Engine Shed Sustainability Assessment

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The Team

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Project Scope

"Produce a fully costed proposal to reduce the Engine Shed's Scope 1&2 emissions by 60% maintaining all building services."

- Scope 1 emissions: Direct Greenhouse gases emissions that occur from sources that are controlled or owned by an organisation
- Scope 2 emissions: Indirect greenhouse emissions associated with the purchase of electricity, steam, heat or cooling

Our Proposal

- CUT CO2 EMISSIONS BY OVER 60%
- EFFECTIVELY ELIMINATE GAS USAGE
- REDUCE POTABLE WATER USE BY 40%
- REQUIRE INVESTMENT OF ~£190,000
- SAVE ~£90,000 PER ANNUM

University of Lincoln and the Climate crisis

- University of Lincoln has committed to a sustainable future
- Committed to achieving net zero emissions by 2040
- At least 60% reductions in emissions by 2030
- Already ranked “gold tier” in the 2023 Uswitch Green Universities report

Business, social and economic factors

It is important to not affect the running of the business:

- Unhappy students
- Cancelled events
- Loss of income
- Damaged reputation

<u>Business aspects of the engine shed:</u>

- The towers bar
- The "Quack" student club night
- Any corporate event being held
- Guest performers and concerts

Therefore, any work implemented should happen with minimal disruption

All implementations should occur between July – September since this is out of term time - With a 1-year notice where no events are booked during this time

Legislation and Standards

For more information, see annex 10.5

In any engineering project it is important to recognise that certain legislation and British engineering standards need to be followed

Sustainability examples

- BREEAM
- The Kite Mark
- Microgeneration Certification Scheme (MCS)
- CIBSE Guides

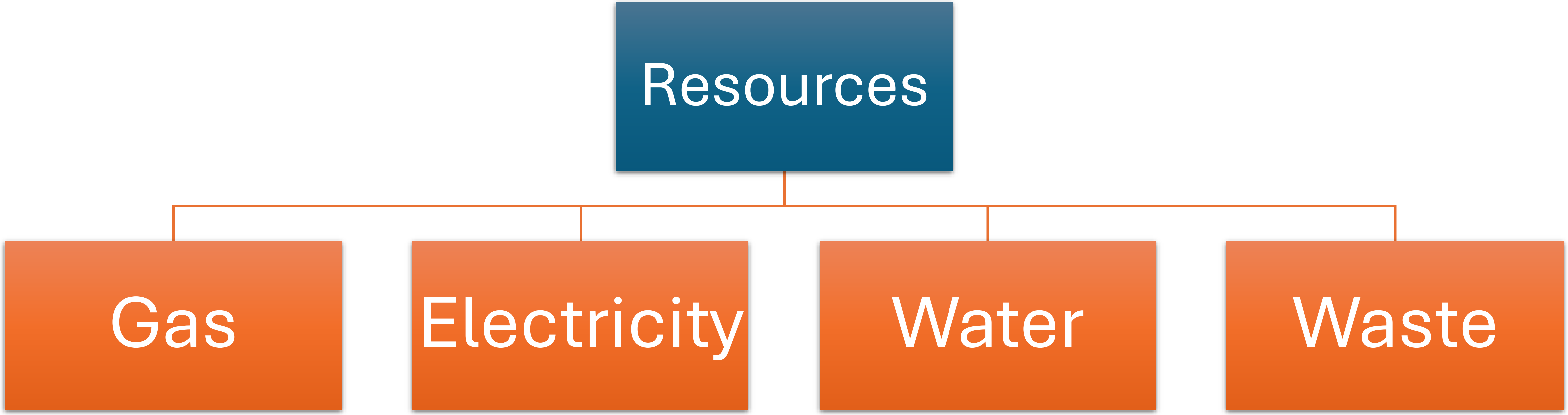
Legislation examples

- Competency person scheme
- COSHH
- Lincoln Council (Regarding the Brayford)
- Various Building regulations

British Standards examples

- BS EN 62446 - Solar
- BS EN 14825 – Heat pumps
- BS 8515 - Rainwater
- BS 8215 - Insulation
- BS 5803-4 - Cellulose

