



The Environment Agency

**2023 UK Report for On-going Particulate Matter (PM₁₀
and PM_{2.5}) Equivalence**

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Contents

Executive Summary	3
1 Introduction to the Legislation	5
2 The Instruments Deployed	7
2.1 Reference Method	7
2.2 Met One Smart Heated BAM 1020	7
2.3 Palas Fidas 200 Method 11	8
3 The Monitoring Sites	10
3.1 London Teddington	10
3.2 Manchester Piccadilly	10
3.3 London Marylebone Road	10
3.4 Port Talbot Margam	10
4 Data Capture	11
5 Calculating the Uncertainty	12
6 Summary of Results	13
7 Combining Years and Sites	15
8 Conclusions	18
Appendix of Figures	19

List of Tables

Table 1:	Summary of Results.....	14
Table 2:	Expanded Uncertainties over the previous 3 years.....	15
Table 3:	Expanded Uncertainties calculated by combining sites for 2023.....	16
Table 3:	Expanded Uncertainties calculated by combining years and sites for 2021-3.....	17

List of Figures

Figure A.1:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 at London Teddington.....	19
Figure A.2:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 at Manchester Piccadilly.....	20
Figure A.3:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 at London Marylebone Road.....	21
Figure A.4:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 at Port Talbot Margam.....	22
Figure A.5:	Equivalence calculations for the $PM_{2.5}$ Smart Heated BAM1020 at London Teddington.....	23
Figure A.6:	Equivalence calculations for the $PM_{2.5}$ Smart Heated BAM1020 at Manchester Piccadilly.....	24
Figure A.7:	Equivalence calculations for the $PM_{2.5}$ Smart Heated BAM1020 at London Marylebone Road.....	25
Figure A.8:	Equivalence calculations for the PM_{10} Fidas 200 Method 11 at London Teddington.....	26
Figure A.9:	Equivalence calculations for the PM_{10} Fidas 200 Method 11 at Manchester Piccadilly.....	27
Figure A.10:	Equivalence calculations for the PM_{10} Fidas 200 Method 11 at London Marylebone Road.....	28
Figure A.11:	Equivalence calculations for the $PM_{2.5}$ Fidas 200 Method 11 at London Teddington.....	29
Figure A.12:	Equivalence calculations for the $PM_{2.5}$ Fidas 200 Method 11 at Manchester Piccadilly.....	30
Figure A.13:	Equivalence calculations for the $PM_{2.5}$ Fidas 200 Method 11 at London Marylebone Road.....	31
Figure A.14:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 at all sites for 2023.....	32
Figure A.15:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 excluding Port Talbot Margam for 2023.....	33
Figure A.16:	Equivalence calculations for the $PM_{2.5}$ Smart Heated BAM1020 at all sites for 2023.....	34
Figure A.17:	Equivalence calculations for the PM_{10} Fidas 200 Method 11 at all sites for 2023.....	35
Figure A.18:	Equivalence calculations for the $PM_{2.5}$ Fidas 200 Method 11 at all sites for 2023.....	36
Figure A.19:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 at all sites for 2021-3.....	37
Figure A.20:	Equivalence calculations for the PM_{10} Smart Heated BAM1020 excluding Port Talbot Margam for 2021-3.....	38
Figure A.21:	Equivalence calculations for the $PM_{2.5}$ Smart Heated BAM1020 at all sites for 2021-3.....	39
Figure A.22:	Equivalence calculations for the PM_{10} Fidas 200 Method 11 at all sites for 2021-3.....	40
Figure A.23:	Equivalence calculations for the $PM_{2.5}$ Fidas 200 Method 11 at all sites for 2021-3.....	41

Executive Summary

The United Kingdom (UK) has a requirement to measure the concentration of particulate matter in air. Two size fractions are measured: PM₁₀ (the concentration of particulate matter below 10 microns in diameter), and PM_{2.5} (the concentration of particulate below 2.5 microns in diameter). The legislation sets out the methods to be followed and the instruments to be used (Reference Methods), but also provides the opportunity for other instruments to be used if they have been shown to be equivalent to the Reference Method (otherwise referred to as Equivalent Methods).

The Reference Methods for both PM₁₀ and PM_{2.5} require taking 24-hour samples on to filters that are weighed before and after sampling. As such, use of the Reference Method across the UK would result in delays in public information (due to laboratory processes) and data being produced at a resolution of one measurement per 24-hours per site per instrument. To meet the needs for public access to real-time, high-resolution data, the UK uses equivalent instruments that automatically produce hourly data, dissemination of which is made into UK-Air (the public facing information portal).

During 2023, concentrations of PM₁₀ and PM_{2.5} continued to be measured through previously proven Equivalent Methods using Smart Heated BAM 1020s (an instrument that can measure either PM₁₀ or PM_{2.5}) or the Fidas 200 Method 11 (a single instrument that can measure both PM₁₀ and PM_{2.5} at the same time).

Testing and approval of these instruments as being equivalent to the Reference Methods was undertaken several years ago through a series of laboratory and field measurements. There is a requirement to confirm annually that these instruments remain “fit for purpose” due to the continually changing composition of particulate matter across the UK. This process is known as “On-going Equivalence”, and this report summarises the findings for the UK for 2023 from this programme.

To prove that the equivalent method instruments are still equivalent to the Reference Method, each of the approved instruments is tested alongside the Reference Method at several sites. The requirement is that the Expanded Uncertainty (as calculated using the equations in EN16450:2017) is less than 25 %. For PM₁₀ the calculations are made at a daily limit value of 50 µg m⁻³. For PM_{2.5} the calculations are made at a pseudo daily limit value of 30 µg m⁻³, consistent with current guidance for such calculations and with other European countries.

During 2023, four sites were used for on-going equivalence testing in the UK:

- London Teddington – An urban background site in the western suburbs of London.

- Manchester Piccadilly – An urban background site in a large pedestrianised square in the centre of Manchester.
- London Marylebone Road – An urban traffic site on a busy London Road.
- Port Talbot Margam – An industrial site close to the Port Talbot Steel Works. This was for PM₁₀ equivalence only.

A summary of the expanded uncertainties found during 2023 is as follows.

Instrument	Site	Expanded Uncertainty / %	Pass/Fail
PM ₁₀ Smart Heated BAM 1020	London Teddington	11.63	Pass
PM ₁₀ Smart Heated BAM 1020	Manchester Piccadilly	20.31	Pass
PM ₁₀ Smart Heated BAM 1020	London Marylebone	14.05	Pass
PM ₁₀ Smart Heated BAM 1020	Port Talbot Margam	22.04	Pass
PM _{2.5} Smart Heated BAM 1020	London Teddington	15.85	Pass
PM _{2.5} Smart Heated BAM 1020	Manchester Piccadilly	11.63	Pass
PM _{2.5} Smart Heated BAM 1020	London Marylebone	25.26	Fail
PM ₁₀ Fidas 200 Method 11	London Teddington	20.73	Pass
PM ₁₀ Fidas 200 Method 11	Manchester Piccadilly	18.98	Pass
PM ₁₀ Fidas 200 Method 11	London Marylebone	26.30	Fail
PM _{2.5} Fidas 200 Method 11	London Teddington	26.34	Fail
PM _{2.5} Fidas 200 Method 11	Manchester Piccadilly	25.89	Fail
PM _{2.5} Fidas 200 Method 11	London Marylebone	10.21	Pass

For 2023 nine of the thirteen datasets passed the Expanded Uncertainty requirement by being below 25%, with the remaining four being only marginally above 25%. However, EN16450:2017 requires that the last three years' worth of data are considered, and by combining these datasets all instruments are shown to pass the uncertainty criterion. Further, by combining data from the same instruments for different sites (as undertaken by some countries in Europe), all these datasets also pass. This supports the UK's decision that these instruments remain equivalent to the Reference Method and can continue to be used in the UK.

Allowing for external site-wide problems at London Teddington (details of which are provided in this report), the only significant loss of data during 2023 was the deletion of Manchester Piccadilly Fidas data from the 6th November 2023 due to the instrument reporting concentrations significantly higher than expected.

1 Introduction to the Legislation

The Ambient Air Quality Directive (2008/50/EC)^[1] and Fourth Daughter Directive (2004/107/EC)^[2] set standards such as statutory limit values and target values for the concentration of pollutants in ambient air. They also define monitoring and reporting obligations. In the UK, responsibility for meeting air quality targets and limit values is the Secretary of State in England but also is devolved to the administrations in Scotland, Wales and Northern Ireland. These Directives were transposed by respective Air Quality Standard Regulations (as detailed below):

- The Air Quality Standards Regulations 2010^[3] in England (UK Government, 2010), and their December 2016 and January 2019 amendments (UK Government, 2016 and 2019).
- The Air Quality Standards (Scotland) Regulations 2010^[4] in Scotland (Scottish Government, 2010), and their December 2016 amendment (Scottish Government, 2016).
- The Air Quality Standards (Wales) Regulations 2010^[5] in Wales (Welsh Government, 2010) and their February 2019 amendment (Welsh Government, 2019).
- The Air Quality Standards Regulations (Northern Ireland) 2010^[6] (DAERA, 2010), and their December 2016, December 2018 and November 2020 amendments (DAERA, 2017, 2018 and 2020).

The Secretary of State for Environment, Food and Rural Affairs has responsibility for meeting the limit values and target values as defined through the Air Quality Standards Regulations 2010 for England and the Department for Environment, Food and Rural Affairs (Defra) co-ordinates assessment for the UK as a whole.

International relations are reserved to the UK Government; therefore, Defra retains overall policy responsibility for the formulation of international air quality policy. Defra continues to represent the UK internationally, which reflects that while new domestic legislation is a devolved responsibility the overall compliance with international agreements will remain the responsibility of the UK Government.

[1] <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008L0050>

[2] <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32004L0107>

[3] <https://www.legislation.gov.uk/ukSI/2010/1001/made>

[4] <https://www.legislation.gov.uk/ssi/2010/204/contents/made>

[5] <https://www.gov.wales/sites/default/files/publications/2019-04/the-air-quality-standards-wales-regulations-2010.pdf>

[6] <https://www.legislation.gov.uk/nisr/2010/188/contents/made>

For Particulate Matter (PM), two size fractions are measured – PM₁₀ (the concentration of particulate matter below 10 microns in diameter), and PM_{2.5} (the concentration of particulate below 2.5 microns in diameter).

The UK Environment Act (2021)^[7] (UK Government, 2021) established a duty for the UK Government to set a legally mandatory target in England to reduce PM_{2.5}, alongside at least one further long-term target on air quality. Within this framework, the Environmental Targets (Fine Particulate Matter) (England) Regulations (2023)^[8] (UK Government, 2023) came into force in January 2023. The Environmental Targets (fine particulate matter) (England) Regulations 2023 set two PM_{2.5} targets to be met by 2040, these provide:

- A legal target to reduce population exposure to PM_{2.5} by 35% in 2040 compared to 2018 levels.
- A legal target to require a maximum annual mean concentration of 10 micrograms of PM_{2.5} per cubic metre (µg m⁻³) by 2040.

For PM₁₀ and PM_{2.5} 2008/50/EC requires that countries use the reference methods or else prove that the instruments they use are equivalent to the reference method. The reference method is covered by EU Standard EN12341:2023^[9]. 2008/50/EC also sets out concentration limits and data quality objectives for different pollutants. 2008/50/EC sets out that instruments used for particulate matter monitoring should have a measurement uncertainty below 25 %.

The process of equivalence testing is covered by EU Standard EN16450:2017^[10]. Primarily this relates to setting out laboratory and field test requirements in order to show that instruments can be proven to have an expanded uncertainty below the 25 % defined in 2008/50/EC. For the field testing this requires operating the instrument to be tested alongside the reference instruments. Additionally, EN16450:2017 requires that countries continually prove that the instruments they deploy are still equivalent to the reference method accounting for the changing pollution climates since the initial tests were undertaken. As with the initial field testing, this process requires operating the instrument alongside the reference instruments.

[7] <https://www.legislation.gov.uk/ukpga/2021/30/contents>

[8] <https://www.legislation.gov.uk/uksi/2023/96/contents/made>

[9] *Standard EN12341:2023 Ambient air - Standard gravimetric measurement method for the determination of the PM₁₀ or PM_{2.5} mass concentration of suspended particulate matter.*

[10] *CEN Standard EN16450:2017 Ambient air - Automated measuring systems for the measurement of the concentration of particulate matter (PM₁₀; PM_{2.5})*

2 The Instruments Deployed

2.1 Reference Method

The Reference Method is based upon the principle of gravimetry – which is the physical weighing of filters. Several manufacturers make different versions of the European Reference Methods in accordance with the requirements set out in EN12341:2023. Those instruments deployed in the present study are the SEQ47/50 as manufactured by Sven Leckel GMBH based in Berlin, Germany and the Digitel DPA14 as manufactured by Digitel AG based in Zurich, Switzerland.

Air is drawn at a rate of $2.3 \text{ m}^3 \text{ hr}^{-1}$ through a sampling head that is designed to remove particles greater than either 10 microns in diameter (when measuring PM_{10}) or 2.5 microns in diameter (when measuring $\text{PM}_{2.5}$). Following removal of the larger particles, the air is passed through a filter for 24 hours. The instrument holds multiple filters that are exchanged automatically every 24 hours.

EN12341:2023 defines four permissible filter materials which in turn can be made by multiple manufacturers to multiple specifications. The UK uses Teflon coated glass fibre filters as these have been shown to have limited effects due to absorption of water (as would quartz fibre or to lesser extent glass fibre) or problems with static and overloading the filter at moderate concentrations (as would Teflon). Further, Teflon coated glass fibre is only manufactured by a single manufacturer (Pall under the brand name Emfab), which reduces the potential for variability. Additionally, Teflon coated glass fibre filters were used in the Reference Methods as a part of the initial equivalence testing process.

Filters are weighed twice before sampling and again twice after sampling. Prior to weighing the filters are conditioned at 45 to 50 % Relative Humidity (RH) and 20 to 21 °C. The mass of the particulate matter collected on the filter is calculated as the average mass post sampling minus the average mass prior to sampling. The concentration is calculated as the mass of the particulate matter divided by the volume as measured by the SEQ47/50.

2.2 Met One Smart Heated BAM 1020

BAM is an acronym of Beta Attenuation Monitor – and relates to the use of beta radiation to measure particulate concentrations. The instruments used are Smart Heated versions of the BAM 1020 as manufactured by Met One based in Grants Pass, Oregon, USA.

