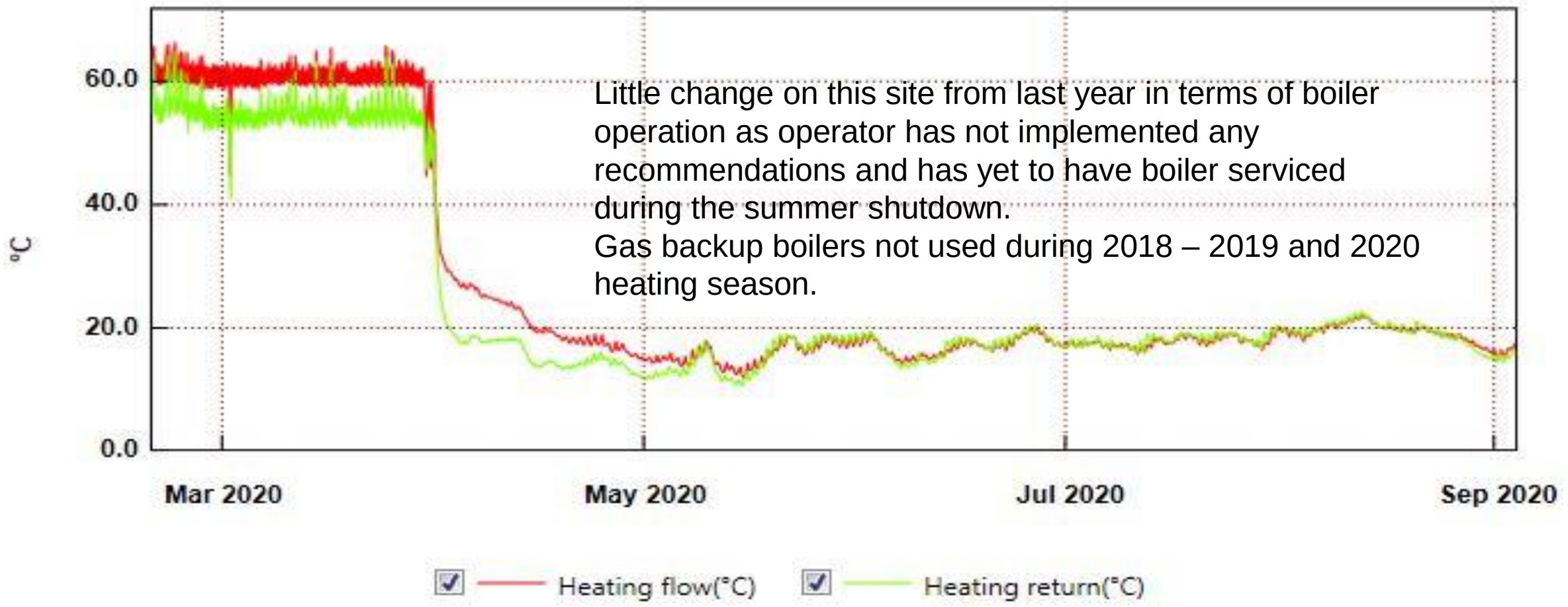
Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

- Initial Summary:-
  - Biomass boiler oversized for the current heat load
  - Water temperature set point lowered to compensate and reduce fuel use to a minimum
  - Buffer vessel temperature differential very small from top to bottom
  - Buffer vessel located outside leading to excessive heat losses
  - Combustion under pressure and flue oxygen content are surprisingly good even allowing for the short cycling

- Action:-
  - Install boiler start / stop delay timer to give longer run times
  - Erect lean-to cover for the buffer vessel
  - Install three port valve to heating water circuit secondary side of the buffer vessel that can reduce flow through the buffer from existing over sized circulation pump

Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

- Sept 2020 update – Heat main flow and return



Little change on this site from last year in terms of boiler operation as operator has not implemented any recommendations and has yet to have boiler serviced during the summer shutdown.
Gas backup boilers not used during 2018 – 2019 and 2020 heating season.

Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

- Conclusions:-
  - The biomass boiler is working reliably with the small heating load
  - Maximum adjustments have been made to the boiler fuel and air parameters
  - Physical changes to modify the boiler output would involve significant expense

  - Recommendations to improve the weather protection for the external buffer vessel have not been installed
  - Recommendations to fit a boiler start / stop delay timer not actioned
  - Recommendations to fit a modulating three port valve to the heating main not fitted
  - Boiler service has not been carried out as of September 2020.

Site 4: Nursery / Retail Space - 900kW Wood Chip Boiler

- Efficiency:- 2018 – 19 - 20

Pilot Project 4 - Retail and greenhouse - 900kW	Wood Fuel Consumption (tonnes at 24% MC - kWh)	Wood Fuel Coverage (% of total heat demand)	Biomass Boiler Efficiency (%)	Costs of Wood Fuel	Tonnes CO_2 Emissions saved (cf with equivalent gas)
Heating Season 2018-19	216	100%	66%	£26,260	155
Heating Season 2019-20	305	100%	69%	£42,000	218
Gain or Loss	+89	-	+3%	+£15,740	+63
Estimated Additional Gain if Recommendations Carried out	Steady state or reduction	100%	+4% (73%)	-£1700	Static or small reduction

Footnote1: timer installed to reduce 'cycling' of boiler and reduced heat loss from buffer tank

Footnote2: Gas boilers on site not in operation

Footnote3: If improvements to boiler 'cycling' and buffer tank insulation and weather protection

Footnote4: Assuming steady state use of boiler but improved efficiencies

Conversion factors used from DEFRA:- UK Govt GHG Conversion Factors for Company Reporting. Version 1.00 Year 2020)

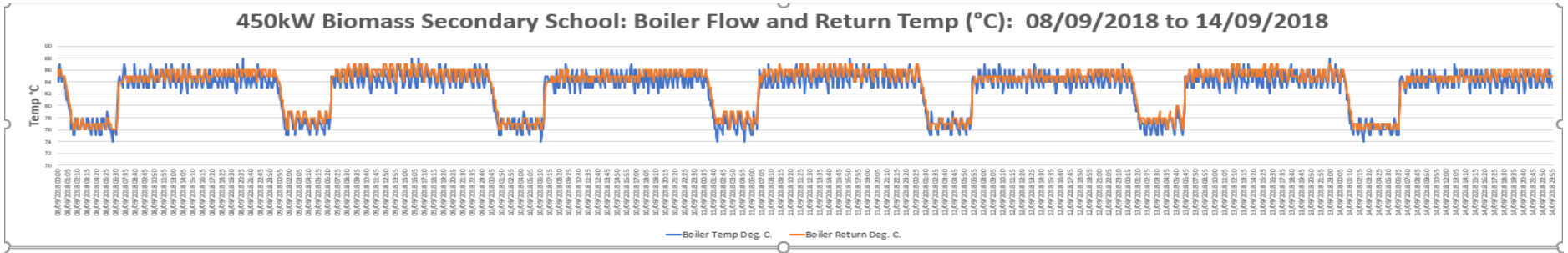
Site 5: Secondary School – 450 kW wood chip boiler

Site 5: Secondary School – 450 kW wood chip boiler

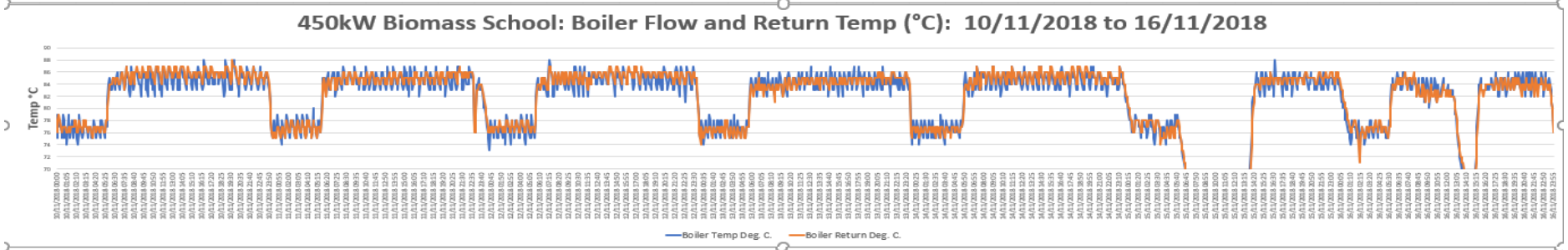
- Main observations:
  - 450kW biomass boiler without buffer vessel but has swimming pool load creating a stable annual heat load
  - Three off 140kW gas boilers in circuit as full time backup