Defining the Problem



Beyond Scope - Waste Management

SU already takes steps towards reduction

Managerial vs Engineering issue

Limited Quantitative data for waste

Electricity

300 MWh annually

Costs £90,000 annually

Prices are wildly variable

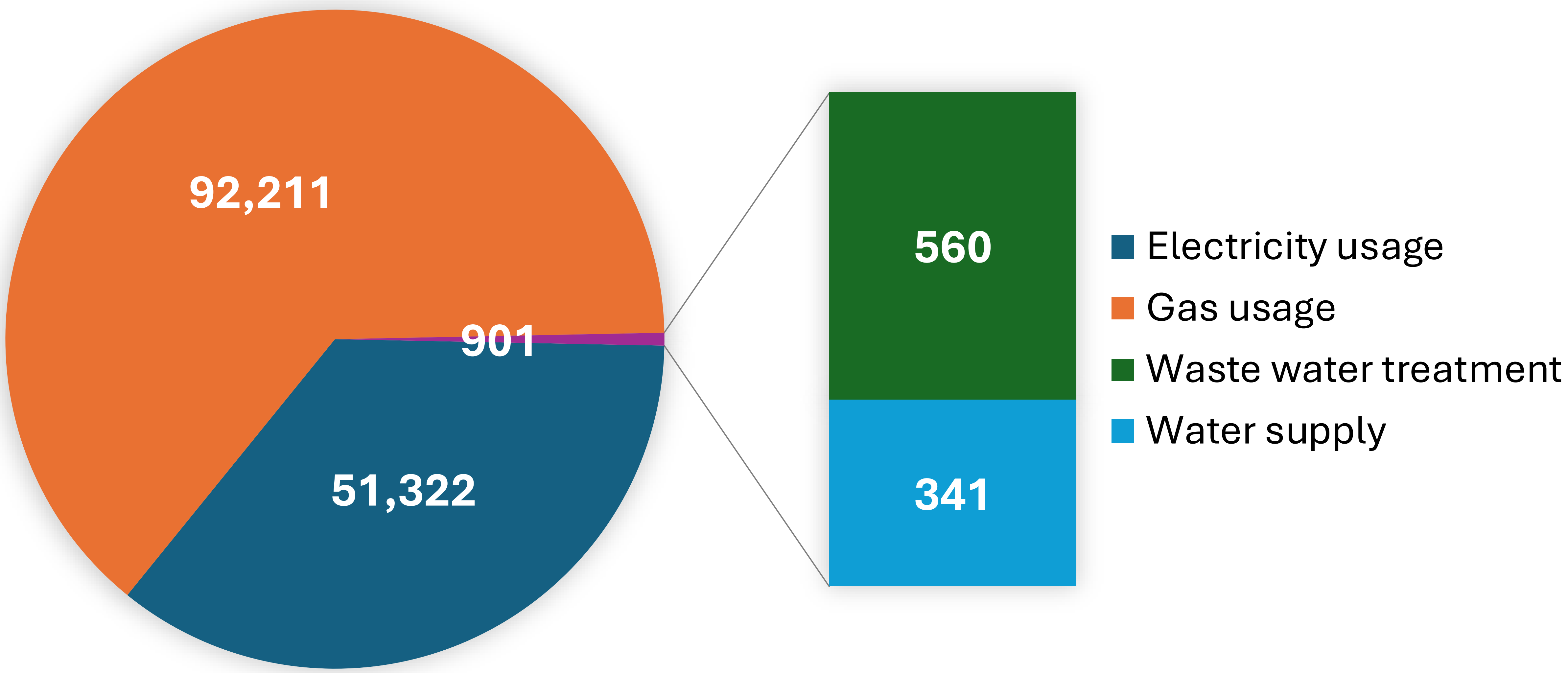
Gas

450 MWh annually

Costs £50,000 annually

High Emissions

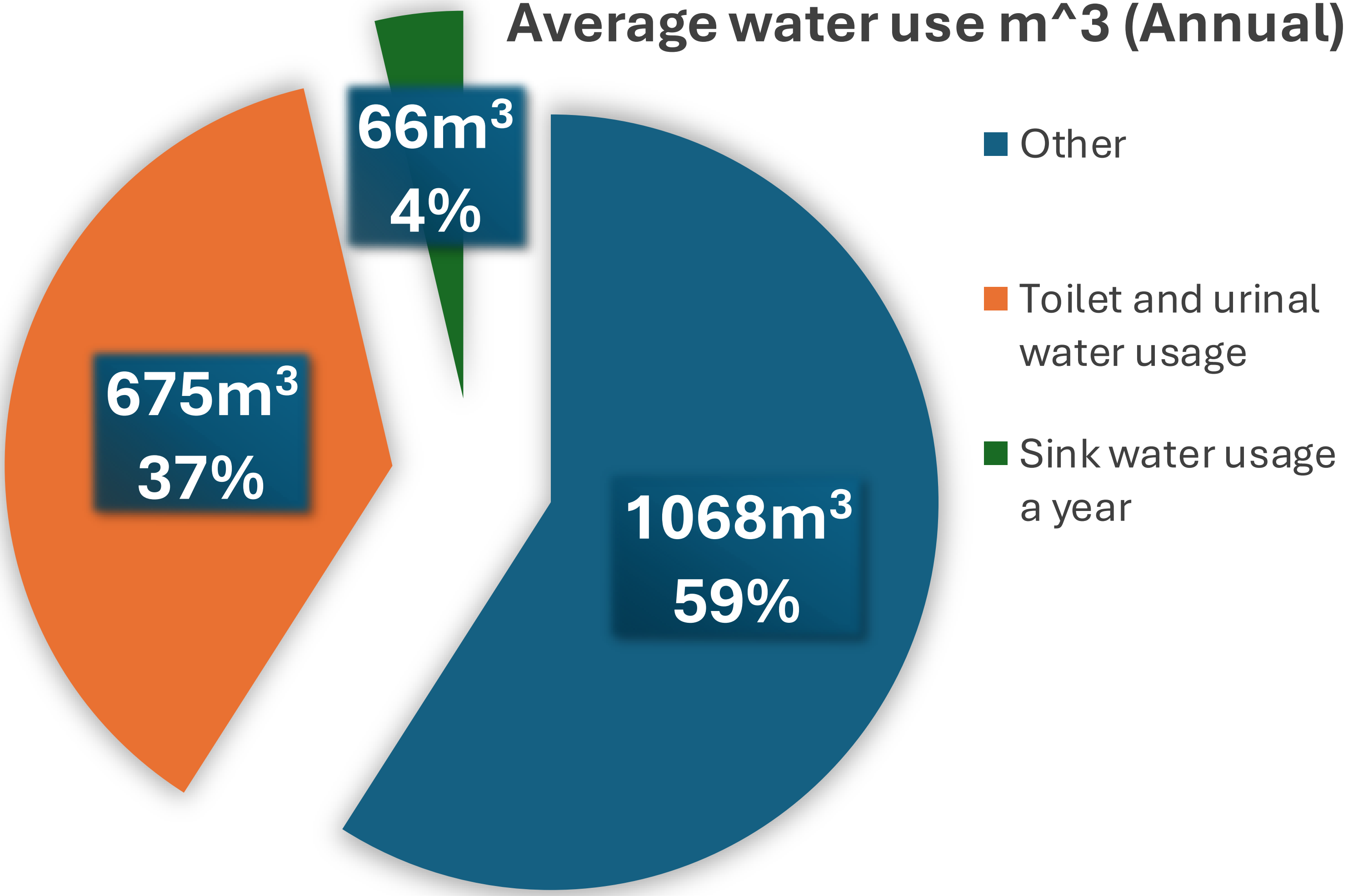
Direct Emissions kg CO_2e breakdown



Water Demand

For more information, see annex 10.7

Average water use m^3 (Annual)