For the PM_{10} version, air is drawn at a rate of $1 \text{ m}^3 \text{ hr}^{-1}$ through a sampling head that is designed to remove particles greater than 10 microns in diameter on to the tape. This is of a different design to that deployed in the Reference Method. Following this, the air stream is heated slightly to force some of the particle bound water and any water droplets to enter the gaseous phase. The air is then passed

through a glass fibre tape, to which the particles are deposited, but the gaseous phase water that was previously in the particle phase passes through. The instrument works by measuring the beta attenuation through a blank of tape for 4 minutes, then following 1 minute to move the tape, sampling PM₁₀ laden air for 50 minutes through the tape, before moving the tape again and measuring the Beta attenuation for a further 4 minutes. The mass of particulate matter is calculated from the change in the beta attenuation before and after sampling. The concentration is calculated as the mass divided by the volume of air sampled.

The PM_{2.5} version is very similar to that of the PM₁₀ instrument. After the PM₁₀ inlet it has a PM_{2.5} cyclone that removes particles greater than 2.5 microns. It performs the beta counts for 8 minutes rather than 4 and the sampling for 42 minutes rather than 50. This is to increase the “signal to noise” ratio, and so more accurately measure PM_{2.5} concentrations which are (by definition) lower than PM₁₀ concentrations.

The initial equivalence certification of the instruments is provided in the following references ^[11,12]. Both had a series of extensive laboratory tests. The PM_{2.5} Smart Heated BAM 1020 had four field tests – two in Germany and two in the UK. To be equivalent, the PM_{2.5} data do not need to be corrected. The PM₁₀ Smart Heated BAM 1020 had seven field tests – three in Germany, two in Austria, one in the Czech Republic, and one in the UK. It was shown that to be equivalent, the PM₁₀ data need to be divided by 1.035.

2.3 Palas Fidas 200 Method 11

The Fidas 200 is manufactured by Palas based in Karlsruhe, Germany. The Fidas 200 utilises optical particle counting and sizing to calculate mass concentrations. Air is drawn at a flow rate of 0.3 m³ hr⁻¹ through a sampling head that is not designed to remove larger particles but is designed to prevent insects entering the instrument. The instrument counts particles of different sizes. The instrument then heats the sample stream slightly to force some of the particle bound water and any water droplets to enter the gaseous phase. Following this the instruments counts particles and puts them into bins of different size ranges. It then uses an algorithm to calculate PM₁₀ and PM_{2.5} based upon the numbers of particle in each bin combined with a pre-determined particle size density distribution.

[11] UK Report on the Equivalence of the Smart Heated PM_{2.5} BAM-1020.
<http://www.csagroupuk.org/wp-content/uploads/2015/05/PM25-Smart-BAM1020-UK-Report-211013.pdf>

[12] UK Report on the Equivalence of the Smart Heated PM₁₀ BAM-1020.
<http://www.csagroupuk.org/wp-content/uploads/2015/05/Smart-BAM-1020-PM10-UK-Report-with-manual-Final.pdf>

The initial equivalence certification of the instruments is provided in the following reference ^[13]. There were six field tests of which four were in Germany and two were in the UK. There were also a series of extensive laboratory tests. The instruments tested were operating with a concentration calculation algorithm known as Method 11. This same algorithm is utilised in those instruments tested at the on-going equivalence sites as well as all other instruments deployed in the UK Network. It was shown that, to be equivalent, the PM₁₀ data did not need correcting, but the PM_{2.5} data needs to be corrected by dividing by 1.06.

[13] UK Report on the Equivalence of the Palas Fidas 200 Method 11 for PM₁₀ and PM_{2.5}.
<http://www.csagroupuk.org/wp-content/uploads/2016/04/Palas-UK-Report-Final-with-Manuals-080316.pdf>

3 The Monitoring Sites

During 2023, four sites were used for on-going equivalence testing.

3.1 London Teddington

London Teddington is an urban background site in the western suburbs of London [14]. The instruments deployed were a PM₁₀ SEQ Reference Method, a PM_{2.5} SEQ Reference Method, a PM₁₀ Smart Heated BAM 1020, a PM_{2.5} Smart Heated BAM 1020, a Fidas 200 Method 11. Data from the Fidas 200 Method 11 are available from UK Air [15].

3.2 Manchester Piccadilly

Manchester Piccadilly is an urban background site in a large pedestrianised square in the centre of Manchester [16]. The instruments deployed were a PM₁₀ SEQ Reference Method, a SEQ PM_{2.5} Reference Method, a PM₁₀ Smart Heated BAM 1020, a PM_{2.5} Smart Heated BAM 1020 and a Fidas 200 Method 11. Data from the Fidas 200 Method 11 are available from UK Air [15].

3.3 London Marylebone Road

London Marylebone Road which is a busy urban traffic site in the centre of London [17]. The instruments deployed were a PM₁₀ Digitel Reference Method, a Digitel PM_{2.5} Reference Method, a PM₁₀ Smart Heated BAM 1020, a PM_{2.5} Smart Heated BAM 1020 and a Fidas 200 Method 11. Data from the Smart Heated BAMs are available from UK Air [15].

3.4 Port Talbot Margam

Port Talbot Margam is an industrial site close to the Port Talbot Steel Works. The site is also susceptible to the influence of the sea upon concentrations due to its proximity to the Bristol Channel [18]. At this site there was deployed a PM₁₀ SEQ Reference Method, and a PM₁₀ Smart Heated BAM 1020. Data from both instruments are available from UK Air [15].

[14] https://uk-air.defra.gov.uk/networks/site-info?site_id=TED2

[15] <https://uk-air.defra.gov.uk/data/>

[16] https://uk-air.defra.gov.uk/networks/site-info?site_id=MAN3

[17] https://uk-air.defra.gov.uk/networks/site-info?site_id=MY1

[18] https://uk-air.defra.gov.uk/networks/site-info?site_id=PT4

4 Data Capture

2008/50/EC requires that data capture be at least 90 %. The European Commission have subsequently released Guidance ^[19] that allows for 5 % maintenance time and stipulates that data capture should be at least 85 %. While there are data capture criteria for initial equivalence testing, there are no data capture criteria for on-going equivalence tests.

All instruments had high data capture at Port Talbot Margam and London Marylebone Road, as did the BAMs and SEQs at Manchester Piccadilly.

As a part of the routine ratification process, Manchester Piccadilly Fidas data were deleted from the 6th November 2023 due to the instrument reporting concentrations significantly higher than expected.

At London Teddington data capture was low for all instruments, though this was due to external factors unconnected to the reliability of the instruments themselves. These are detailed below:

- The BAMs were temporarily removed from site between 16th November 2022 and 5th January 2023 due to a leak in the roof directly above them.
- There were additional periods of loss of data due to electrical works, and a period where the PM_{2.5} SEQ was operating incorrectly.
- From the 14th August 2023 a building adjacent to the site was demolished. The demolition debris was left on site resulting in short term spikes and an inhomogeneous air mass. Data from this period were deleted.
- All instruments were decommissioned on the 9th October 2023 to allow for construction of a new enclosure.

[19] *Guidance on the Commission Implementing Decision laying down rules for Directives 2004/107/EC and 2008/50/EC of the European Parliament and of the Council as regards the reciprocal exchange of information and reporting on ambient air (Decision 2011/850/EU). European Commission. DG ENV 2013.*

5 Calculating the Uncertainty

The equations to calculate the uncertainty are covered in EN16450:2017. The calculations are undertaken with 24-hour average data and using graphs with the reference method on the “x axis” and the continuous monitor on the “y axis”. A straight line of best fit is drawn using orthogonal linear regression and the intercept is not forced through the origin.

The slope and intercept of the lines of best fit are calculated as are the uncertainties associated with the slope and intercept. EN16450:2017 then define the slopes and intercept as being significant based upon whether the slope is within two uncertainties of 1 and the intercept is within two uncertainties of 0.

When undertaking the initial approval of equivalent instruments, there are requirements to check whether slope and/or intercept correction would result in a lower expanded uncertainty. However, for on-going equivalence testing there is no requirement to do so unless there is evidence of a consistent shift in results across many sites and years.

For PM₁₀ the calculations are made at a daily limit value (LV) of 50 µg m⁻³. For PM_{2.5} the calculations are made at a pseudo daily limit value of 30 µg m⁻³.

The uncertainty is made up of two parts – the bias at the LV, which is how far from the line of best fit is from the reference method at the Limit Value, and the random term, which is a measure of how noisy the distribution is. Both the bias and random terms are expressed in µg m⁻³. To calculate the expanded uncertainty, the two uncertainty components are combined by squaring them, adding the two squared uncertainties, and then square rooting the total. The units are still in µg m⁻³. This is then expressed as a percentage by dividing by the limit value (*i.e.* 50 µg m⁻³ for PM₁₀ or 30 µg m⁻³ for PM_{2.5}), and then multiplied by 2 (otherwise known as expanded) to express as an uncertainty at the 95 % confidence interval.

As the uncertainty (expressed in µg m⁻³) is divided by the LV to express as a percentage, and the LV is lower for PM_{2.5} than it is for PM₁₀, it is more difficult to meet the 25 % Expanded Uncertainty requirement for PM_{2.5} than it is for PM₁₀. As such, a PM₁₀ instrument may have a significantly higher bias at LV than a PM_{2.5} instrument yet have a lower Expanded Uncertainty overall.

6 Summary of Results

The results are summarised in Table 1 and shown in more detail in the Figures in the Appendix. Site names and instrument names have been truncated to fit the Table on to a single page and to improve the legibility of the Graphs. The PM_{2.5} Fidas 200 Method 11 data have been corrected by dividing by 1.06 prior to plotting the graph and performing the calculations. Similarly, the PM₁₀ Smart Heated BAM 1020 data have been corrected by dividing by 1.035 prior to plotting the graph and performing the calculations. It is not necessary to correct any of the other instruments.

The parameters described in the above Section are given in the Table and the Graphs. In addition to these, the number of points is given (n) as is the coefficient of determination (R^2) – this is a measure of how straight the line is, with 1 being a perfect straight line. There are no requirements on n or R^2 in EN16450:2017.

Where a slope is not significantly different from 1 or the intercept is not significantly different from 0 based on two standard deviations, then an **NS** (Not Significant) is given in green. Where a slope is significantly different from 1 or the intercept is significantly different from 0 based on 2 standard deviations, then an **S** (Significant) is given in red.

Where an Expanded Uncertainty is below 25 % then **Pass** is given in green. Where an Expanded Uncertainty is above 25 % then **Fail** is given in red.

Many of the slopes and intercepts were statistically significant. Within EN16450:2017, when considering the initial equivalence testing of an instrument there are requirements to test whether improvements to the distribution can be made by applying slope and intercept correction. This is why the PM₁₀ Smart Heated BAM 1020 and PM_{2.5} Fidas Method 11 are both corrected for slope. However, when undertaking on going equivalence testing, there is no requirement to consider the slope and intercept unless an expanded uncertainty is above 25 %.

Table 5.1 below provides for a summary of the 2023 results for ongoing equivalence. Nine of the thirteen datasets passed the Expanded Uncertainty requirement by being below 25%, with the remaining four being only marginally above 25%.

Table 1: Summary of Results.

Instrument	Site	Figure	Slope, Uncertainty of Slope	Intercept, Uncertainty of Intercept / $\mu\text{g m}^{-3}$	Expanded Uncertainty / %	n	Bias at LV / $\mu\text{g m}^{-3}$	Random Term / $\mu\text{g m}^{-3}$	R ²
PM ₁₀ BAM	Teddington	A.1	1.038 +/- 0.020 NS	0.555 +/- 0.269 S	11.63 Pass	191	2.438	1.583	0.932
PM ₁₀ BAM	Manchester	A.2	0.885 +/- 0.013 S	0.954 +/- 0.226 S	20.31 Pass	334	-4.805	1.639	0.929
PM ₁₀ BAM	Marylebone	A.3	0.907 +/- 0.015 S	1.871 +/- 0.301 S	14.05 Pass	325	-2.776	2.153	0.911
PM ₁₀ BAM	Port Talbot	A.4	1.049 +/- 0.009 S	2.335 +/- 0.268 S	22.04 Pass	323	4.773	2.751	0.975
PM _{2.5} BAM	Teddington	A.5	1.027 +/- 0.021 NS	1.186 +/- 0.192 S	15.85 Pass	161	2.003	1.281	0.932
PM _{2.5} BAM	Manchester	A.6	0.960 +/- 0.020 S	0.488 +/- 0.205 S	11.63 Pass	309	-0.700	1.599	0.873
PM _{2.5} BAM	Marylebone	A.7	1.009 +/- 0.017 NS	3.185 +/- 0.171 S	25.26 Fail	329	3.458	1.551	0.906
PM ₁₀ Fidas	Teddington	A.8	1.112 +/- 0.020 S	-0.682 +/- 0.279 S	20.73 Pass	212	4.909	1.663	0.929
PM ₁₀ Fidas	Manchester	A.9	0.900 +/- 0.016 S	0.657 +/- 0.277 S	18.98 Pass	297	-4.361	1.869	0.909
PM ₁₀ Fidas	Marylebone	A.10	0.910 +/- 0.016 S	-1.678 +/- 0.310 S	26.30 Fail	350	-6.179	2.245	0.898
PM _{2.5} Fidas	Teddington	A.11	1.108 +/- 0.021 S	0.488 +/- 0.180 S	26.34 Fail	188	3.727	1.313	0.934
PM _{2.5} Fidas	Manchester	A.12	0.861 +/- 0.018 S	0.505 +/- 0.187 S	25.89 Fail	279	-3.362	1.290	0.877
PM _{2.5} Fidas	Marylebone	A.13	0.982 +/- 0.016 NS	0.481 +/- 0.162 S	10.21 Pass	353	-0.054	1.530	0.904

7 Combining Years and Sites

EN16450:2017 requires that data are considered over the preceding three-year period. Some countries and regions throughout Europe combine data for the same instrument type from all three years, whilst others also combine data for the same instrument type from different sites. Care must be taken when combining sites, as sites with much higher concentrations can dominate the regression.

Data from the previous three years are summarised in Table 2. There is some variability year by year, though the number of combinations greater than 25% has increased for 2023. Three of the four sites were unique this year in being marginally above 25%, having previously passed in 2022 and 2021. Only one of the four sites, Manchester Piccadilly FIDAS 200 PM_{2.5}, was marginally above 25% for two years running in 2023 and 2022.

Ongoing equivalence has been undertaken at an expanding number of sites since 2013, though the instruments deployed have changed over the years. During this period the number of combinations greater than 25% has varied year by year.