Site 5: Secondary School – 450 kW wood chip boiler

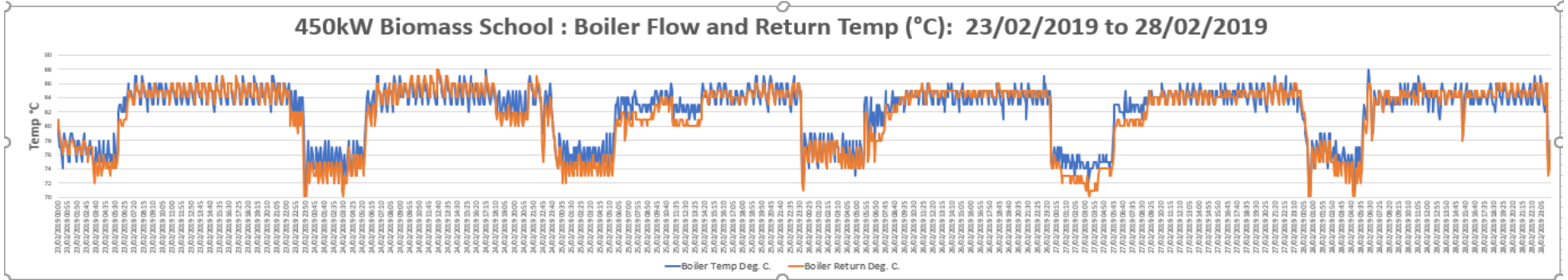
- Biomass boiler flow and return temperatures:-
- Chart formation different on this site as the information collected from the existing data collection in the boiler control panel



Steady state running with swimming pool load and clear day night variation.



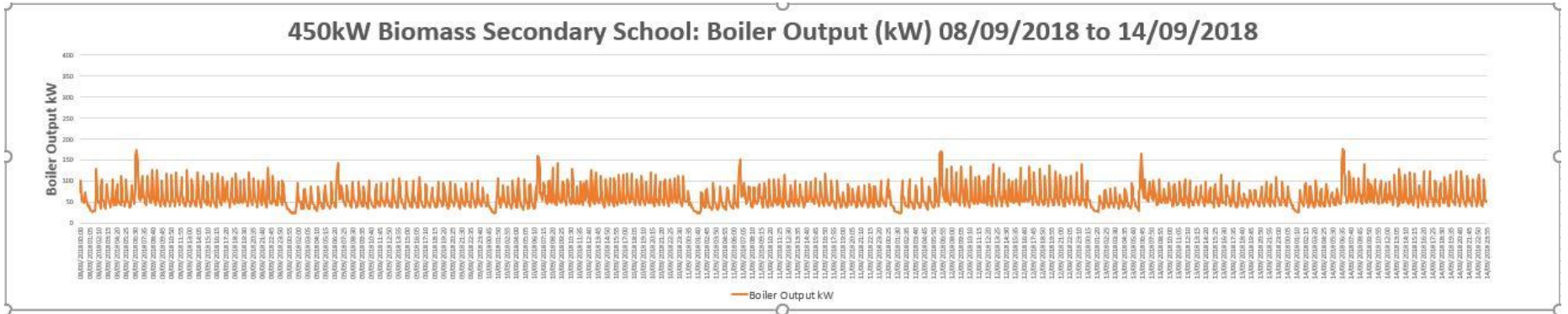
Light school load with swimming pool. One failure to start but quick response from operator to restart following a lack of fuel.