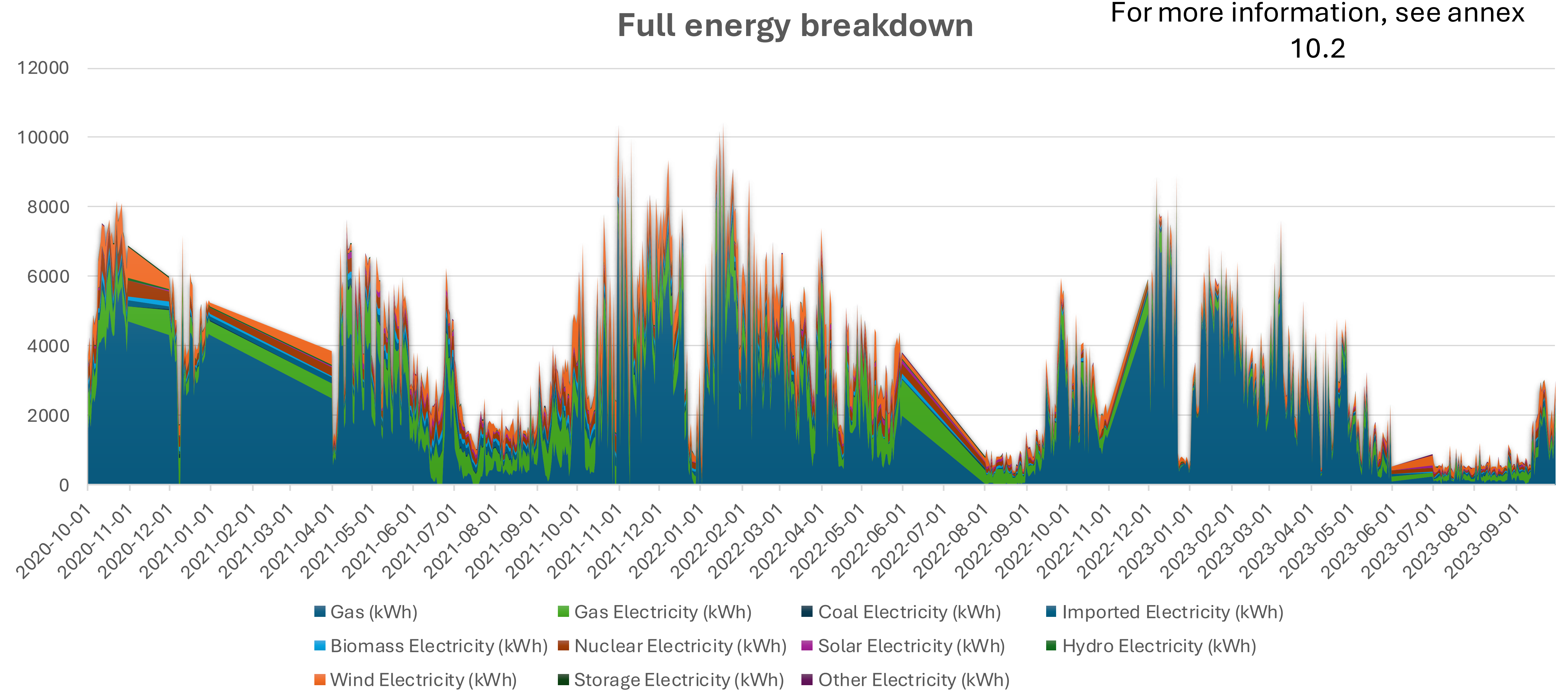
1809.21m³ annually

£3222.04 annually

Flushes and sinks are largest areas of waste

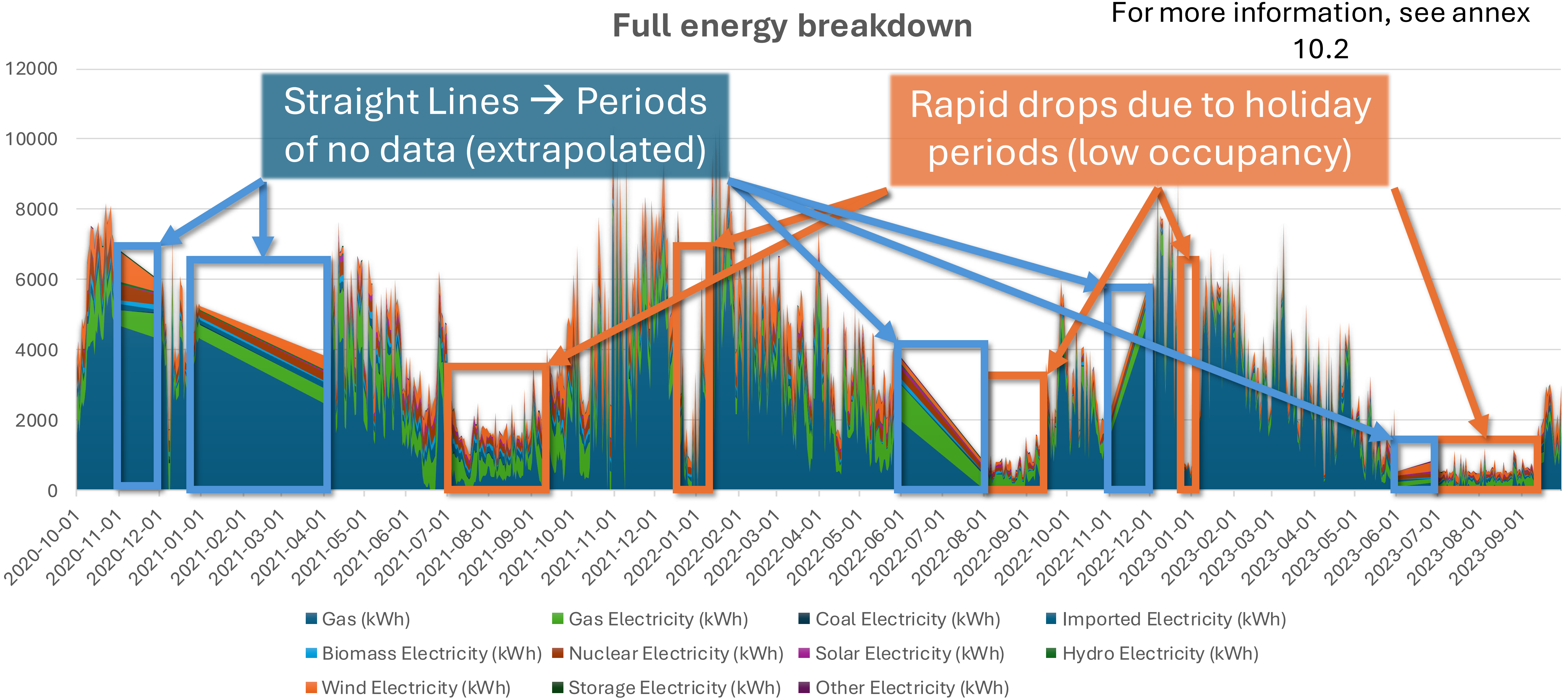
Collecting Data – Gas and Electricity

For more information, see annex 10.2

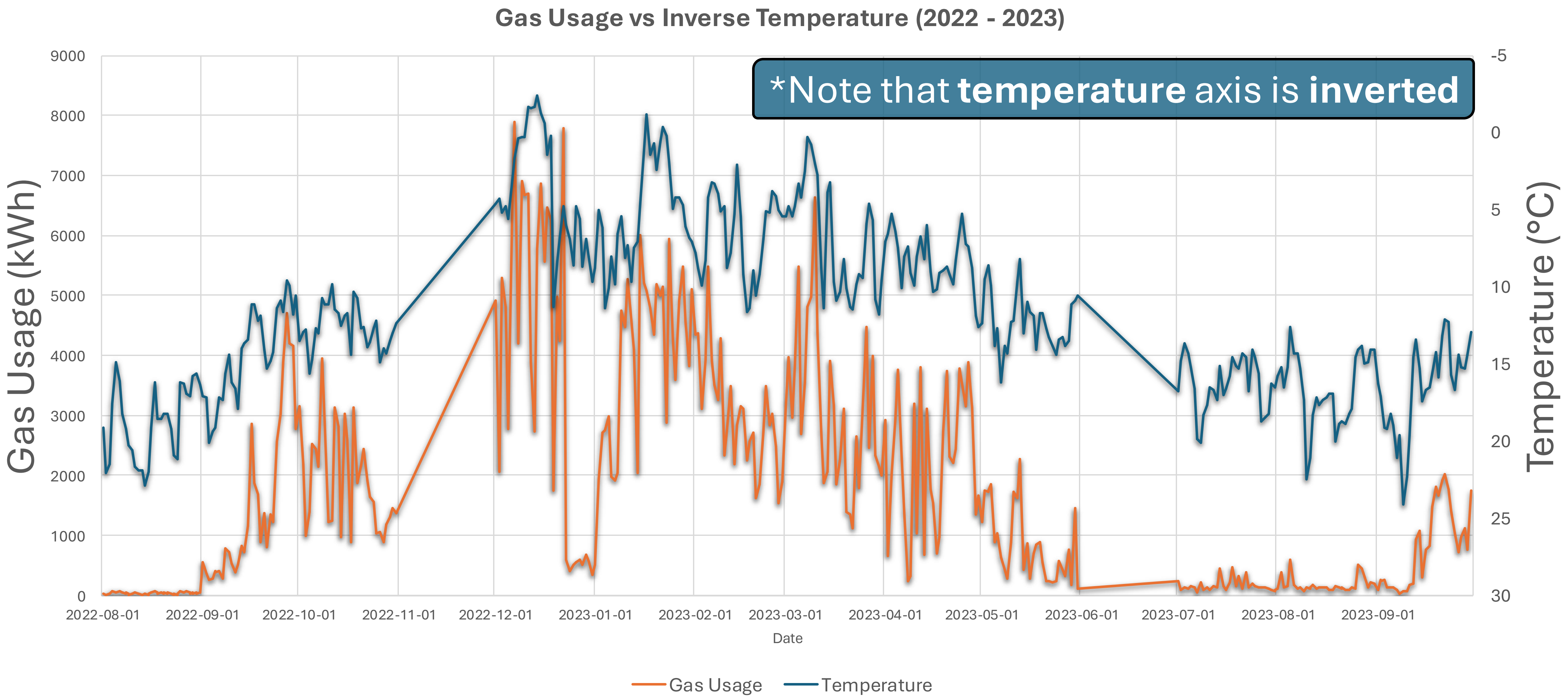


Collecting Data – Gas and Electricity

For more information, see annex 10.2

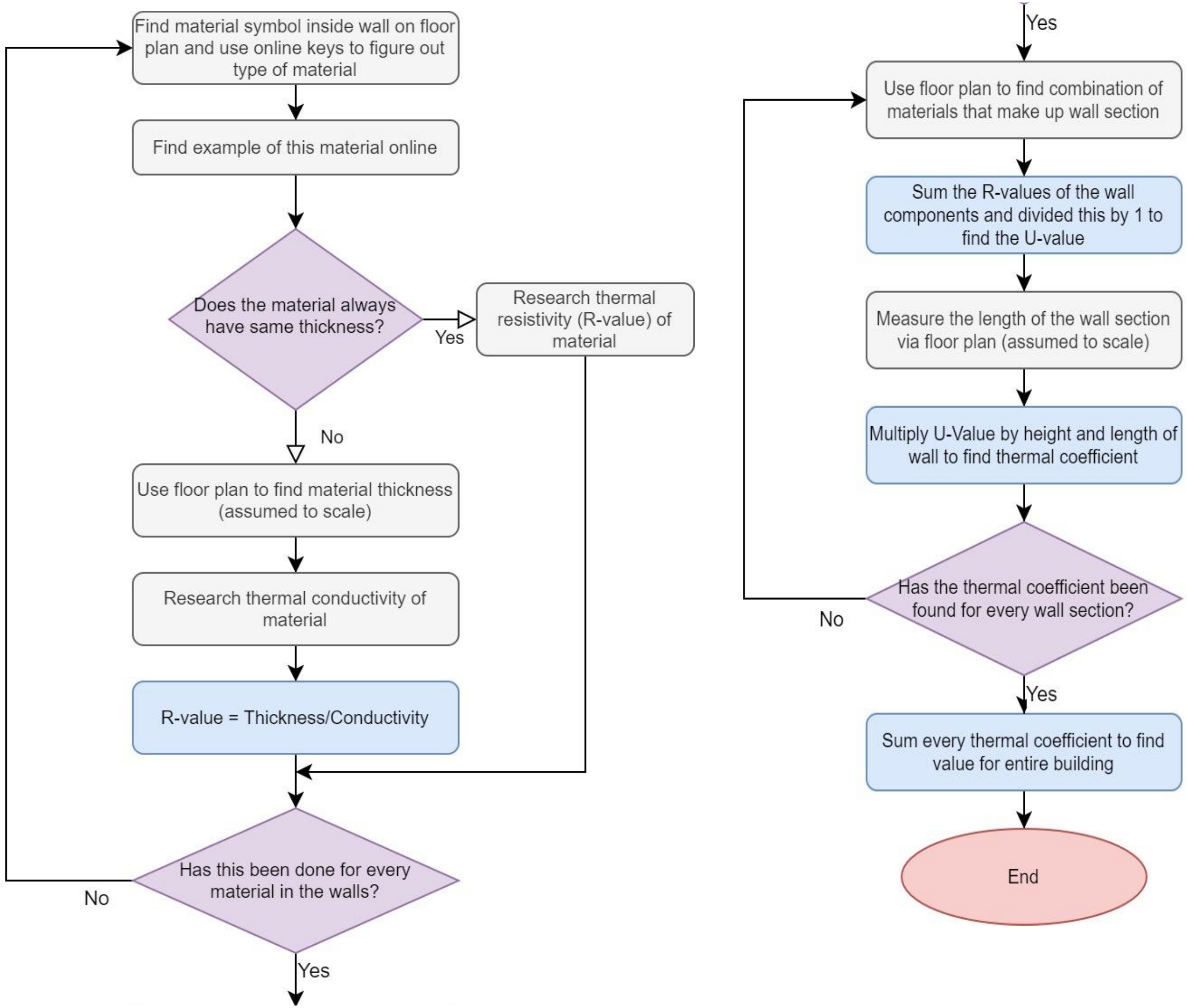


Collecting Data – Weather



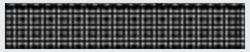
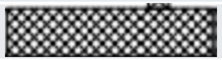
For more information, see annex 10.3

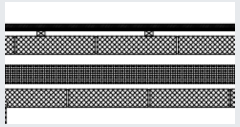
Heat - Fabric heat loss model



Heat - Fabric heat loss model

For more information, see annex 10.3

Picture of Insulation	Type of Insulation	Assumption	Conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	Thickness (m)	R-Value (K m^2/W)
	Solid Insulation	Polyurethane Foam	0.024	0.1	4.17
	Batt Insulation	ROCKWOOL Thermal Insulation Batt	0.037	0.1	2.70
	Batt Insulation (Thin)			0.075	2.03
	Concrete Blocks	Autoclaved Aerated Concrete	0.23	0.1	0.43

Picture of Insulation	Components	R-Value (K m^2/W)	Summed R-Value	U-Value (W/K m^2)	Overall Length (m)	Temperature Coefficient (W/K)
	Brick	0.14				
	Air Gap (1 inch)	0.02				
	Concrete Blocks	0.43				
	Air Gap (2 inch)	0.06				
	Solid Insulation	4.17				
	Air Gap (1 inch)	0.03				
	Concrete Blocks	0.43	5.29	0.19	21.47	40.60