Table 2: *Expanded Uncertainties over the previous 3 years.*

Instrument	Site	Expanded Uncertainty / %		
		2023	2022	2021
PM ₁₀ BAM	Teddington	11.63	9.75	24.94
PM ₁₀ BAM	Manchester	20.31	6.33	8.68
PM ₁₀ BAM	Marylebone	14.05	14.34	Not Deployed
PM ₁₀ BAM	Port Talbot	22.04	20.54	14.96
PM _{2.5} BAM	Teddington	15.85	10.73	14.20
PM _{2.5} BAM	Manchester	11.63	18.31	17.14
PM _{2.5} BAM	Marylebone	25.26	10.19	Not Deployed
PM ₁₀ Fidas	Teddington	20.73	8.27	8.20
PM ₁₀ Fidas	Manchester	18.98	14.42	20.94
PM ₁₀ Fidas	Marylebone	26.30	15.17	Not Deployed
PM _{2.5} Fidas	Teddington	26.34	10.64	12.26
PM _{2.5} Fidas	Manchester	25.89	25.26	20.62
PM _{2.5} Fidas	Marylebone	10.21	13.12	Not Deployed

Figures A.14 to A.18 in the Appendix summarise the equivalence calculations when combining sites. The PM₁₀ Smart Heated BAM 1020 is shown with and without the inclusion of Port Talbot Margam data as the concentrations were much

higher at this site and might dominate the regression. In each case the black text corresponds to the combined dataset. In each case the expanded uncertainty (Wcm) of the combined dataset is below the required 25%. The results are summarised in Table 3 below.

Table 3: Expanded Uncertainties calculated by combining sites for 2023.

Instrument	Figure	Expanded Uncertainty / %
PM ₁₀ BAM incl. Port Talbot	A.14	15.71
PM ₁₀ BAM 1020 excl. Port Talbot	A.15	13.69
PM _{2.5} BAM	A.16	19.83
PM ₁₀ Fidas	A.17	21.71
PM _{2.5} Fidas	A.18	11.40

Figures A.19 to A.23 in the Appendix summarise the equivalence calculations when combining years. In each case the data from London Teddington are in red, Manchester Piccadilly data are in blue, London Marylebone Road data are in green, and Port Talbot Margam data are in purple. In each case the expanded uncertainty (Wcm) of the combined dataset is below the required 25%. Further, the data from all sites (and therefore years) are combined in the black dataset. In each case the expanded uncertainty (Wcm) of the combined dataset is below the required 25%. As before, the PM₁₀ Smart Heated BAM 1020 is shown with and without the inclusion of Port Talbot Margam data as the concentrations were much higher at this site. The results are summarised in Table 4 overleaf.

Table 4: *Expanded Uncertainties calculated by combining years and sites for 2021-3.*

Instrument	Site	Figure	Expanded Uncertainty / %		
PM ₁₀ BAM	Teddington	A.19 & 20	12.26	9.8	16.28
PM ₁₀ BAM	Manchester	A.19 & 20	10.96		
PM ₁₀ BAM	Marylebone	A.19 & 20	14.10		
PM ₁₀ BAM	Port Talbot	A.19	21.79		
PM _{2.5} BAM	Teddington	A.21	13.12	14.67	
PM _{2.5} BAM	Manchester	A.21	15.92		
PM _{2.5} BAM	Marylebone	A.21	16.22		
PM ₁₀ Fidas	Teddington	A.22	10.48	16.74	
PM ₁₀ Fidas	Manchester	A.22	17.61		
PM ₁₀ Fidas	Marylebone	A.22	21.76		
PM _{2.5} Fidas	Teddington	A.23	14.12	13.42	
PM _{2.5} Fidas	Manchester	A.23	24.15		
PM _{2.5} Fidas	Marylebone	A.23	11.60		

The expanded uncertainty for the PM₁₀ BAM is shown for both including and excluding Port Talbot. As such one cell in the above Table is empty.

8 Conclusions

For 2023, nine of the thirteen datasets passed the Expanded Uncertainty requirement by being below 25%, with the remaining four being only marginally above 25%. However, when determining ongoing equivalence, EN16450:2017 requires that data is also considered over the preceding three-year period. Combining years and/or sites and undertaking this leads to all expanded uncertainties dropping to below 25%.

Allowing for external site-wide problems at London Teddington, the only significant loss of data during 2023 was the deletion of Manchester Piccadilly Fidas data which was found to be over-reading.

Taken together, these results support the continued use of the following instruments in the UK:

- PM₁₀ Smart Heated BAM 1020 after dividing by 1.035.
- PM_{2.5} Smart Heated BAM 1020.
- PM₁₀ Fidas 200 Method 11.
- PM_{2.5} Fidas 200 Method 11 after dividing by 1.06.

Appendix of Figures

Figure A.1: *Equivalence calculations for the PM₁₀ Smart Heated BAM1020 at London Teddington.*

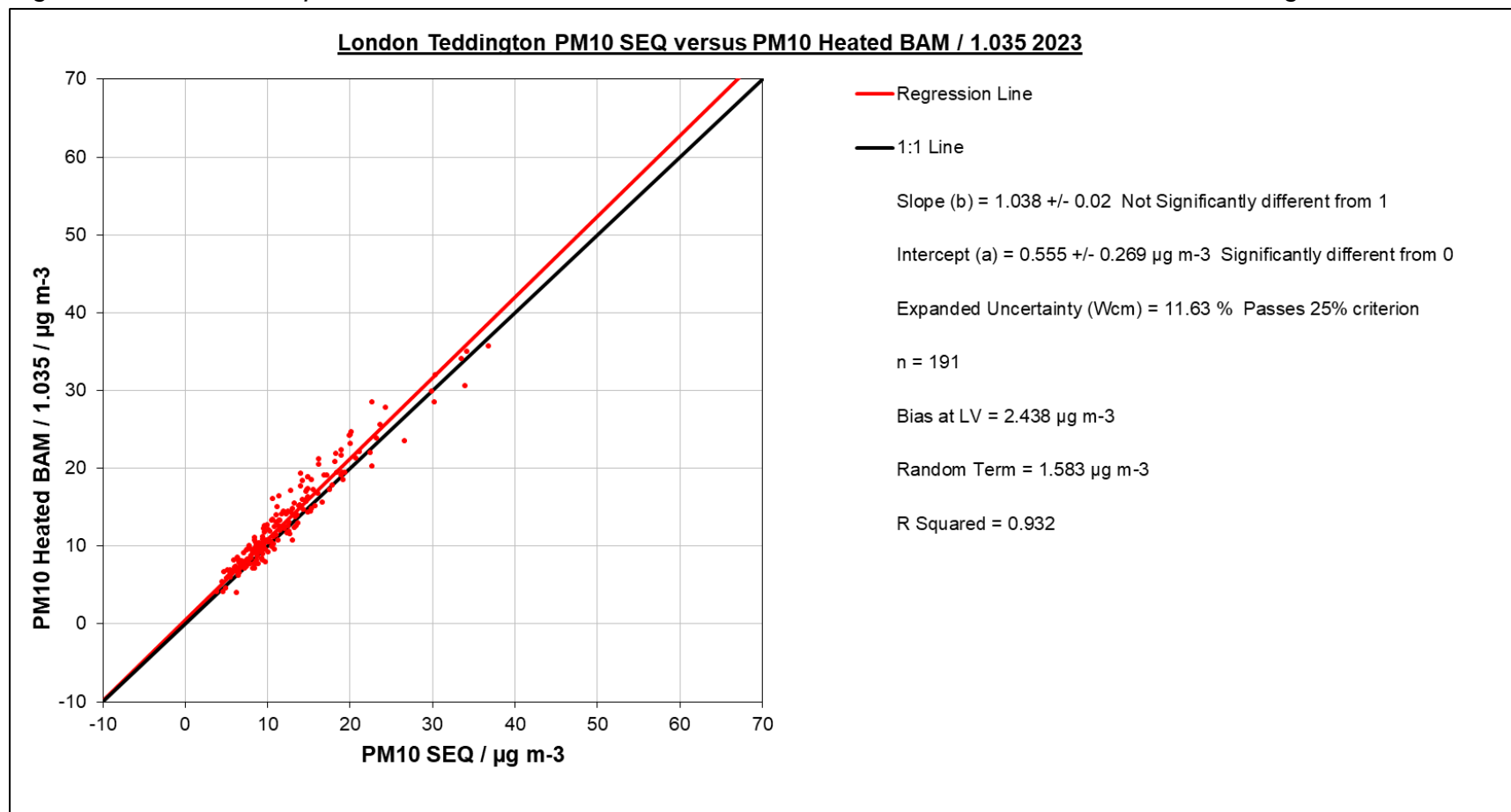


Figure A.2: Equivalence calculations for the PM₁₀ Smart Heated BAM1020 at Manchester Piccadilly.

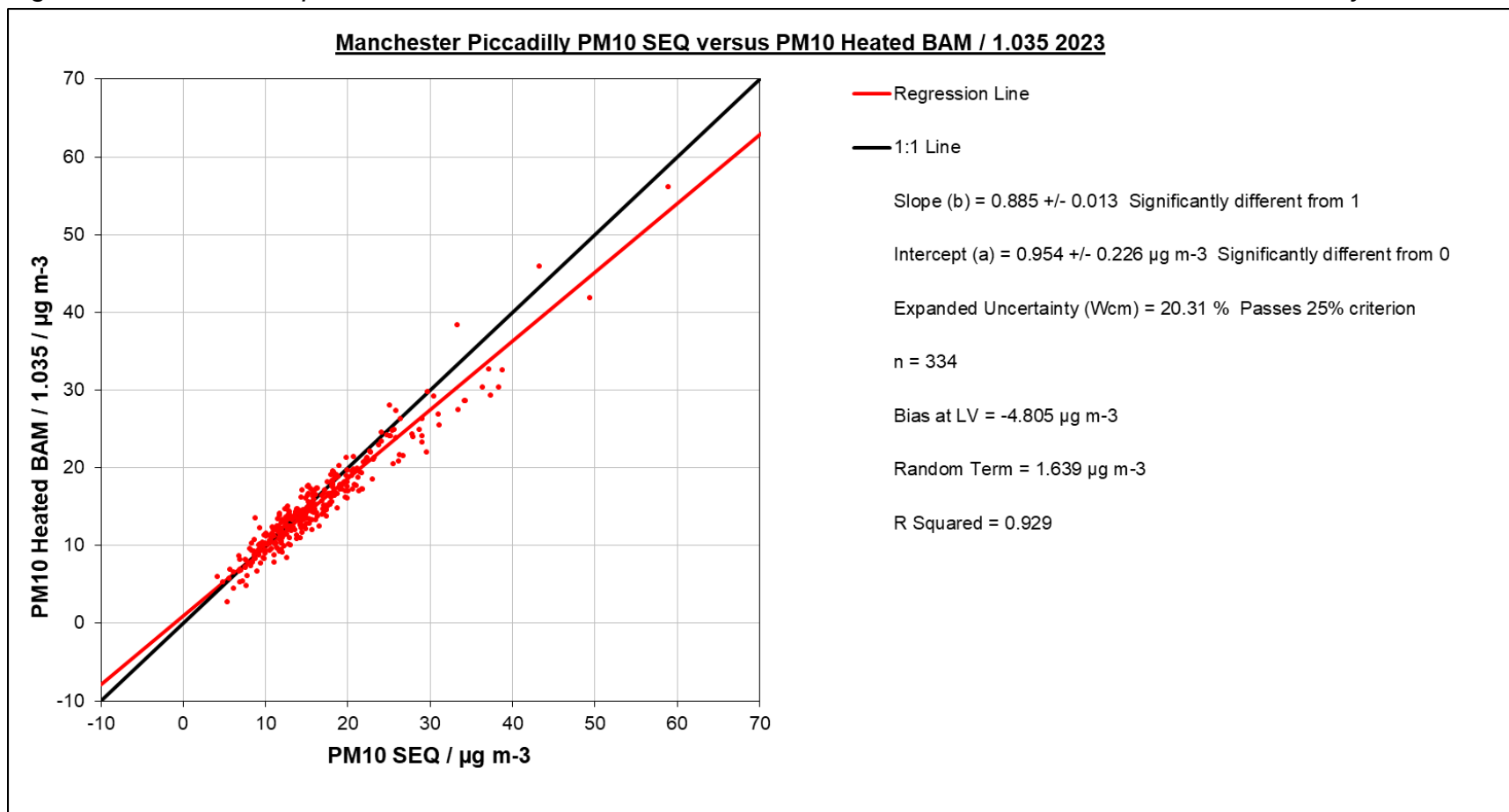


Figure A.3: Equivalence calculations for the PM₁₀ Smart Heated BAM1020 at London Marylebone Road.

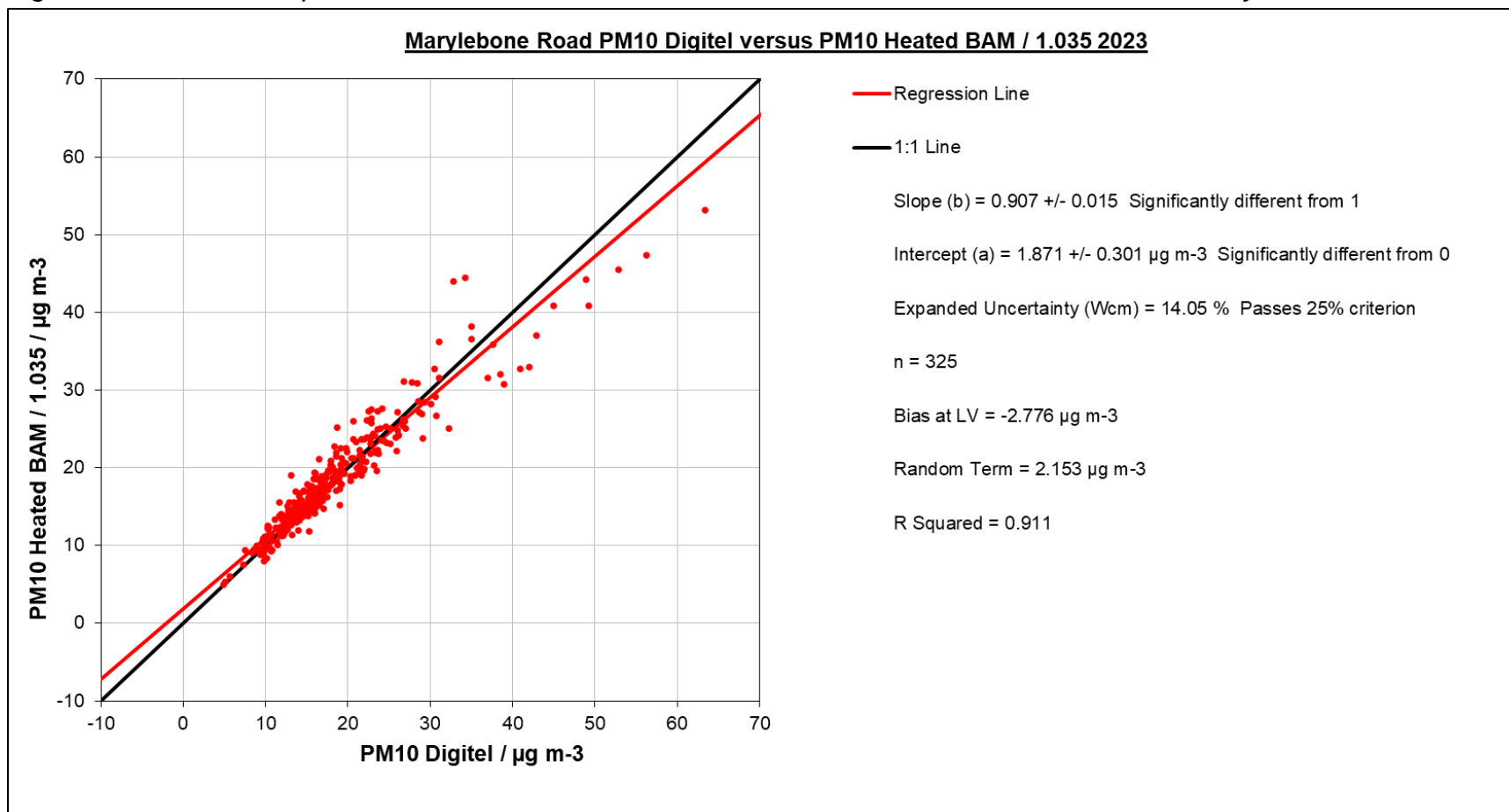


Figure A.4: Equivalence calculations for the PM_{10} Smart Heated BAM1020 at Port Talbot Margam. Note the extended axes ranges.