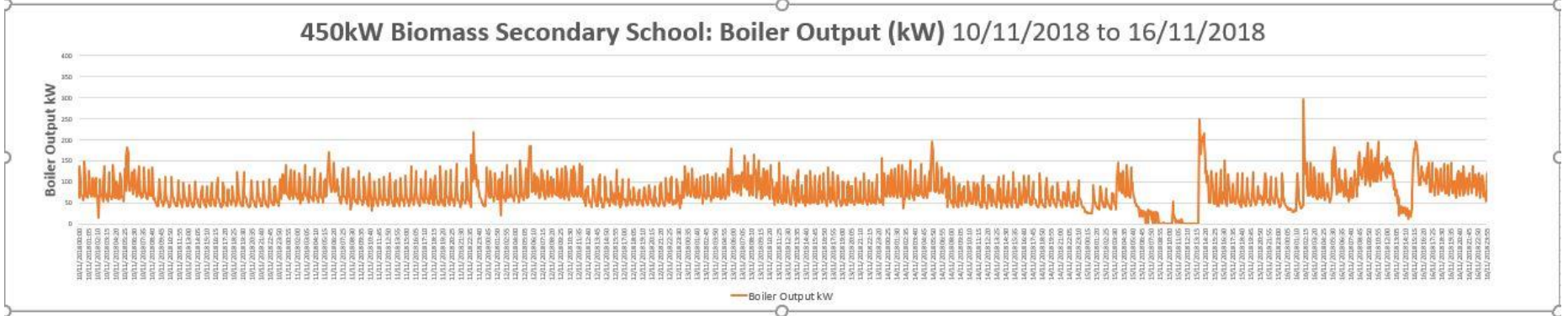
Large school load with swimming pool. Increased temperature differential and temperature variation. Unknown influence from backup boilers.

Site 5: Secondary School – Boiler output (kW)

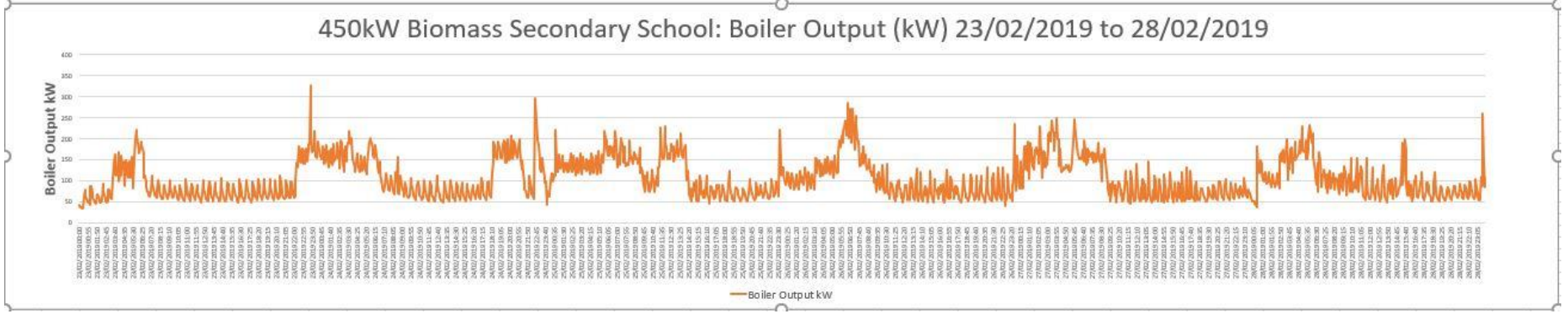
- Boiler estimated power output from the boiler control panel. This information was not available from the stand alone data loggers.