Total: 3632 W/°K

Fabric heat loss model – main loss

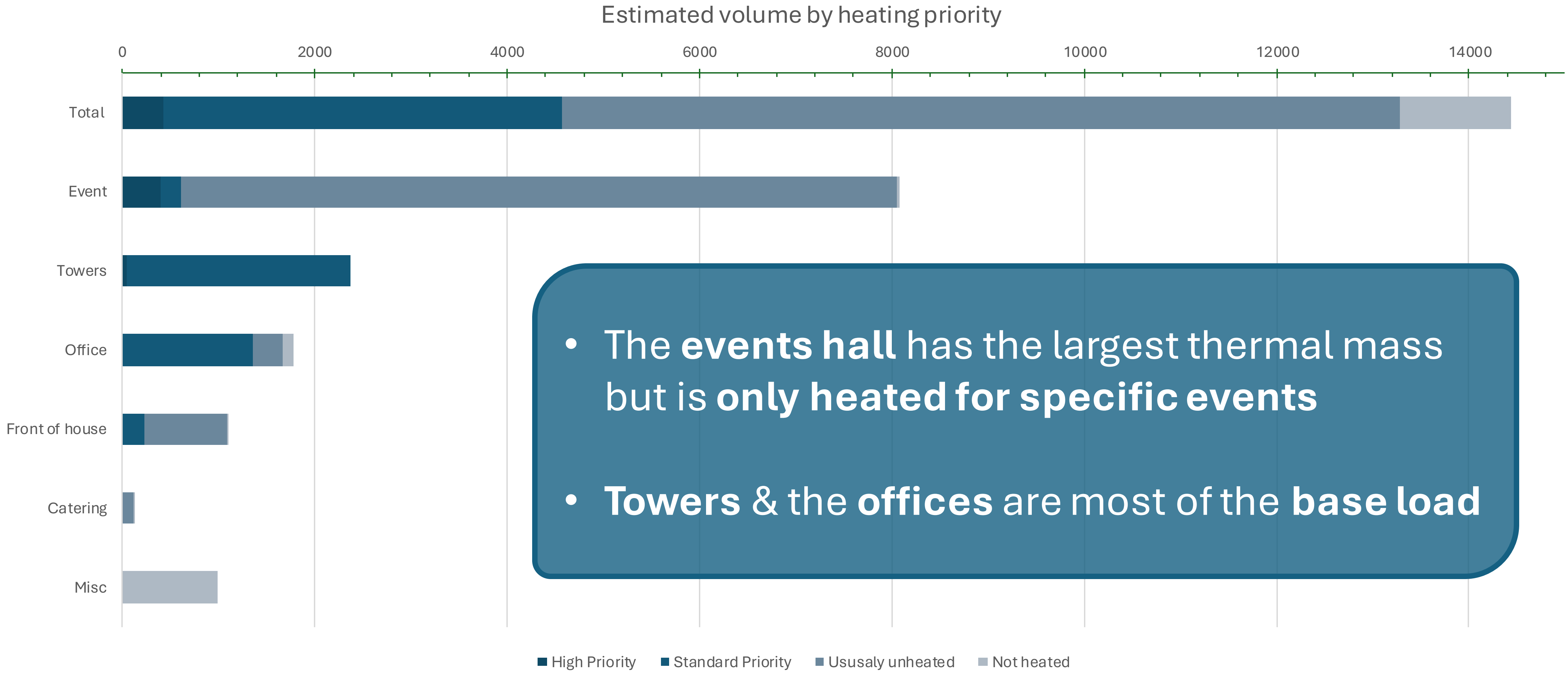
For more information, see annex 10.3

- Total: 714.9 W/°K
- <u>~ 20% of Overall heat loss</u>

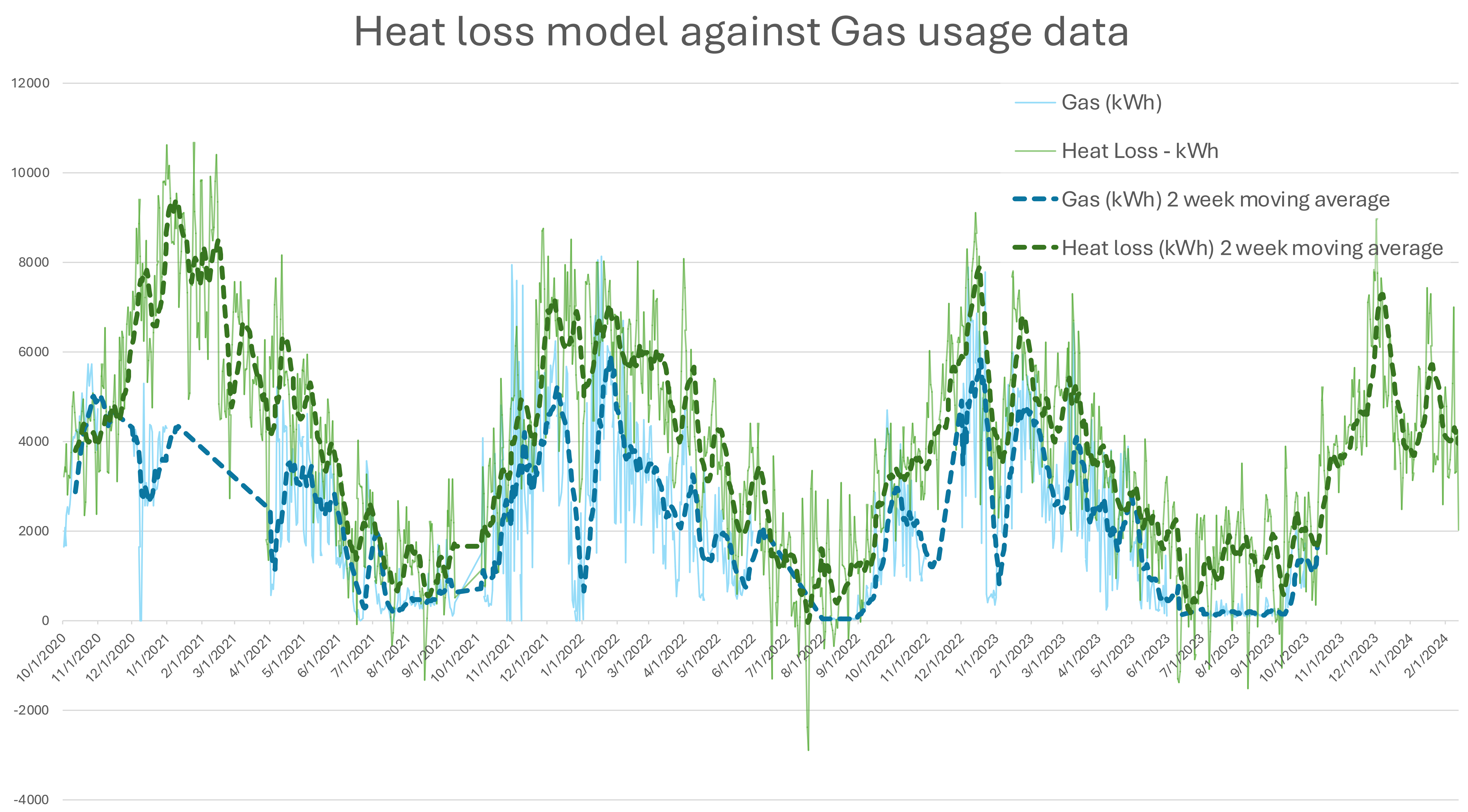
Steel Walls	0.002				
Air Gap (1 inch)	0.056				
Steel Walls	0.002	0.06	16	2.68	**444**
Brick (Engine Shed)	0.714	0.714	1.4	19	**270**

Heat - Ventilation heat loss estimates

For more information, see annex 10.3

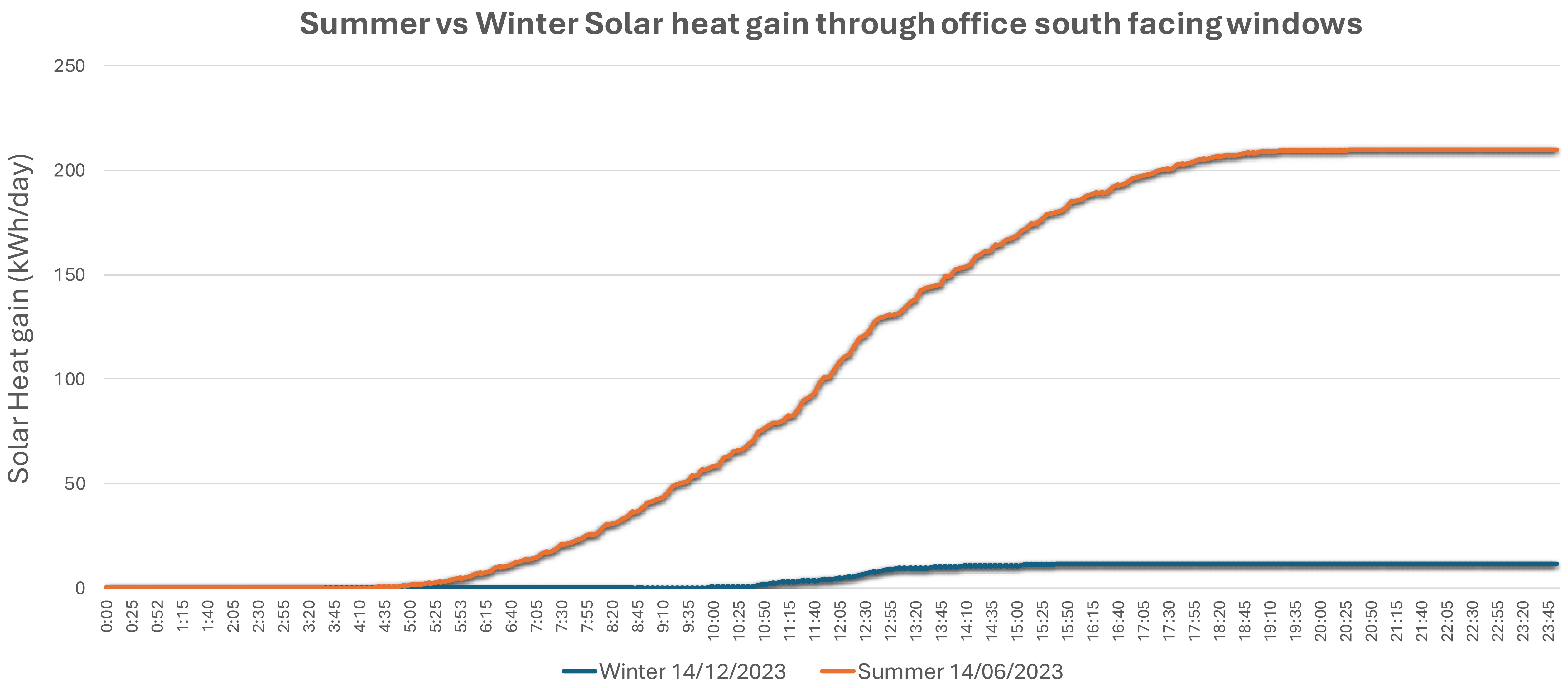


- The **events hall** has the largest thermal mass but is **only heated for specific events**
- **Towers** & the **offices** are most of the **base load**