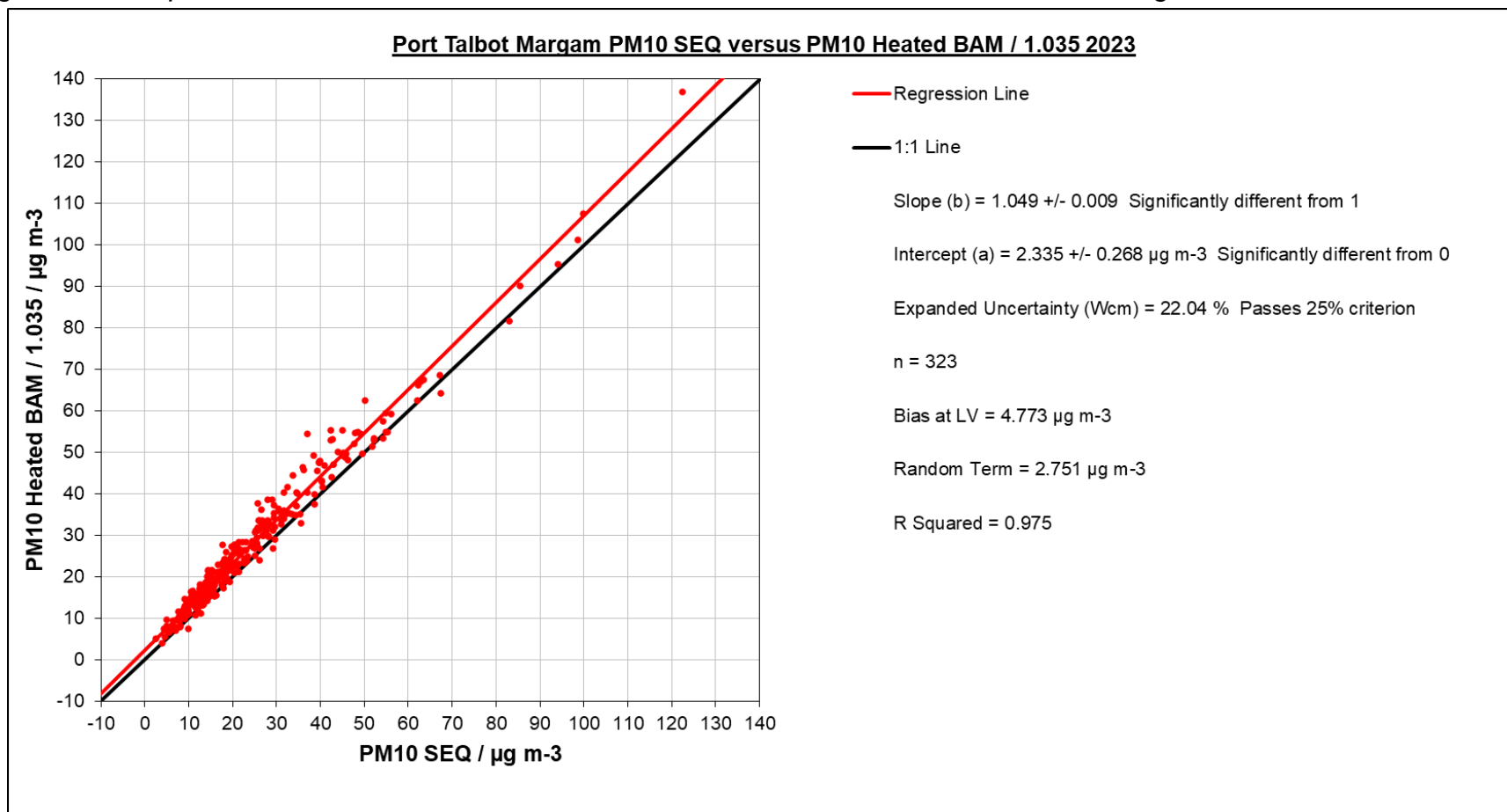


Figure A.5: *Equivalence calculations for the PM_{2.5} Smart Heated BAM1020 at London Teddington.*

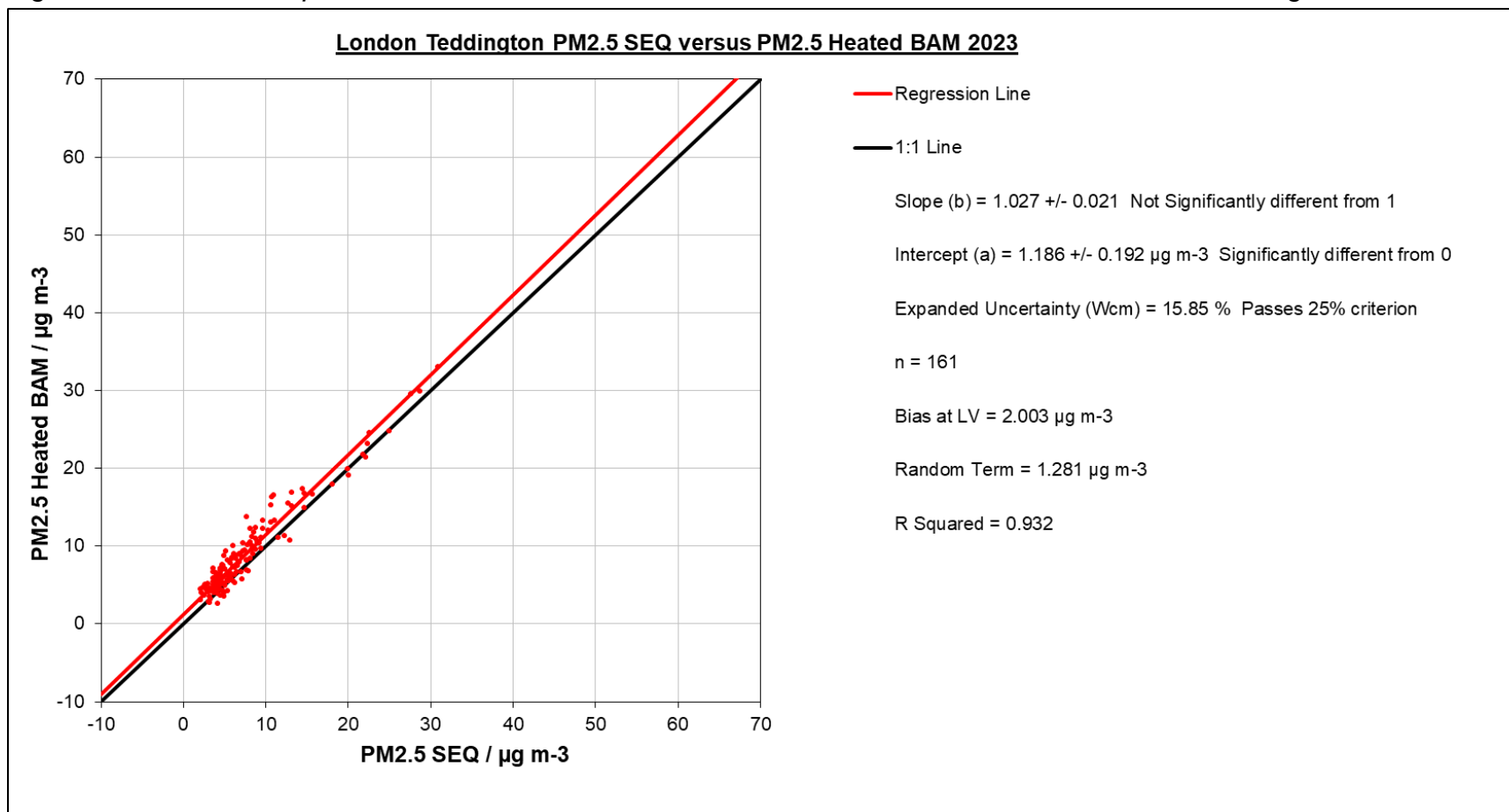


Figure A.6: *Equivalence calculations for the PM_{2.5} Smart Heated BAM1020 at Manchester Piccadilly.*

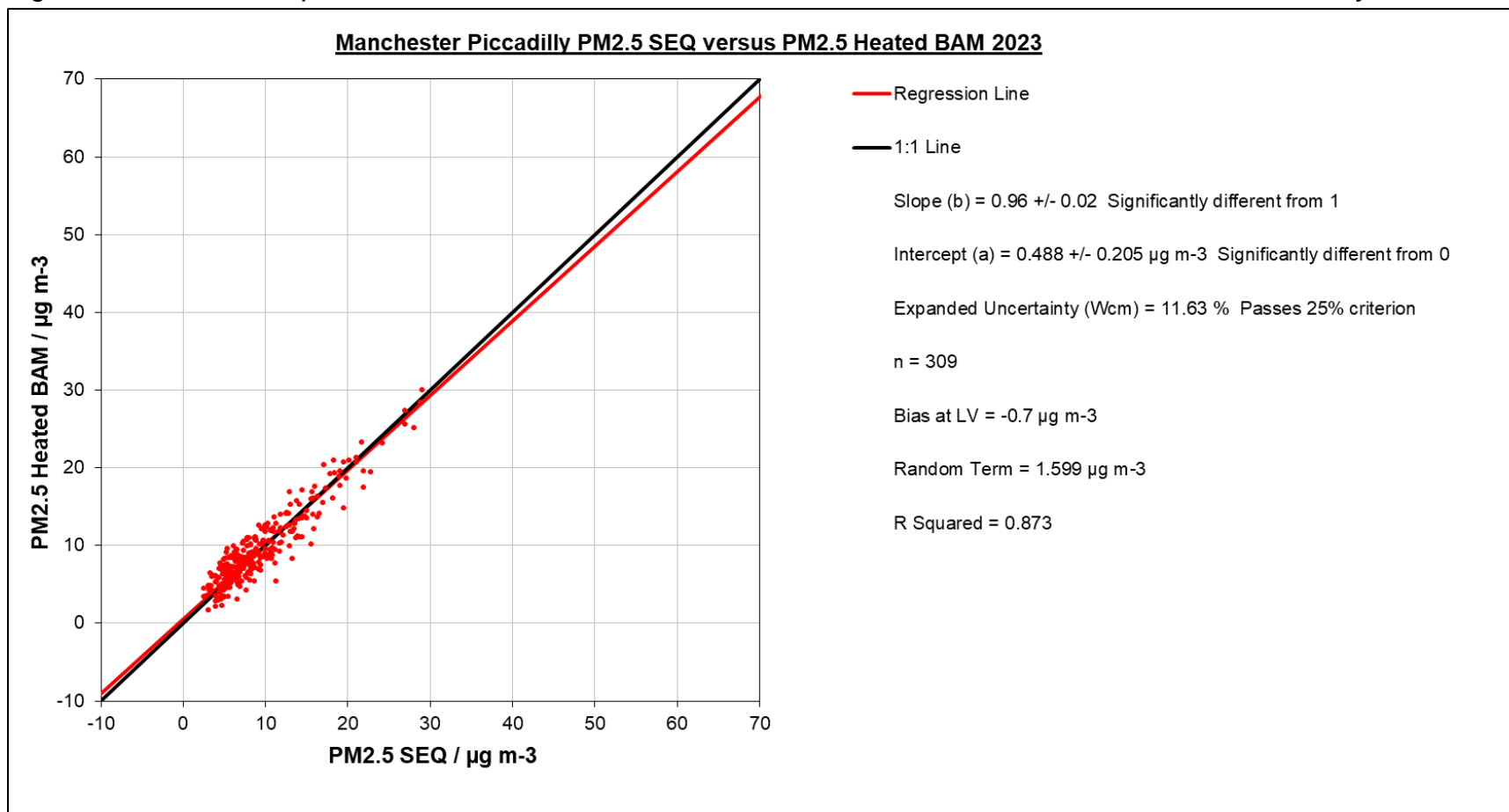


Figure A.7: Equivalence calculations for the PM_{2.5} Smart Heated BAM1020 at London Marylebone Road.