Steady state running with swimming pool load

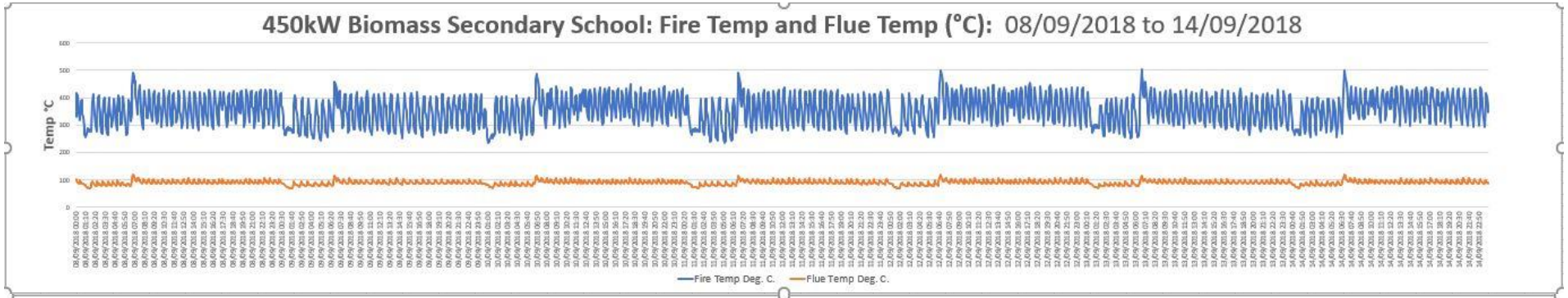


Light school load with swimming pool

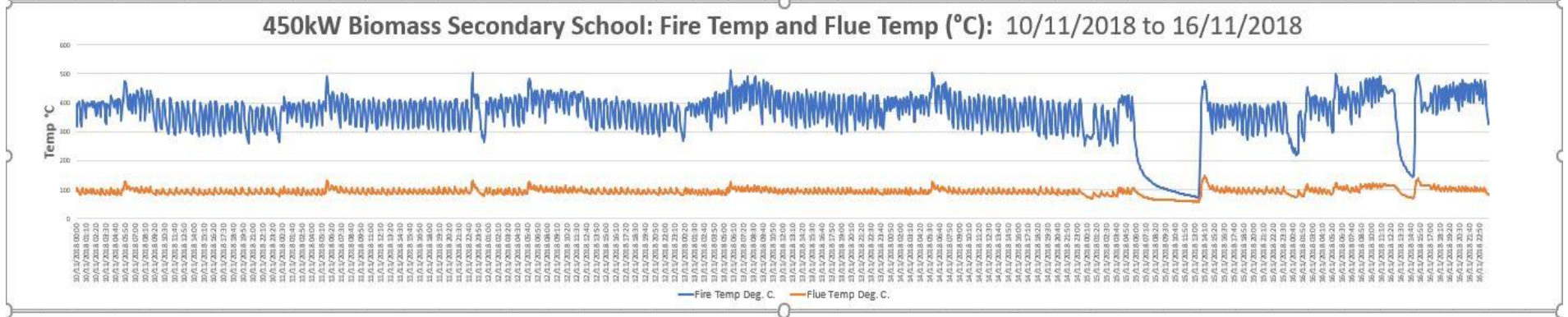


Combined large school load with swimming pool. Peaks of increased output but full effect limited by interaction with gas backup boilers and pipe work layout.

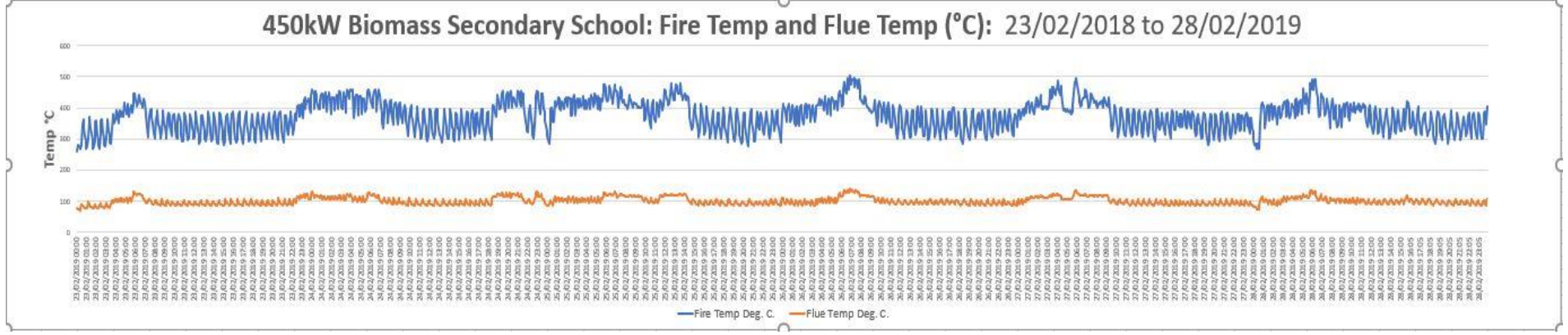
Site 5: Secondary School – Combustion and Flue Temperature