Heat loss model against Gas usage data
12000
10000
8000
6000
4000
2000
0
-2000
-4000
10/1/2020
11/1/2020
12/1/2020
1/1/2021
2/1/2021
3/1/2021
4/1/2021
5/1/2021
6/1/2021
7/1/2021
8/1/2021
9/1/2021
10/1/2021
11/1/2021
12/1/2021
1/1/2022
2/1/2022
3/1/2022
4/1/2022
5/1/2022
6/1/2022
7/1/2022
8/1/2022
9/1/2022
10/1/2022
11/1/2022
12/1/2022
1/1/2023
2/1/2023
3/1/2023
4/1/2023
5/1/2023
6/1/2023
7/1/2023
8/1/2023
9/1/2023
10/1/2023
11/1/2023
12/1/2023
1/1/2024
2/1/2024
Gas (kWh)
Heat Loss - kWh
Gas (kWh) 2 week moving average
Heat loss (kWh) 2 week moving average

Heat Gain


Summer vs Winter Solar heat gain through office south facing windows
Solar Heat gain (kWh/day)
250
200
150
100
50
0
0:00
0:25
0:52
1:15
1:40
2:05
2:30
2:55
3:20
3:45
4:10
4:35
5:00
5:25
5:53
6:15
6:40
7:05
7:30
7:55
8:20
8:45
9:10
9:35
10:00
10:25
10:50
11:15
11:40
12:05
12:30
12:55
13:20
13:45
14:10
14:35
15:00
15:25
15:50
16:15
16:40
17:05
17:30
17:55
18:20
18:45
19:10
19:35
20:00
20:25
20:50
21:15
21:40
22:05
22:30
22:55
23:20
23:45
Winter 14/12/2023
Summer 14/06/2023

Our Proposals

Heating – Insulation

For more information, see annex 10.9

- Implement cellulose into steel wall sections
- Reduce total heat loss by 12%
- Total estimated cost: £304.65
- ROI of ~ 1 week

Heating – Insulation

For more information, see annex 10.9

- Environmentally friendly
- Cost-effective
- Fire-resistance
- Soundproofing

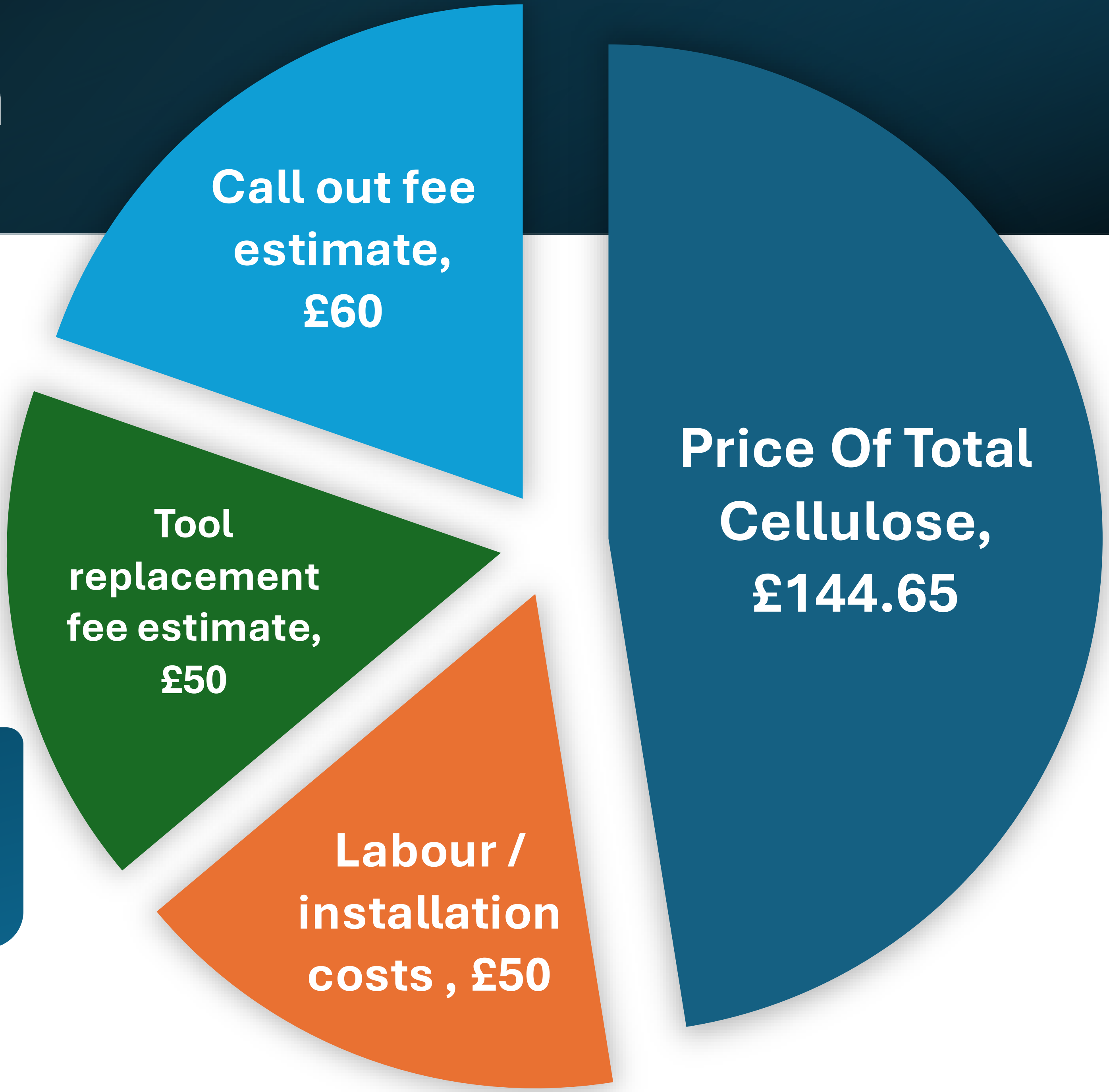
Range of R-Values: 3.2-3.8 per inch thickness