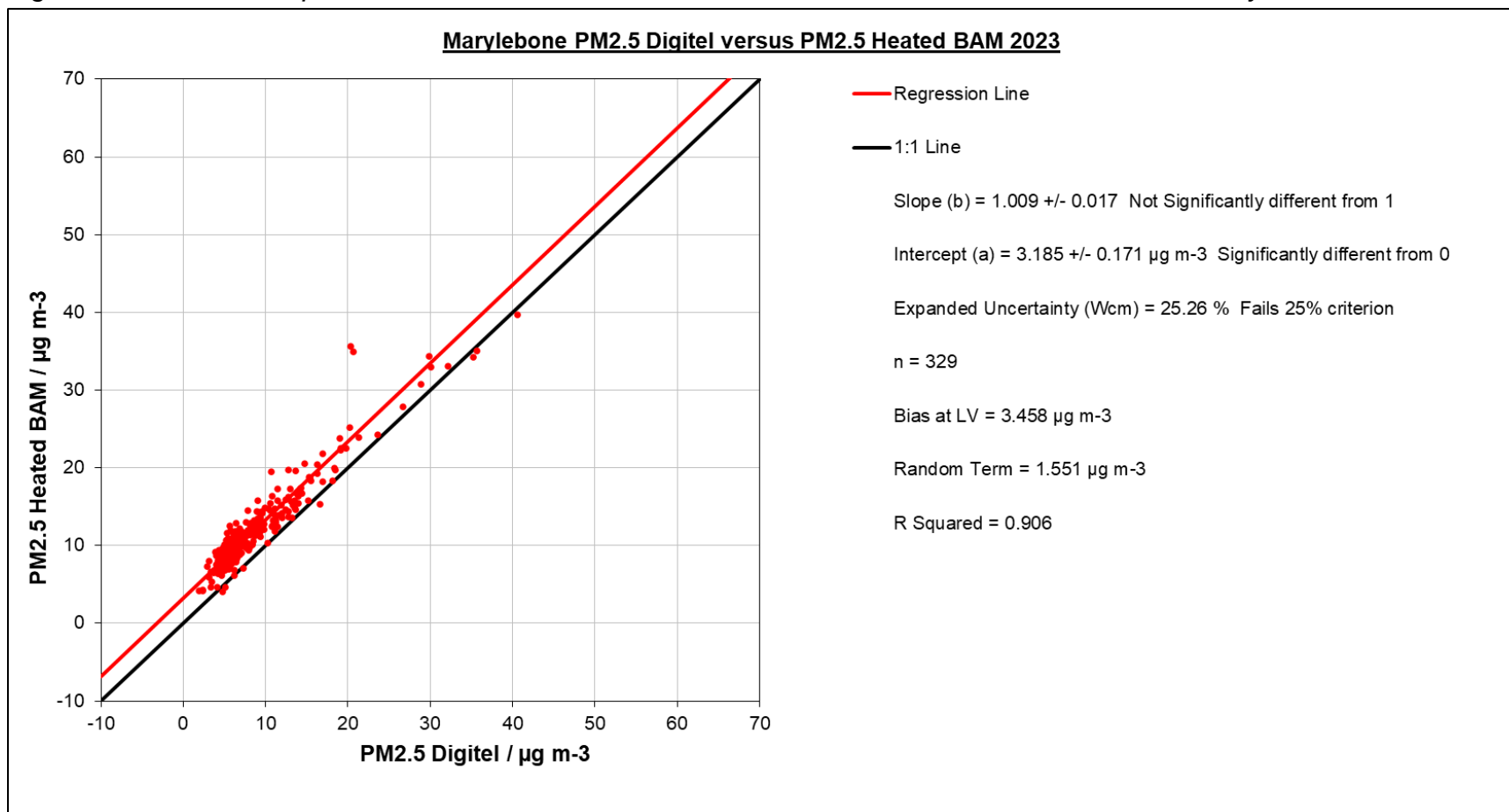


Figure A.8: Equivalence calculations for the PM₁₀ Fidas 200 Method 11 at London Teddington.

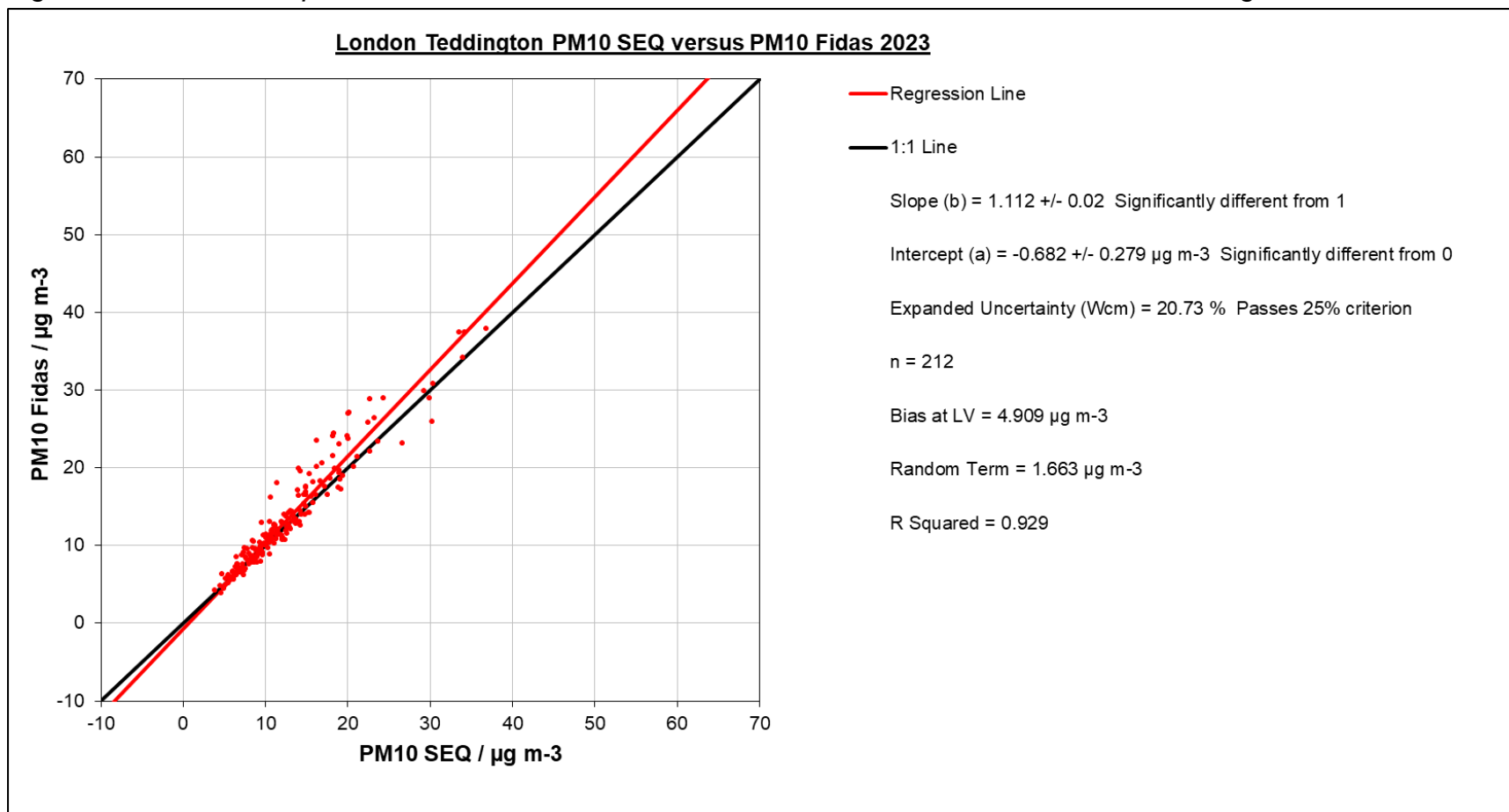


Figure A.9: Equivalence calculations for the PM₁₀ Fidas 200 Method 11 at Manchester Piccadilly.

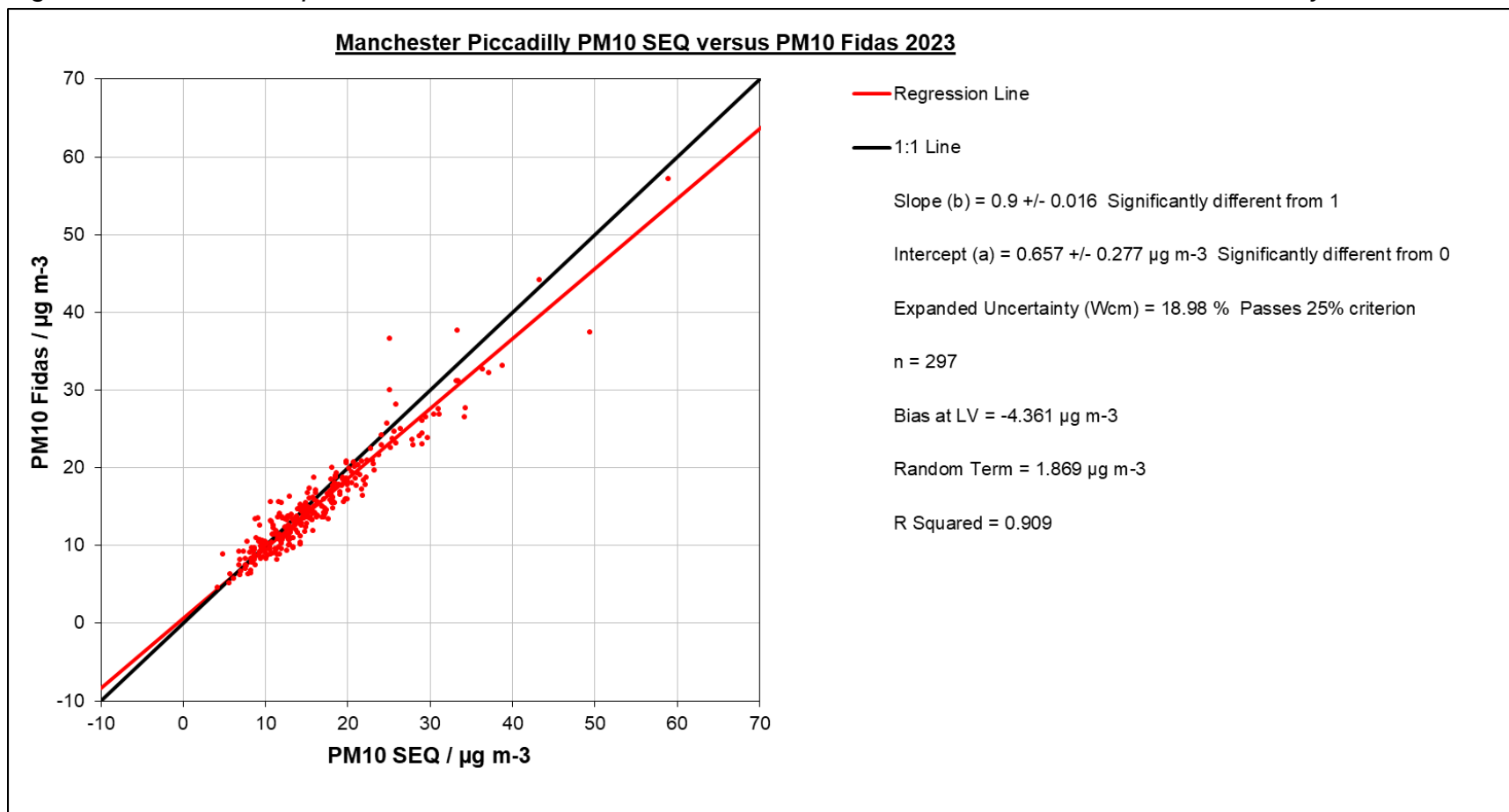


Figure A.10: Equivalence calculations for the PM_{10} Fidas 200 Method 11 at London Marylebone Road.

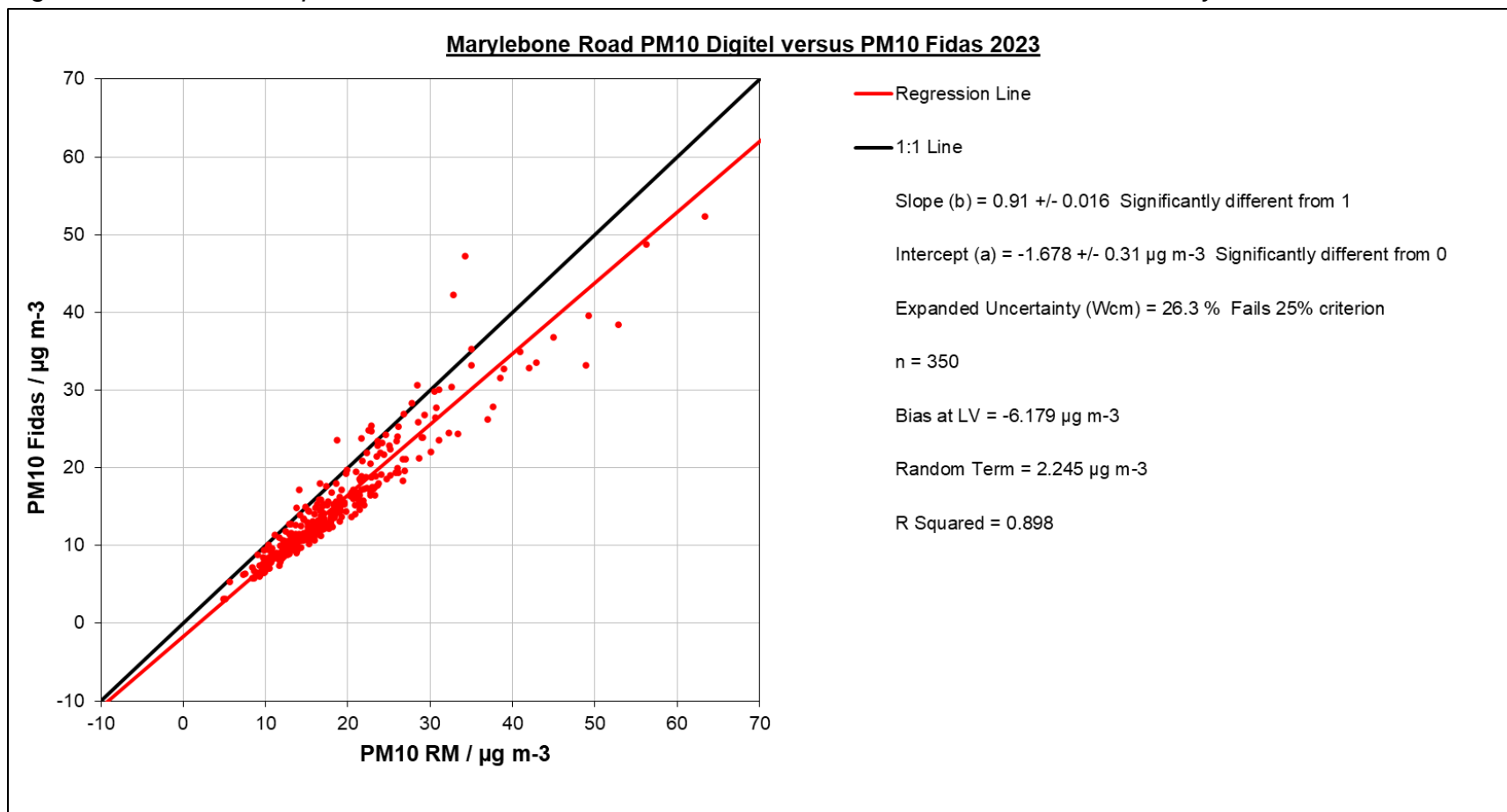


Figure A.11: Equivalence calculations for the PM_{2.5} Fidas 200 Method 11 at London Teddington.