Steady state running with day / night operation just visible



Increased load showing in combustion temperature but not significant in flue temperature



Combustion temperatures now increasing with higher boiler load but flue temperature is still steady. NOTE flue temperature maintained week in / week out with the assistance of the automatic compressed air boiler tube cleaning system

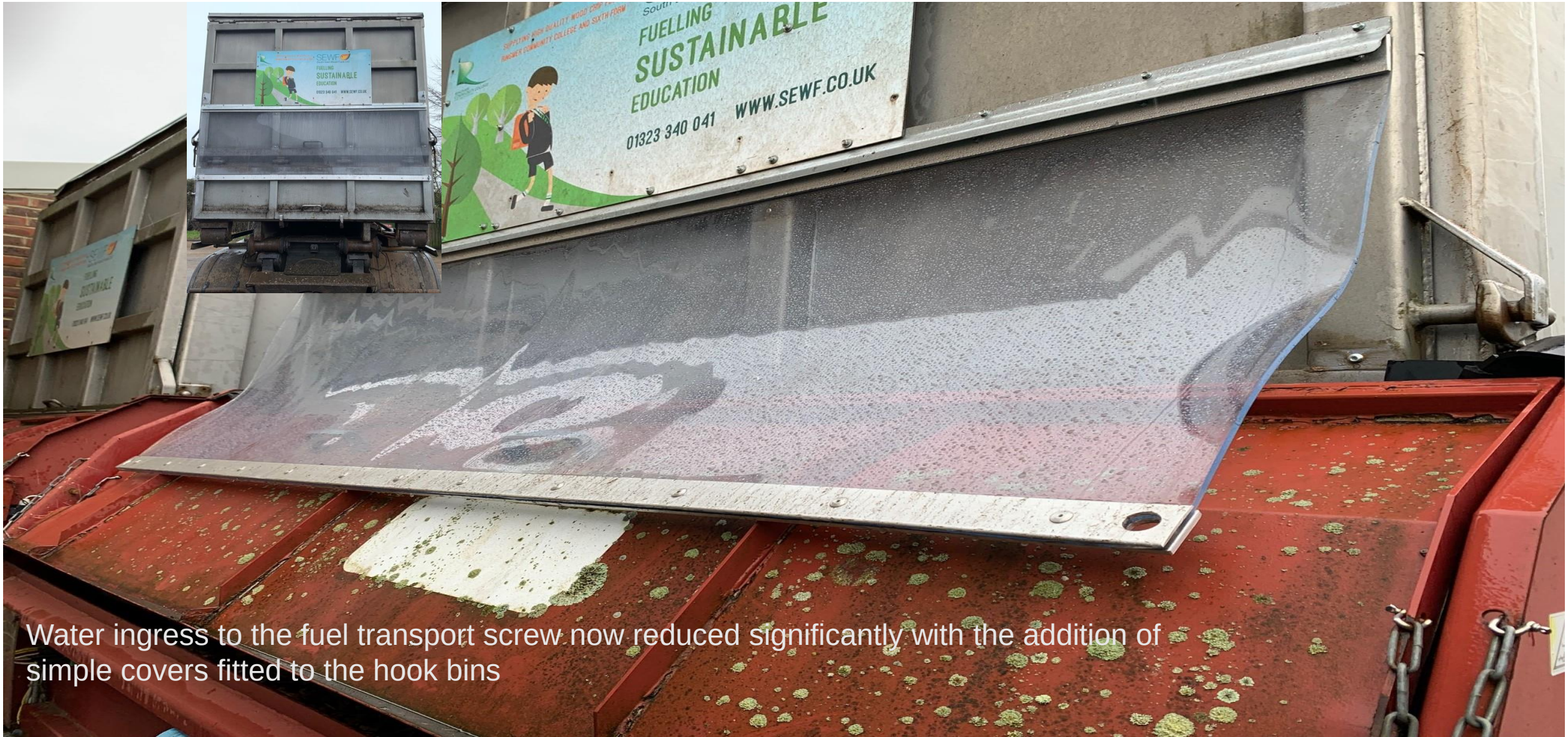
Site 5: 450kW Biomass Secondary School – Initial Summary