Heating – Insulation

Price of cellulose: **£1.36 / m^3**

Bags needed: **5**

Total Cost: £304.65



Heating – Heat Pumps

For more information, see annex 10.10

Max daily heating: 338kW – 445kW

Spec for 450kW: two 150kW heat pumps, one remaining gas boiler

Gas boiler protects against extremes will only be needed on ~20 coldest days

Quality Function Deployment

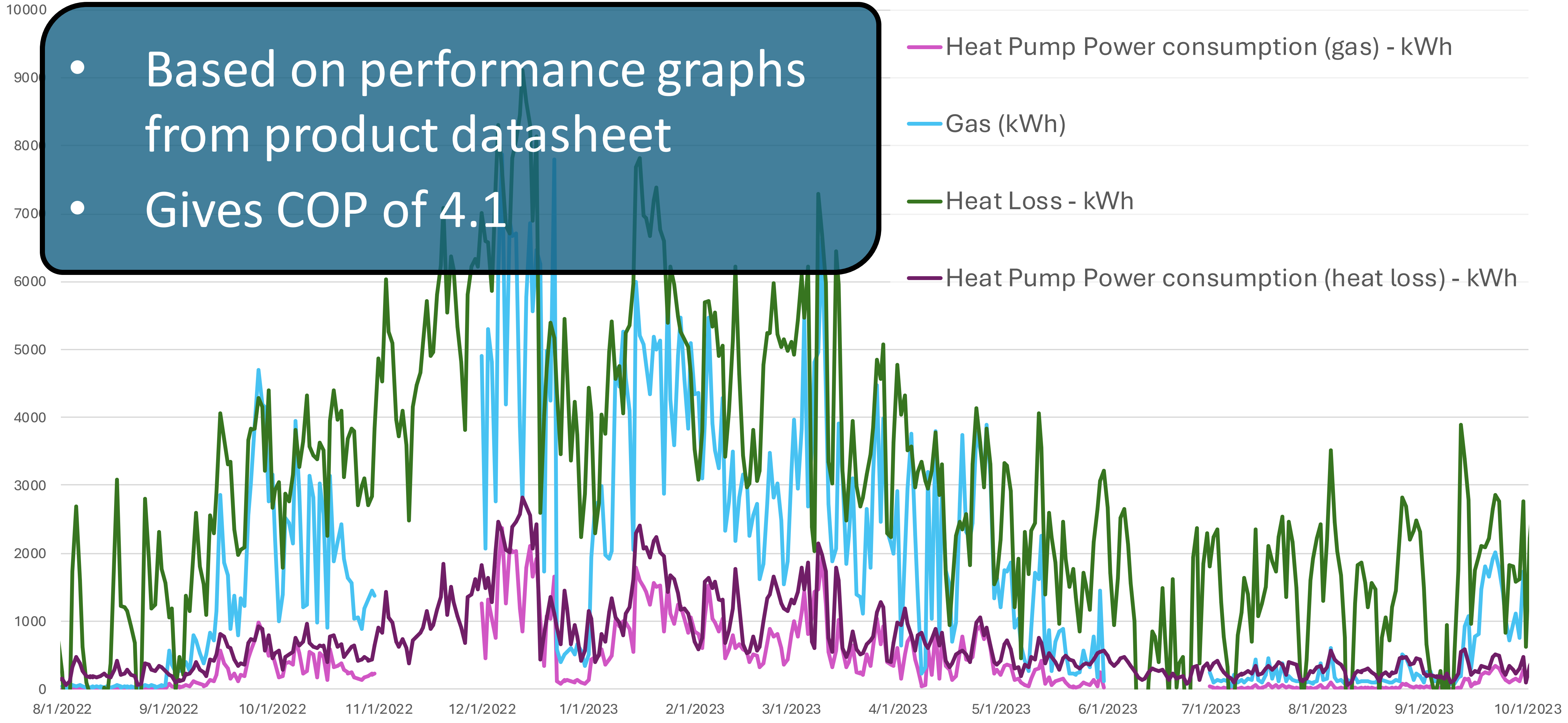
Project title: Sub Sub QFD - Heat Pumps

Project leader: Group 2

Date: 26/02/2024

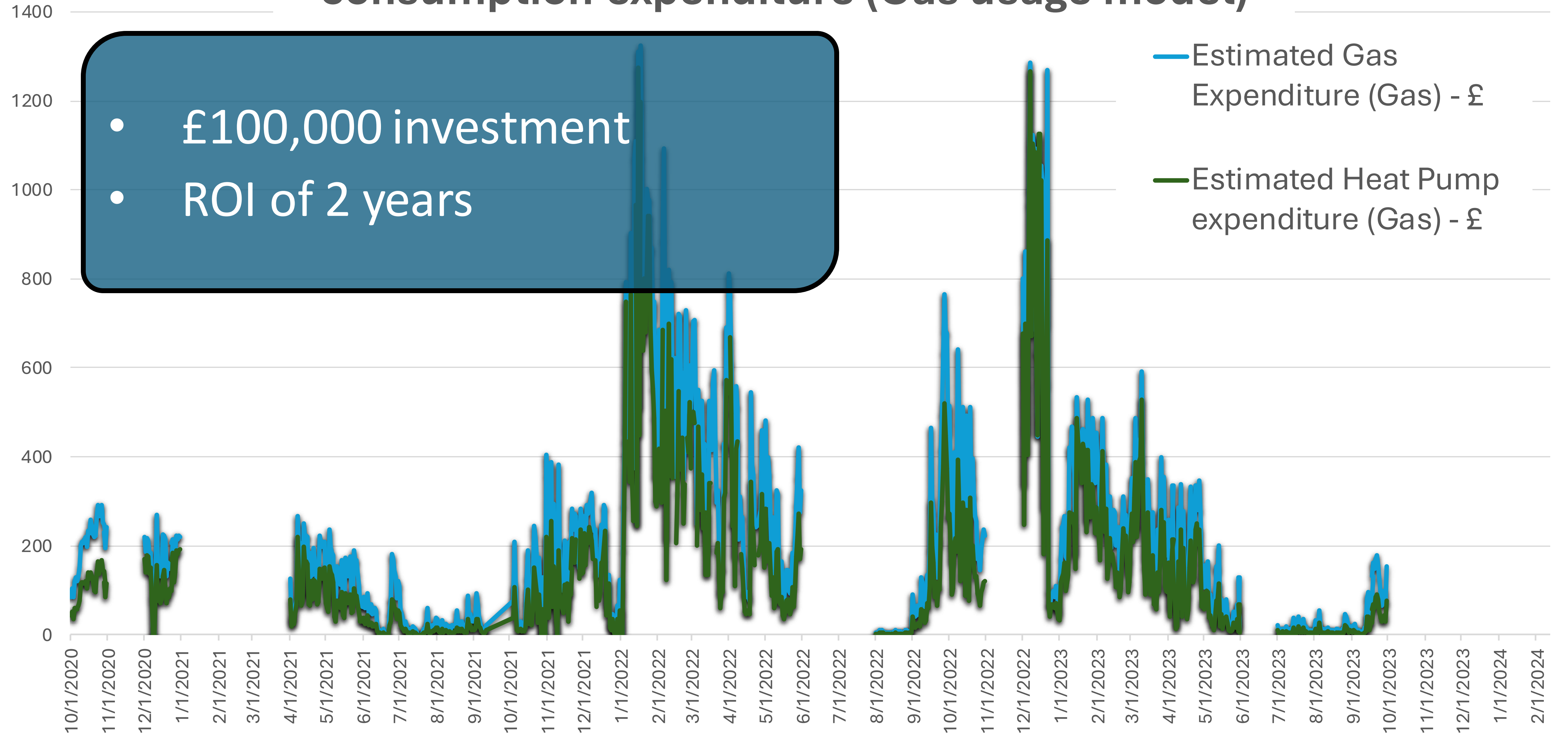
1: low, 5: high	Desired direction of improvement (↑,0,↓)	↑	↑	↑	↑
Stakeholder importance rating	Technical Requirements (How's) → / Stakeholder Requirements - (What's) ↓	Horizontal Ground	Vertical Ground	Air	Water
3	Space Requirements	1	3	8	7
3	Maintenance	2	1	7	5
4	Cost/ROI	2	2	8	6
3	Lifespan	7	7	4	7
4	Feasability of Installation	2	4	8	6
4	Efficiency	7	8	6	7
	Technical importance score	74	89	145	133
	Importance %	17%	20%	33%	30%
	Priorities rank	**4**	**3**	**1**	**2**

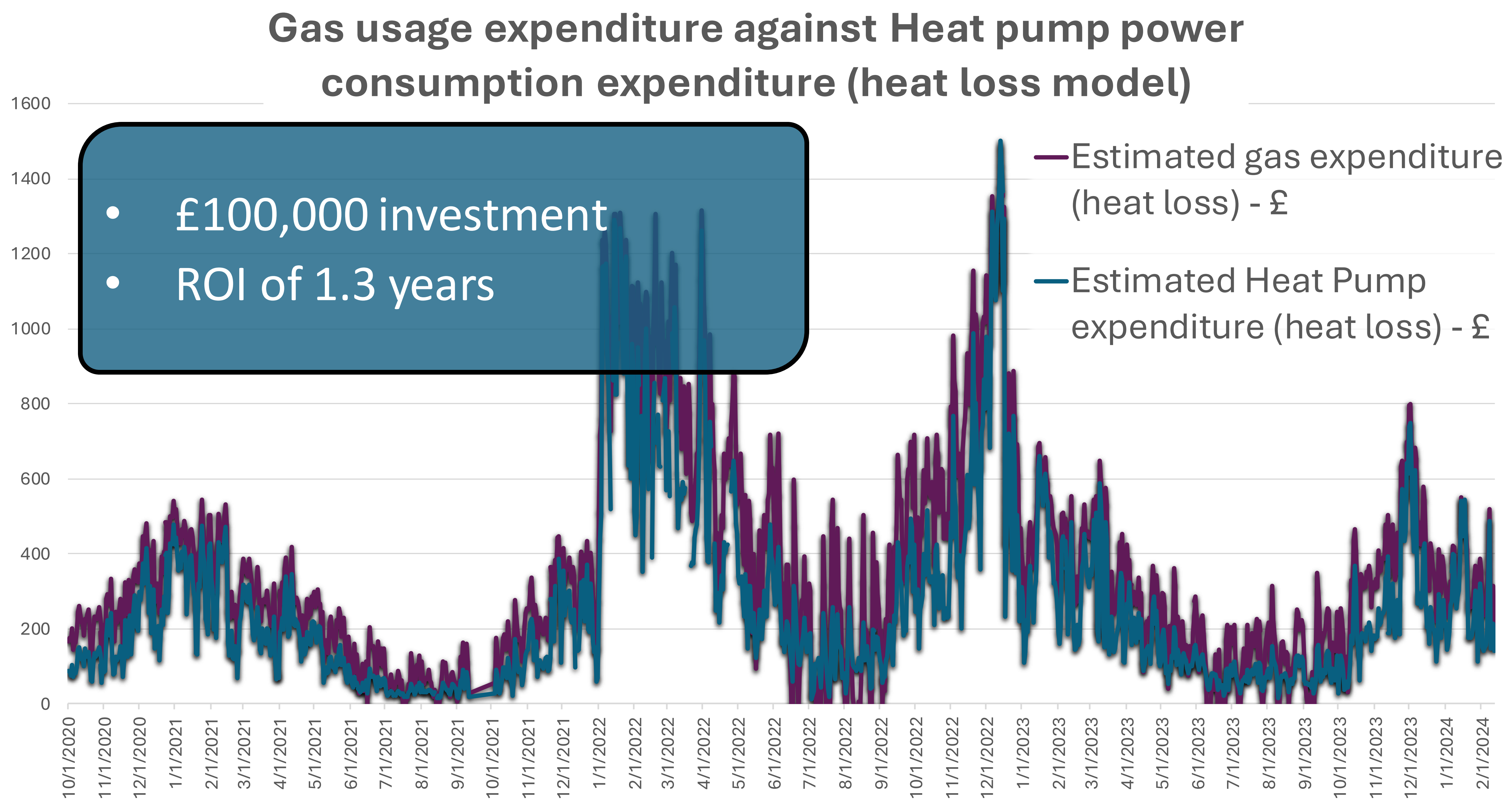
Gas usage against Heat pump power consumption



- Based on performance graphs from product datasheet
- Gives COP of 4.1

Gas usage expenditure against Heat pump power consumption expenditure (Gas usage model)