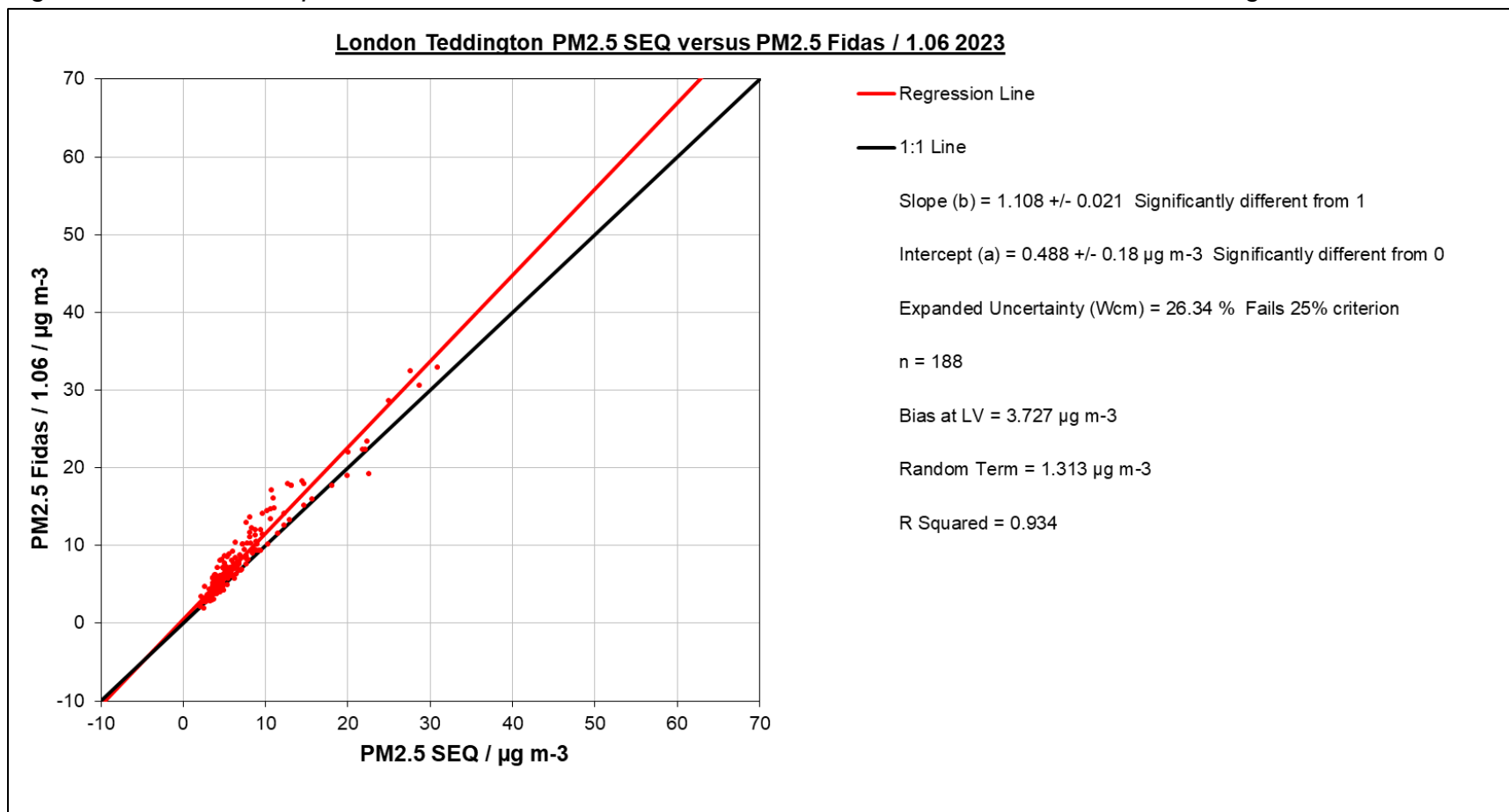


Figure A.12: Equivalence calculations for the $PM_{2.5}$ Fidas 200 Method 11 at Manchester Piccadilly.

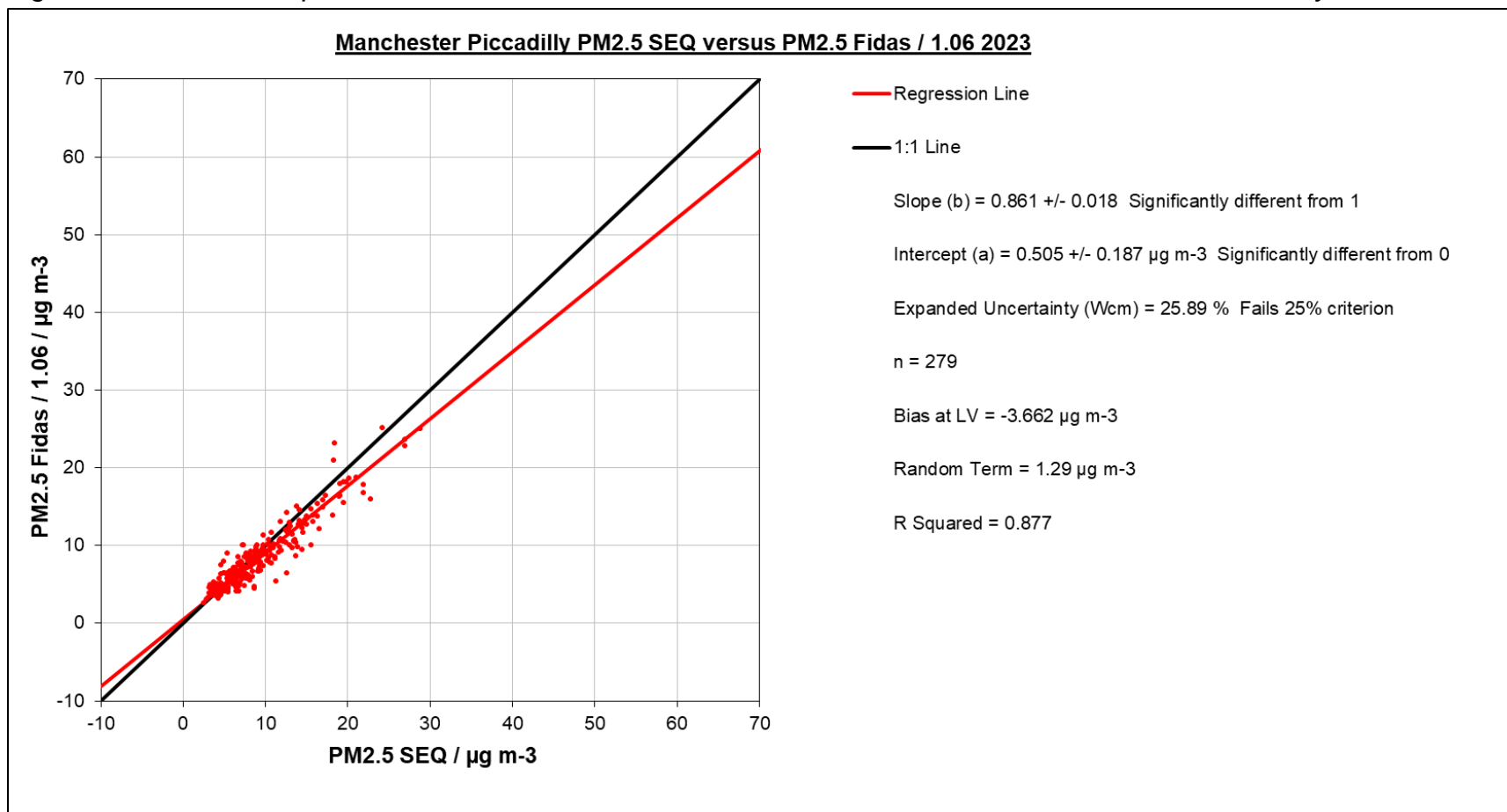


Figure A.13: Equivalence calculations for the PM_{2.5} Fidas 200 Method 11 at London Marylebone Road.

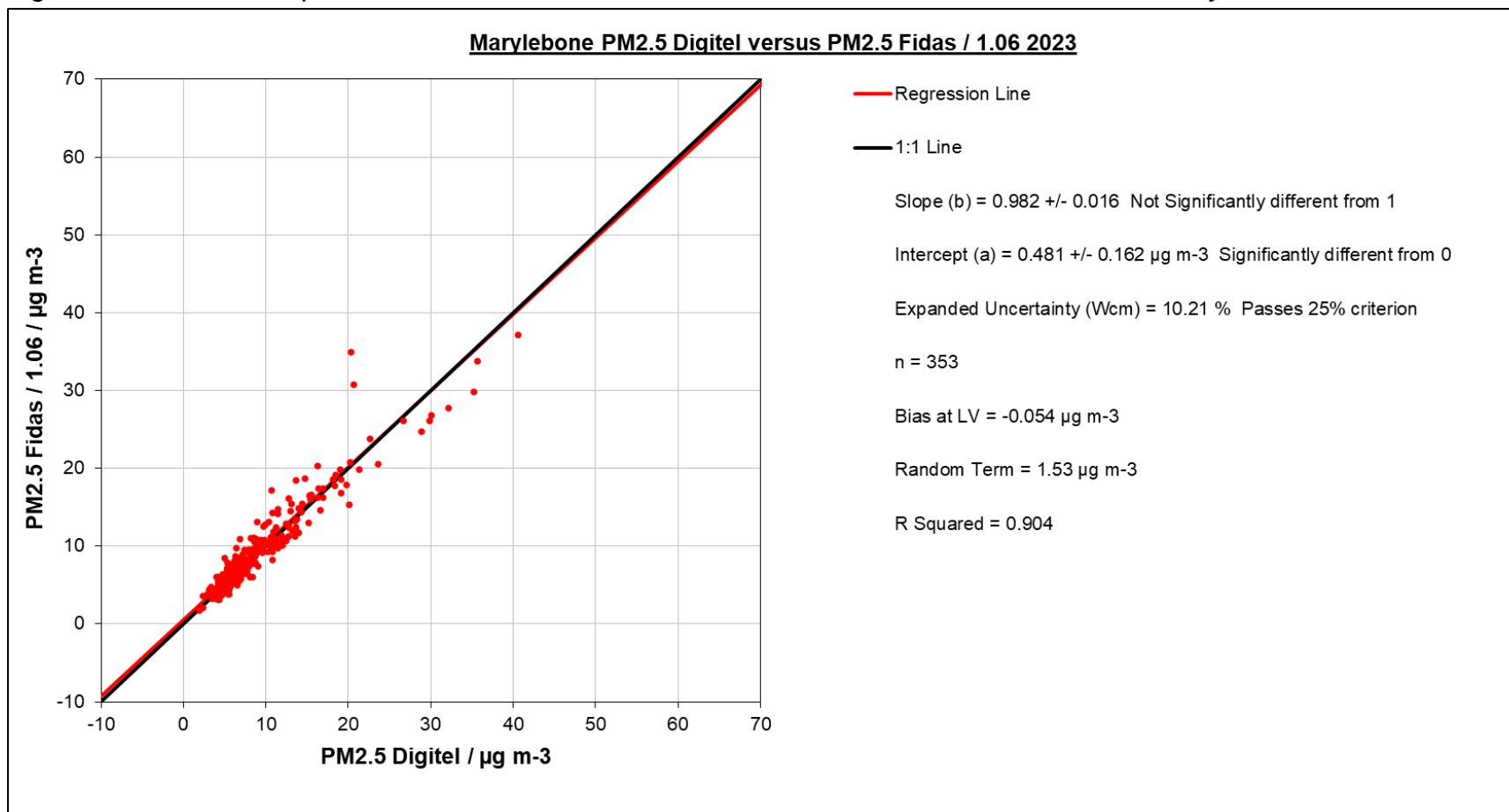


Figure A.14: Equivalence calculations for the PM₁₀ Smart Heated BAM1020 at all sites for 2023.

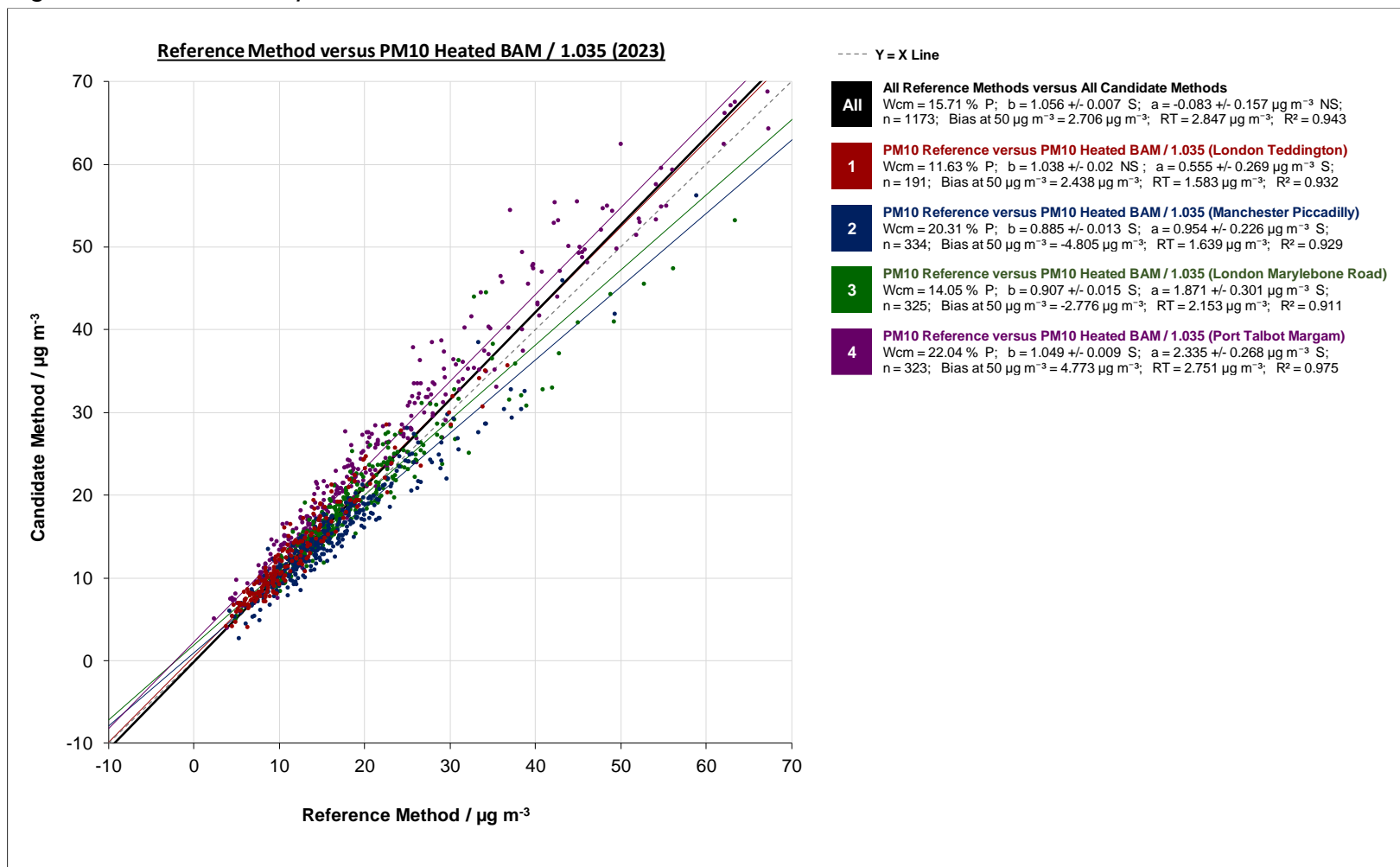


Figure A.15: Equivalence calculations for the PM₁₀ Smart Heated BAM1020 excluding Port Talbot Margam for 2023.