- Boiler working efficiently:
  - Motivated and knowledgeable boiler operator resolves issues rapidly
  - Regular servicing regime
  - Maintenance budget made available by interested senior managers

- One main issue:
  - Water ingress to external wood fuel transfer auger
  - Results in fuel clinkering following periods of high rainfall
  - Simple weather protection screen to be fitted during February 2020

Site 5: 450kW Biomass Secondary School- Update

- Low cost weather protection installation on first container – complete with rain.



Water ingress to the fuel transport screw now reduced significantly with the addition of simple covers fitted to the hook bins

Site 5: 450kW Biomass Secondary School - Conclusions

- Biomass boiler working well with good combustion characteristics and generally providing a substantial contribution to the site heating requirements.
- Informed operator and regular servicing regime has resulted in reliable biomass boiler operation.

- Recommended additional fuel bin weathering protection has been actioned and appears to be effective

Site 5: 450kW Biomass Secondary School – Efficiency 2018 – 19 - 20

Pilot Project 5 - Academy School (450kW)	Wood Fuel Consumption (tonnes at 30% MC - kWh)	Wood Fuel Coverage (% of total heat demand)	Biomass Boiler Efficiency (%)	Costs of Wood Fuel	Tonnes CO_2 Emissions saved (cf with equivalent gas)
Heating Season 2018-19	115	72%	77%	N/A	54
Heating Season 2019-20	85	64%	80%	N/A	45
Gain or Loss	-30	-8	+3%	N/A	-9
Estimated Additional Gains if Recommendations Carried out			+2% (82%)		0

Footnote1: reduction due to less use of boiler during COVID restrictions - swimming pool closed for 3 months

Footnote2: As per Footnote 1

Footnote3: Improvements to Mobile Fuel Silos and less down time

Footnote4: Reduced use of biomass boiler due to Academy being closed (COVID)

Conversion factors used from DEFRA:- UK Govt GHG Conversion Factors for Company Reporting. Version 1.00 Year 2020)

Overall Optiwood Biomass Boiler data logging - Conclusions

- Data logging exercise worked well:-
  - Several faults and inefficient boiler system operating trends uncovered
  - Data has helped confirm and communicate issues identified
- Action plans developed for each site:-
  - Good improvements already taken place at some sites (action significantly delayed at others)
- Engagement with decision-makers was essential:-
  - Operators often unable to make financial decisions
  - Collecting data is part of the process and not the solution
- Site collection data logging was chosen primarily to keep costs down:-
  - Face-to-face interaction with operators remains vital
  - Assessing behaviours checking associated site equipment can help identify issues

- Remote data collection can save travelling time/costs but with the loss of face-to-face interaction and site installed equipment inspection.

The Key Role of Operators

- Can often be neglected in the biomass system training, maintenance and servicing.
- They are responsible for the day to day boiler operations and picking up issues early before they become expensive problems with significant down-time.
- A lack of training and resources – this will be a weak link in any biomass system.
- Optiwood highlights their key role and has offered support through information, training, one-on-one help, mentoring via other operators and on-line support
- In the U.K. reluctance to network with other Operators but keen to share experiences in a limited way

Overall Optiwood Conclusions

- It has been estimated up to 25% of U.K. biomass boiler installations not operating well and have potential for improvements
- Reasons? – ill-informed system design, installation, controls, commissioning settings and wood fuel issues. Lack of knowledge from operators, sometimes coupled with inadequate management can lead to long operational down-times
- Low cost data logging can be significant step in improving biomass boiler installations. Many similarities between system issues in U.K. and France
- Data analysis should be linked to experienced interpretation of the results/trends
- Optiwood project now in the dissemination phase; partnerships in order to help improve the performance of biomass heating in the U.K.
- A very BIG positive from the studies shows modern biomass boilers can function well if they are connected to an appropriate heating system and fuel supply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