Gas usage expenditure against Heat pump power consumption expenditure (heat loss model)
• £100,000 investment
• ROI of 1.3 years
Estimated gas expenditure (heat loss) - £
Estimated Heat Pump expenditure (heat loss) - £
1600
1400
1200
1000
800
600
400
200
0
10/1/2020
11/1/2020
12/1/2020
1/1/2021
2/1/2021
3/1/2021
4/1/2021
5/1/2021
6/1/2021
7/1/2021
8/1/2021
9/1/2021
10/1/2021
11/1/2021
12/1/2021
1/1/2022
2/1/2022
3/1/2022
4/1/2022
5/1/2022
6/1/2022
7/1/2022
8/1/2022
9/1/2022
10/1/2022
11/1/2022
12/1/2022
1/1/2023
2/1/2023
3/1/2023
4/1/2023
5/1/2023
6/1/2023
7/1/2023
8/1/2023
9/1/2023
10/1/2023
11/1/2023
12/1/2023
1/1/2024
2/1/2024

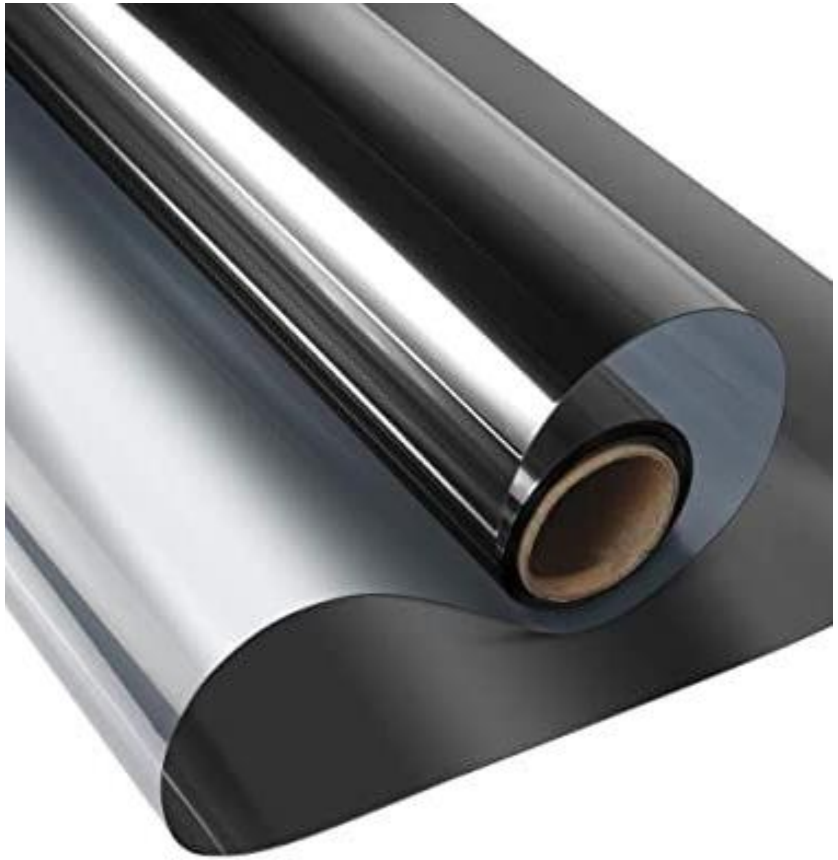
Heat – Reflective film

For more information, see annex 10.3

46% visible light → 34% solar energy transmission

£1150 investment

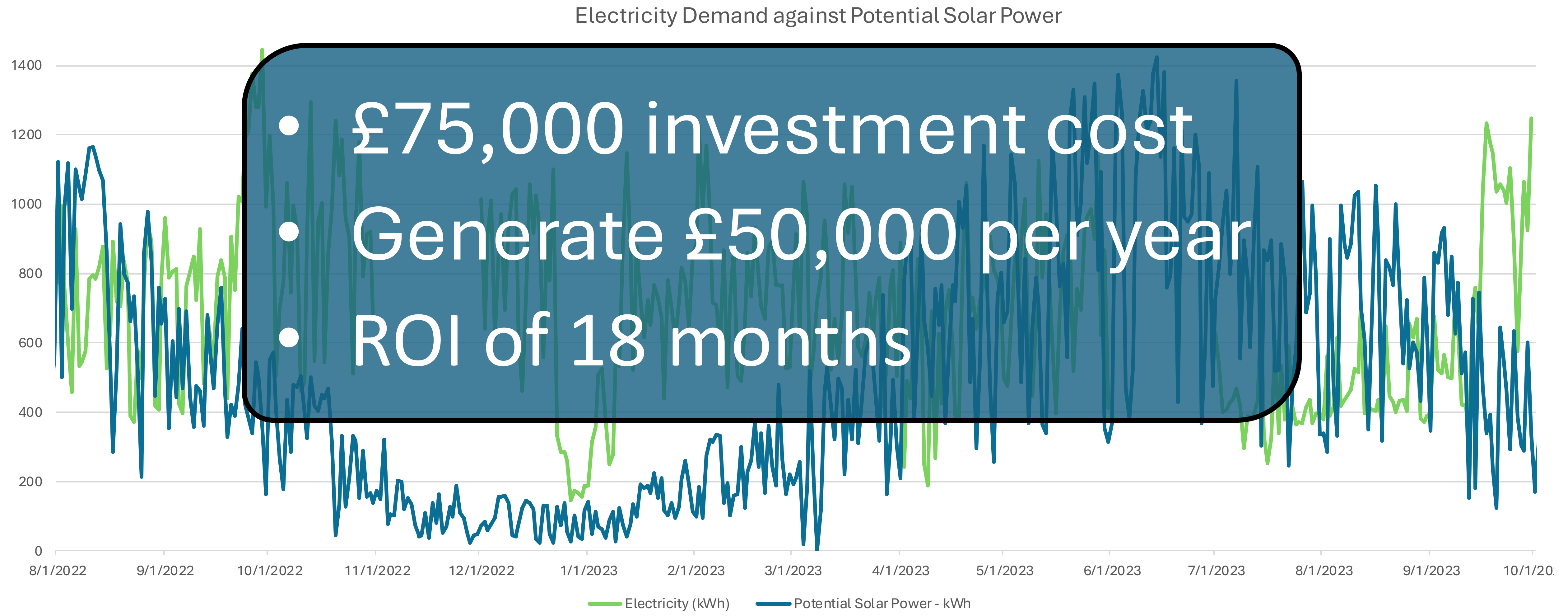
ROI less than a year



Solar Installation

For more information, see annex 10.11

Metric	Electricity expenditure	Estimated solar electricity value
Average	£131	£140
Max	£507	£751
Min	£17	£0



- £75,000 investment cost
- Generate £50,000 per year
- ROI of 18 months

Solar Installation

For more information, see annex 10.11

Midlands Net Zero Hub community energy fund

"Stage 1 ***Feasibility*** *Grant of up to* ***£40,000*** *to produce a* ***feasibility study*** *to establish the technical and financial viability of a project"*

"Stage 2 ***Development*** *Grant of up to* ***£100,000*** *for a more detailed investigation of the technology, for planning applications and to develop a* ***business case****."*

Water Solutions

For more information, see annex 10.7

POTABLE USAGE REDUCTION

RAINWATER COLLECTION

WATER HEATING

Why water reduction?

QFD Shows water usage in bathrooms should be a focus.

1: low, 5: high	Desired direction of improvement (↑,0,↓)	↓	↓	↓	↓	↓	↓
Stakeholder importance rating	Technical Requirements (How's) → / Stakeholder Requirements - (What's) ↓	Bathroom Water Usage - Toilets, Sinks, Urinals	heatloss from doors being open	Energy used from automatic lights being on	Energy Used by and Dryers	External Lighting Use	Office Items On standby
5	Sustainability	7	6	8	8	7	9
4	Low Carbon	9	7	8	6	6	9
4	Low Waste	8	7	7	8	6	9
4	Customer Wellbeing	7	3	6	5	8	6
4	Staff Wellbeing	7	4	6	5	4	4
4	Low Disruption to current practice	8	9	8	8	6	5
4	Usable Periods	7	8	6	8	6	8
4	Solution Longevity	9	8	6	8	6	9
	Technical importance score	255	214	228	232	203	245
	Importance %	19%	16%	17%	17%	15%	18%
	Priorities rank	**1**	**5**	**4**	**3**	**6**	**2**