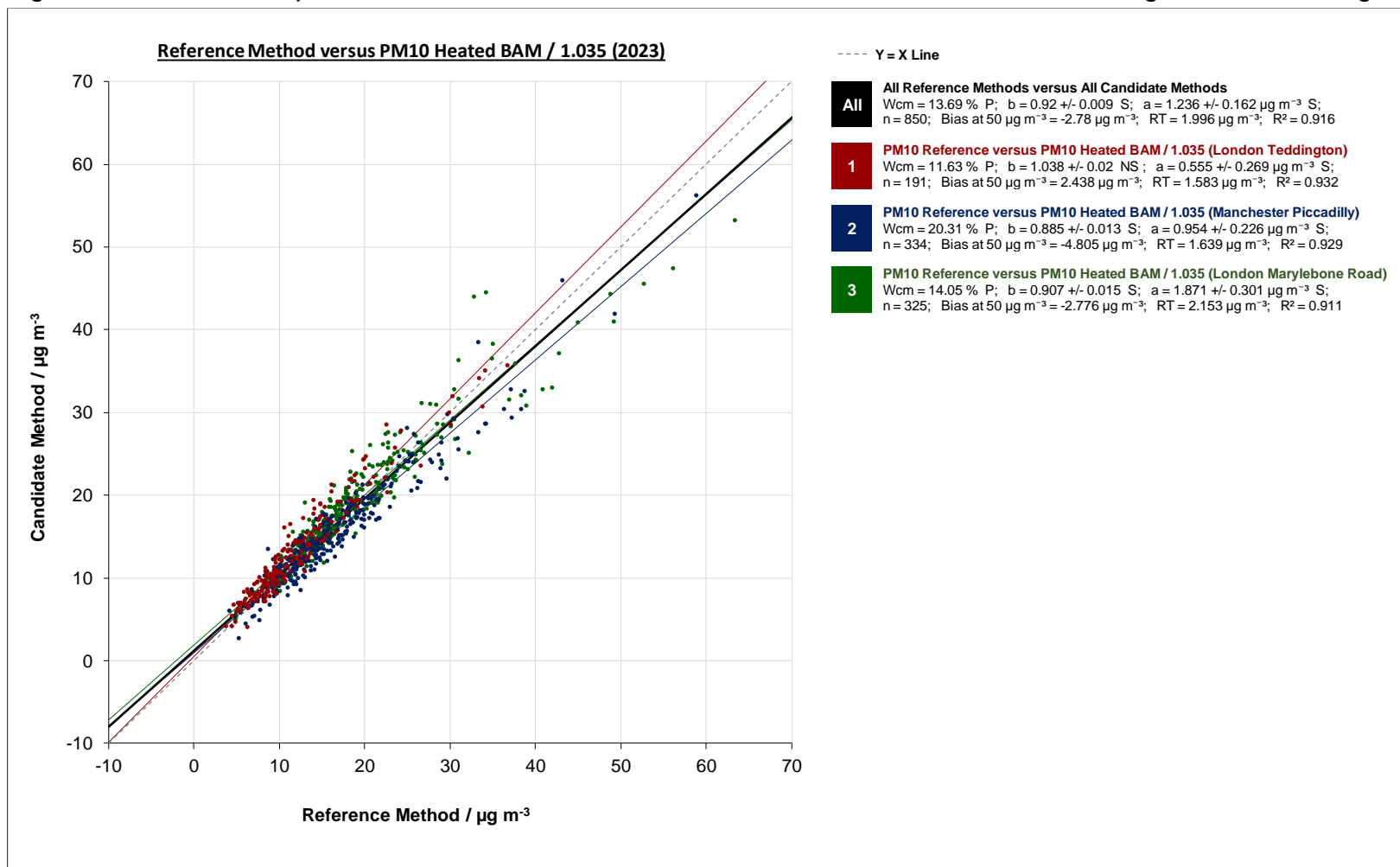


Figure A.16: Equivalence calculations for the PM_{2.5} Smart Heated BAM1020 at all sites for 2023.

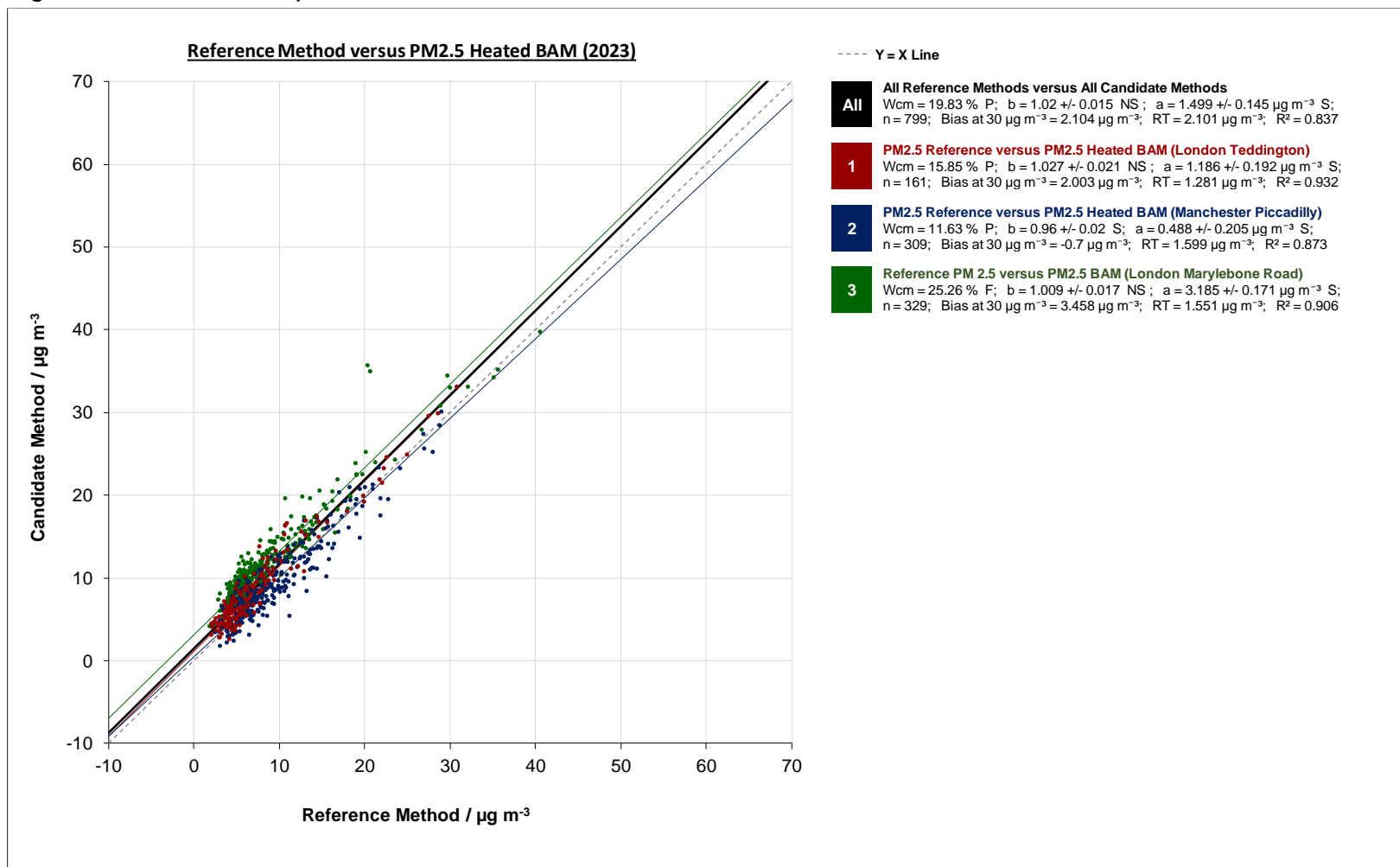


Figure A.17: Equivalence calculations for the PM₁₀ Fidas 200 Method 11 at all sites for 2023.

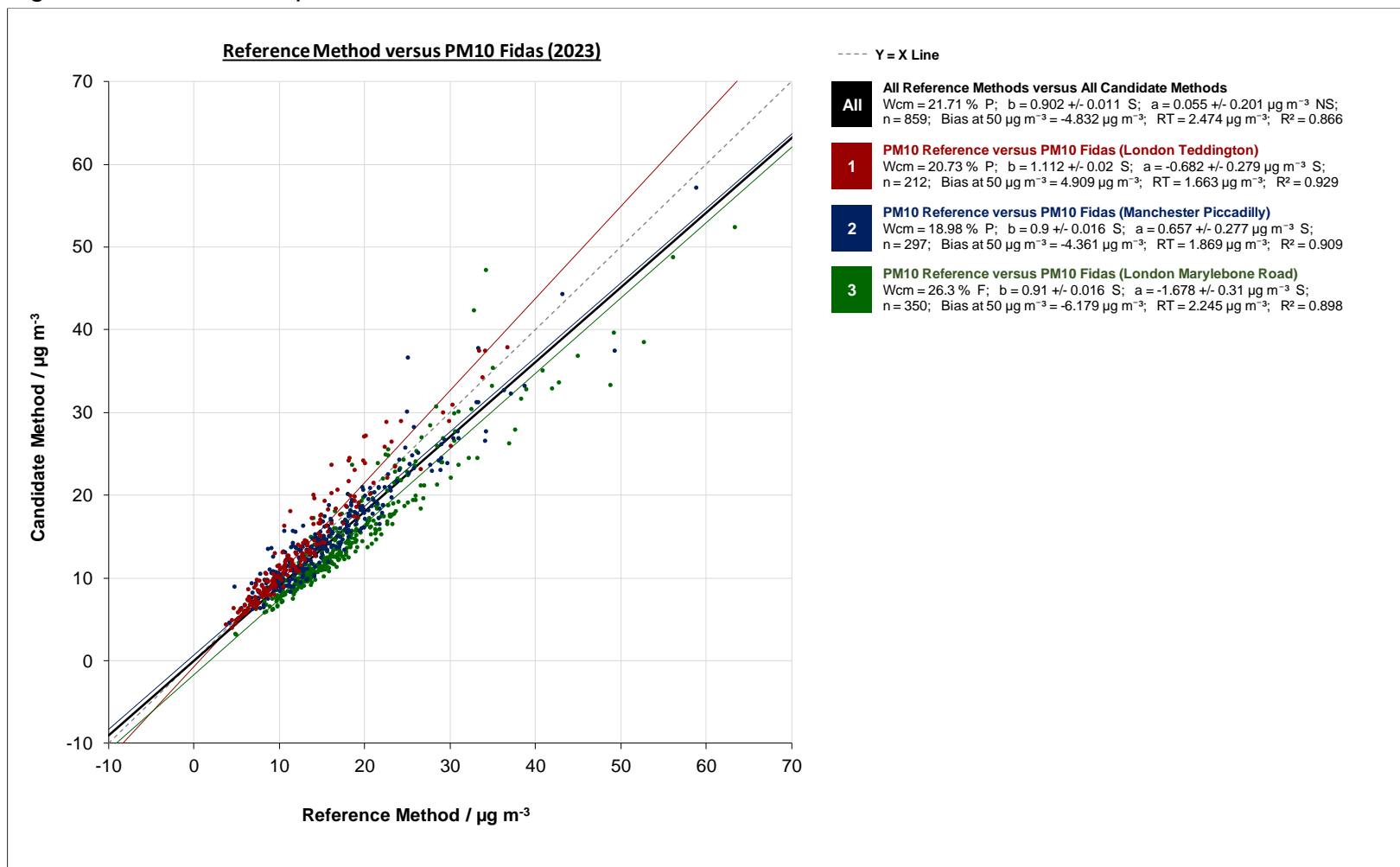


Figure A.18: Equivalence calculations for the PM_{2.5} Fidas 200 Method 11 at all sites for 2023.