Water - Reducing Potable Water Use

For more information, see annex 10.7.1

27% reduction in water usage

Tap flow rate
6 L/min → 3 L/min

Toilet flush
7.3 L → 4.5 L

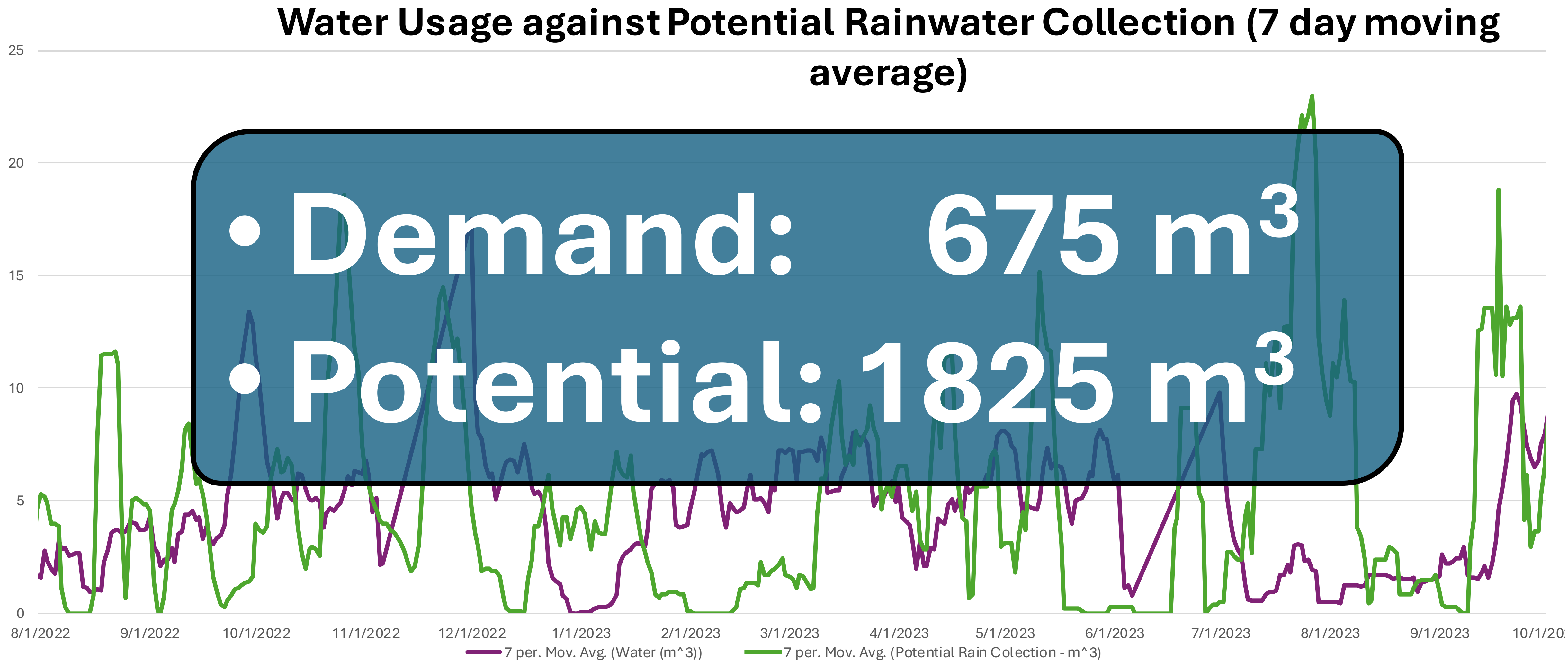
Urinal flush
7.5 L → 1 L

Water - Rainwater Collection

For more information, see annex 10.7.4

- Compared rainwater collection potential against usage
- Cost - £7630
- Saving - £1200 annually
- 6.4 years ROI

Can we collect enough water?



- **Demand: 675 m^3**
- **Potential: 1825 m^3**

Specification

For more information, see annex 10.7.3

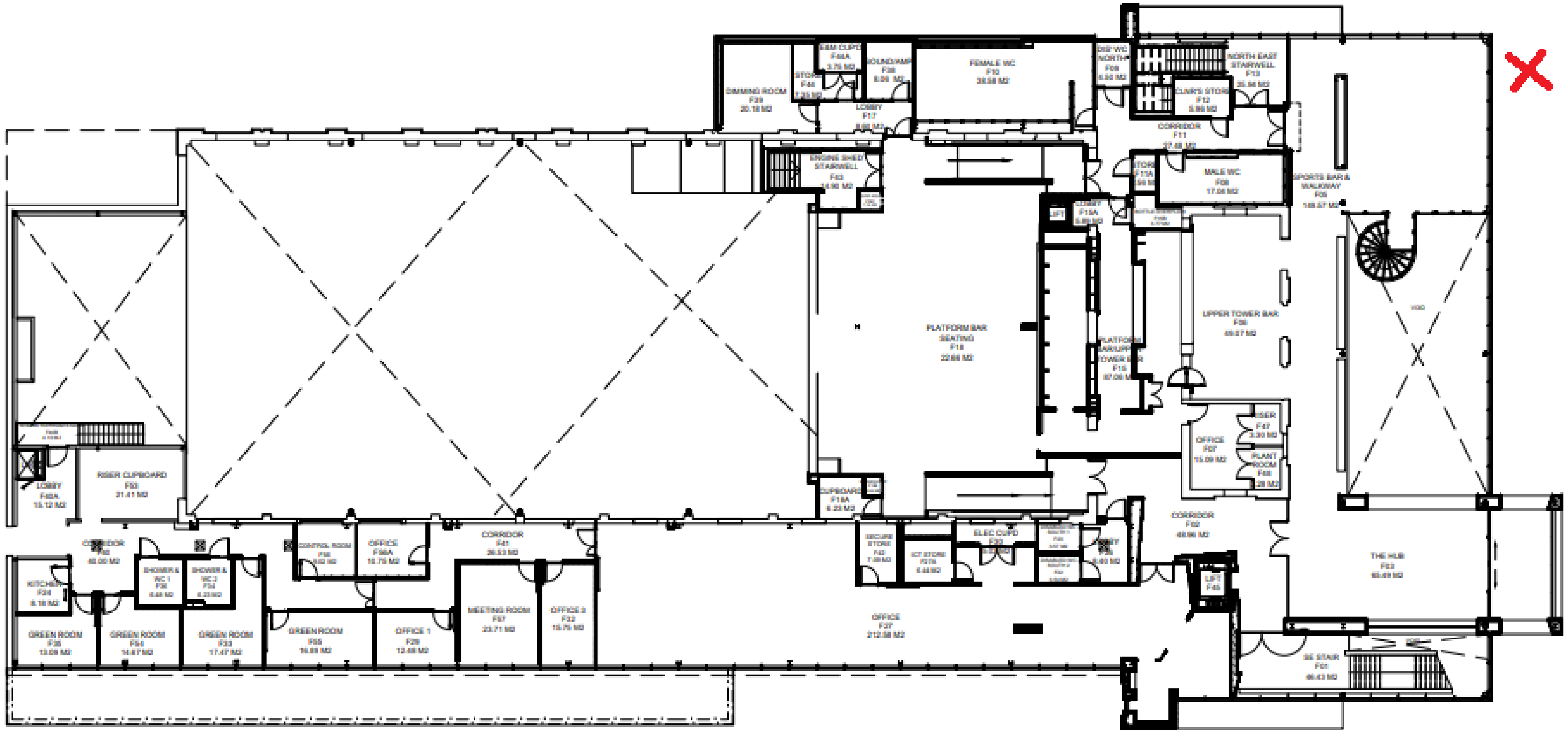
30,000L Tank
(5% of annual requirement)

$50m^3$/hour Water pump

Room for expansion with potable filters

Tank Location

For more information, see annex 10.7.3



3320mm

3720mm

Inlet 2940mm

500kg

Water - Heat Pump

For more information, see annex 10.8

Annual water heating cost - £5045

Cost of system and installation - £6362.90

Saving - £3363 annually

1.89 years ROI

The Boilers

For more information, see annex 10.8.1 and 1.8.2

500L Peak Requirement

Two 270 L Boilers

Potential for cooling and dehumidifying offices

System	Component	Component Functions	Potential Failure Mode	Failure Effects	Severity	Failure Cause	Occurrence	Detection	Action Priority	Reccomended Action	Accountibility	Severity	Occurrence	Detection	Action Priority
Air Source Heat		Provide				▶ Misunderstanding current Cooling system									
			Innability to Integrate with existing ventilation system	▶ No improvement in cooling efficincy ▶ No reduction in cooling related emmisions	9	▶ Not checking component specification carefully enough	3	6	108	▶ Peer reviewing the specifications	▶ Innovation Group	4	2	9	8
			Insufficient Power Output	▶ Inability to effectively heat the required space	5	▶System not correctly specced to accomodate current ventilation	7	5	175	▶Compare specced heat pump against SOR	▶ Innovation Group	4	2	8	16
	Pump	Presurise Refrigerant	Oversized Pump	▶ Damage Other components	9	▶ Not checking component specification carefully enough	3	4	162	▶ Peer reviewing the specifications against the refrigerant ▶ Purchase and usage of a pre-assembled system (increases reliability and ease of installation)	▶ Heat pump supplier in case of pre-assembeled system	3	2	8	12
				▶ Increase cost ▶ Reduced efficiency	4		3	4	72			2	2	8	8
			Undersized Pump	▶ Reduced efficiency	4		3	4	72			2	2	8	8
				▶ Damage other components	9		3	4	162			3	2	8	12
	Backflow Preventer	Prevent balckflow from the heating system into the potable water system	Allows backflow	▶ Potentially contaminated drinking water supply with debris / polution	6	▶ Exceeds max: ▶ Working pressure ▶ Working temperature	4	7	72	▶ Peer reviewing the maximum pressure/temperature that the valve is specced for before purchase	▶ Innovation Group	2	1	8	4
						▶ Not installed at inlet to system	1	6	24	▶ Check system plans ▶ Peer review installation		2	1	9	2
						▶ Installed backwards	2	6	48			2	1	7	6
			Blocks water flow to heating system	▶ Damage Other components ▶ No Hot water	9	▶ Installed backwards ▶ Blocked ▶ Frozen	4	6	144	▶Ensure existing loop includes adquete filters		4	2	8	16

DFMEA

For more information, see annex 10.12

Conclusion

CUT CO2 EMISSIONS BY OVER 60%

EFFECTIVELY ELIMINATE GAS USAGE

REDUCE POTABLE WATER USE BY 40%

REQUIRE INVESTMENT OF ~£190,000

SAVE ~£90,000 PER ANNUM

**Follow QR code for report, annexes, meeting notes etc.*

QR code will take you to this page

Innovation Project 2024 Homepage

1 backlink

See Gate 5 Report:

PDF (*Reccomended*)

G2 Gate 5 Report.pdf 4186.5KB

Word

G2 Gate 5 Report.docx 52561.5KB

Gate 5 Presentation

G2 Gate 5 Presentation.pptx 51607.6KB

See Annexes:

Annexes - Innovation Project 2024

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