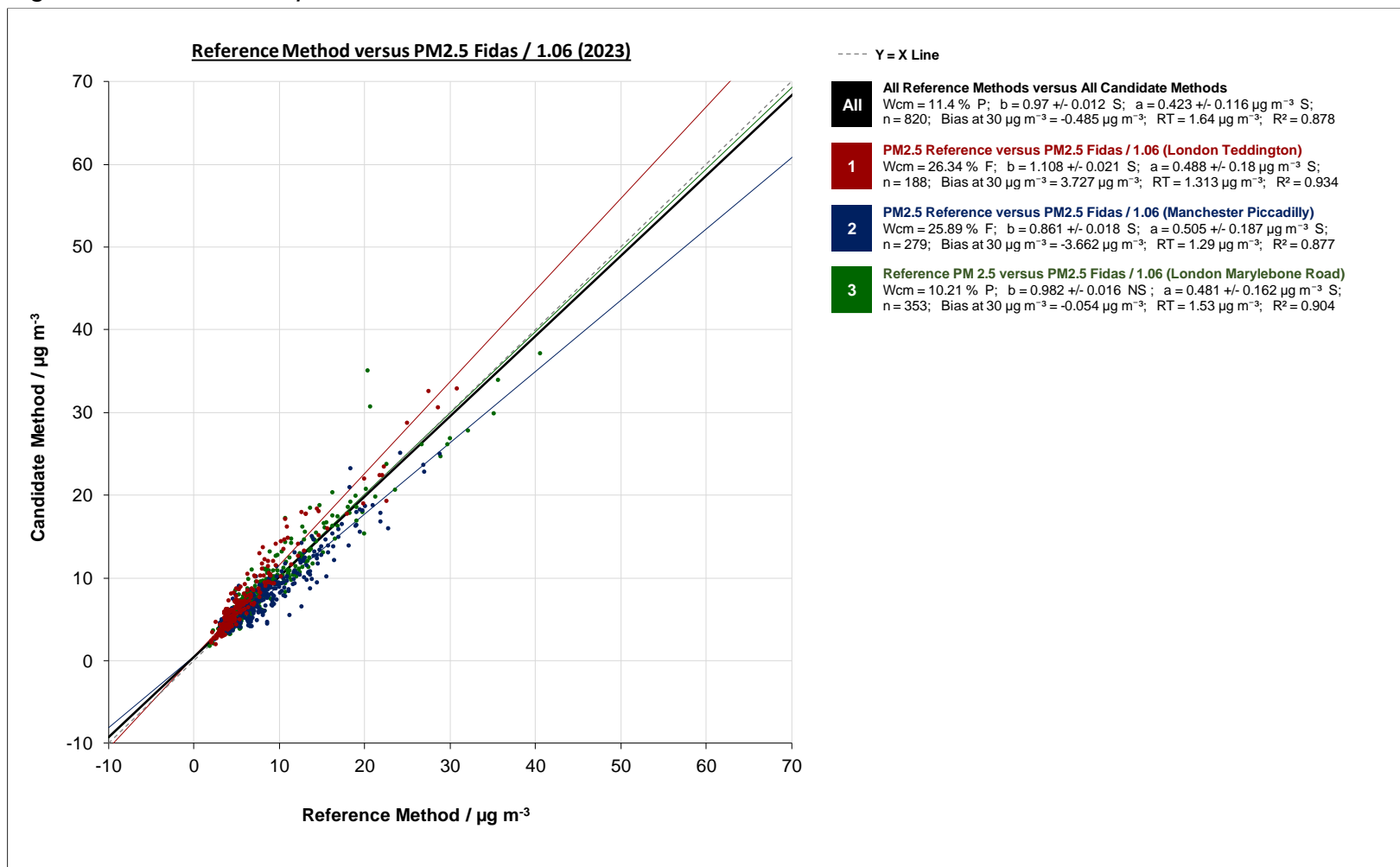


Figure A.19: Equivalence calculations for the PM₁₀ Smart Heated BAM1020 at all sites for 2021-3.

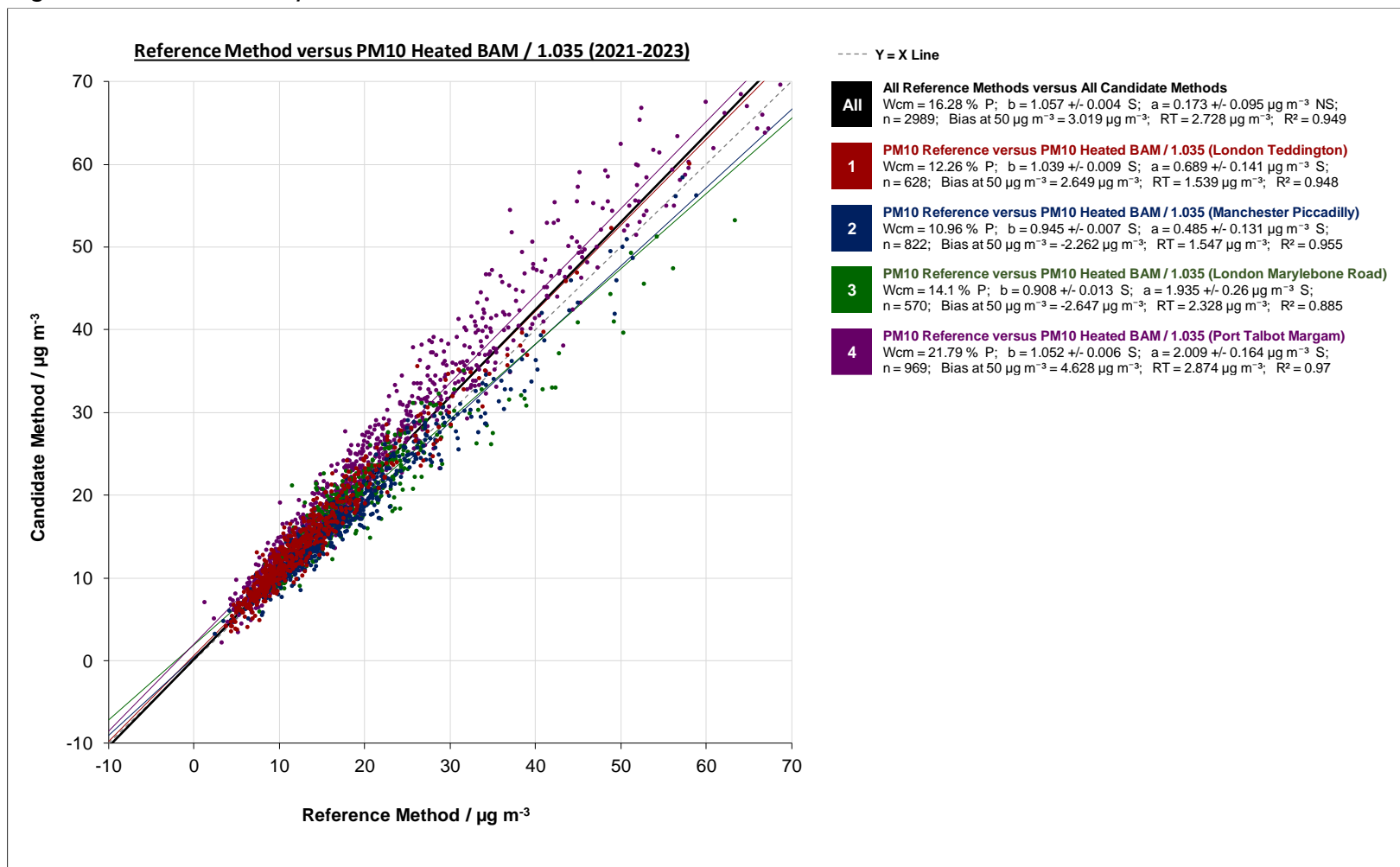


Figure A.20: Equivalence calculations for the PM₁₀ Smart Heated BAM1020 excluding Port Talbot Margam for 2021-3.

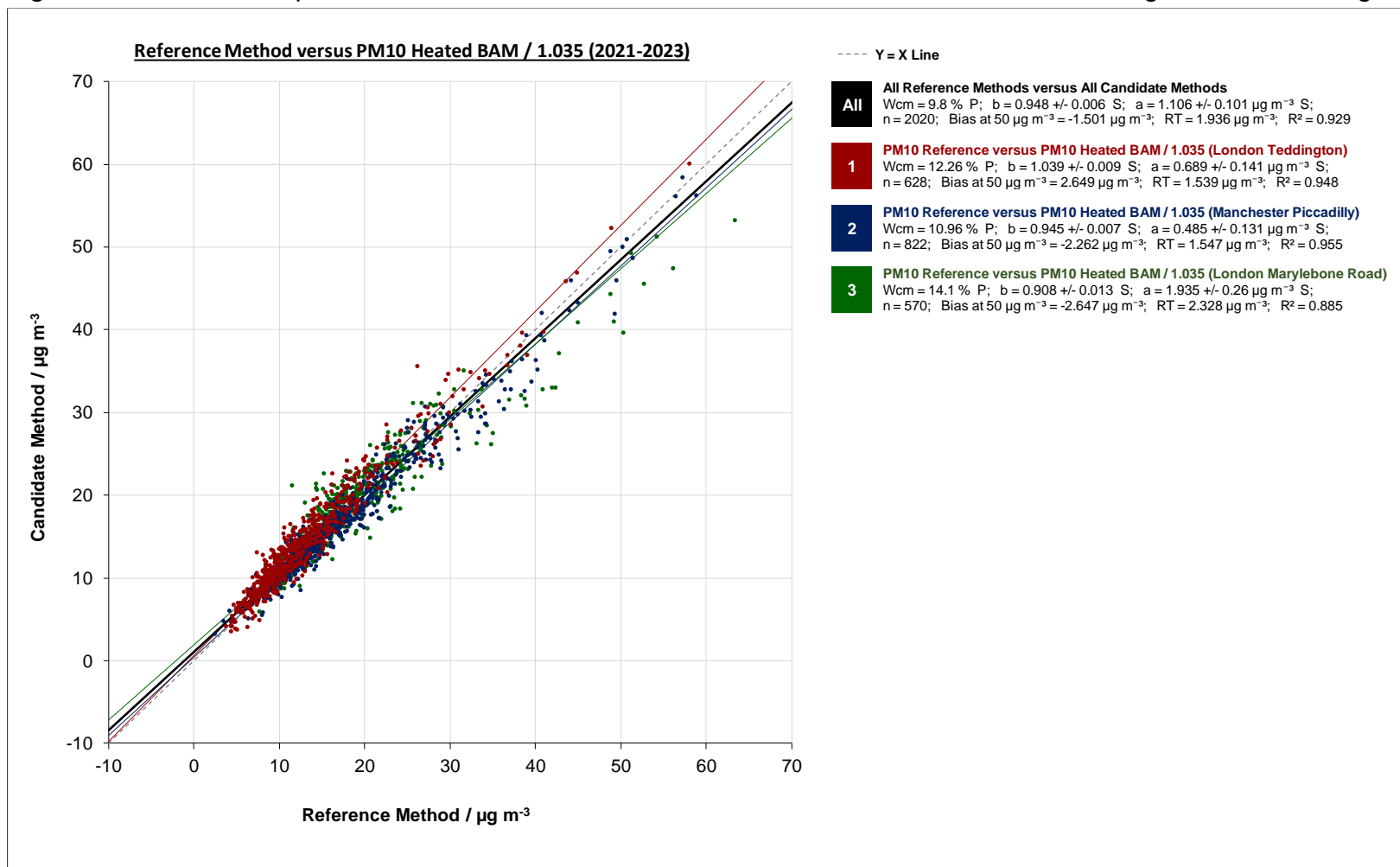


Figure A.21: Equivalence calculations for the PM_{2.5} Smart Heated BAM1020 at all sites for 2021-3.

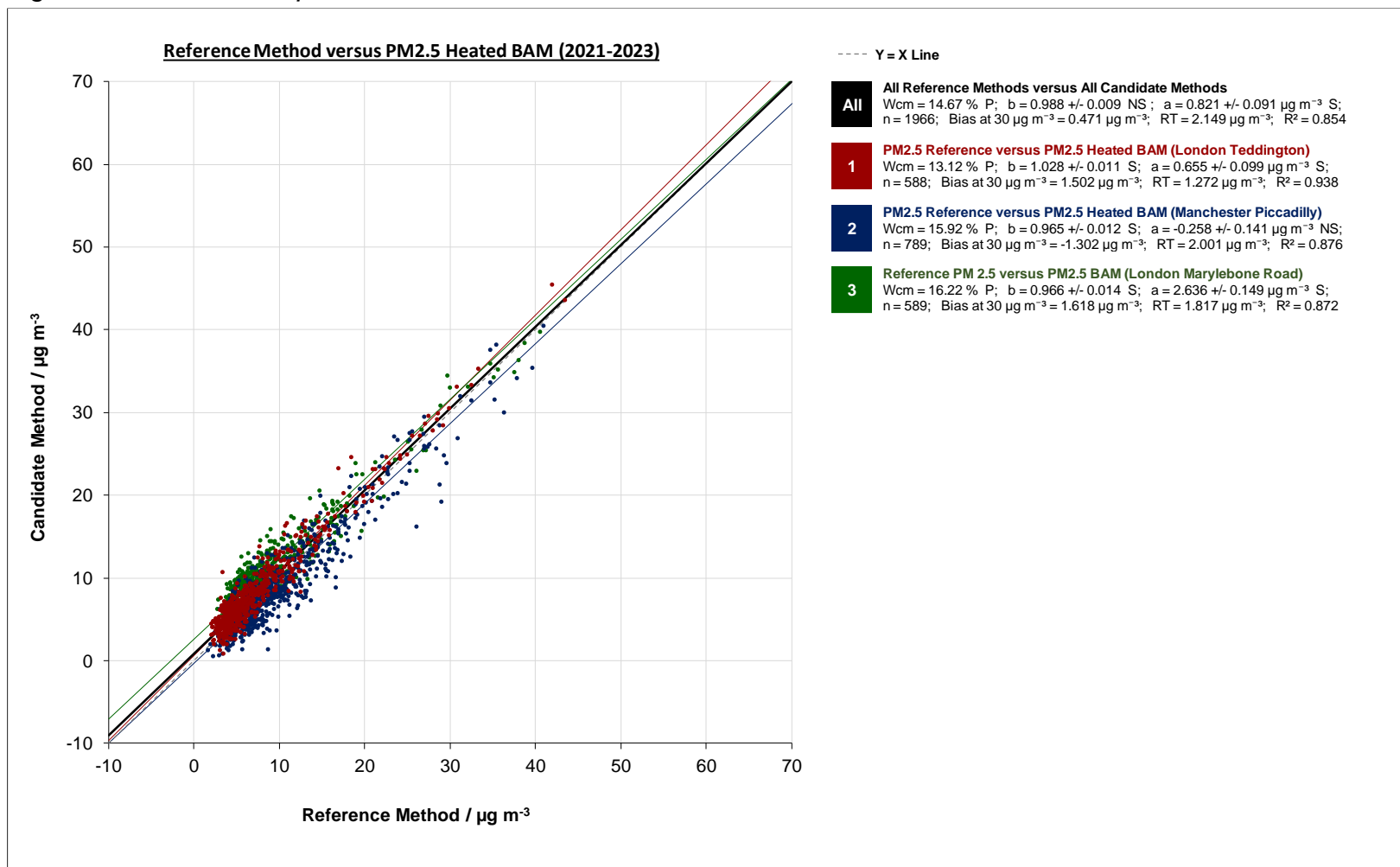


Figure A.22: Equivalence calculations for the PM₁₀ Fidas 200 Method 11 at all sites for 2021-3.

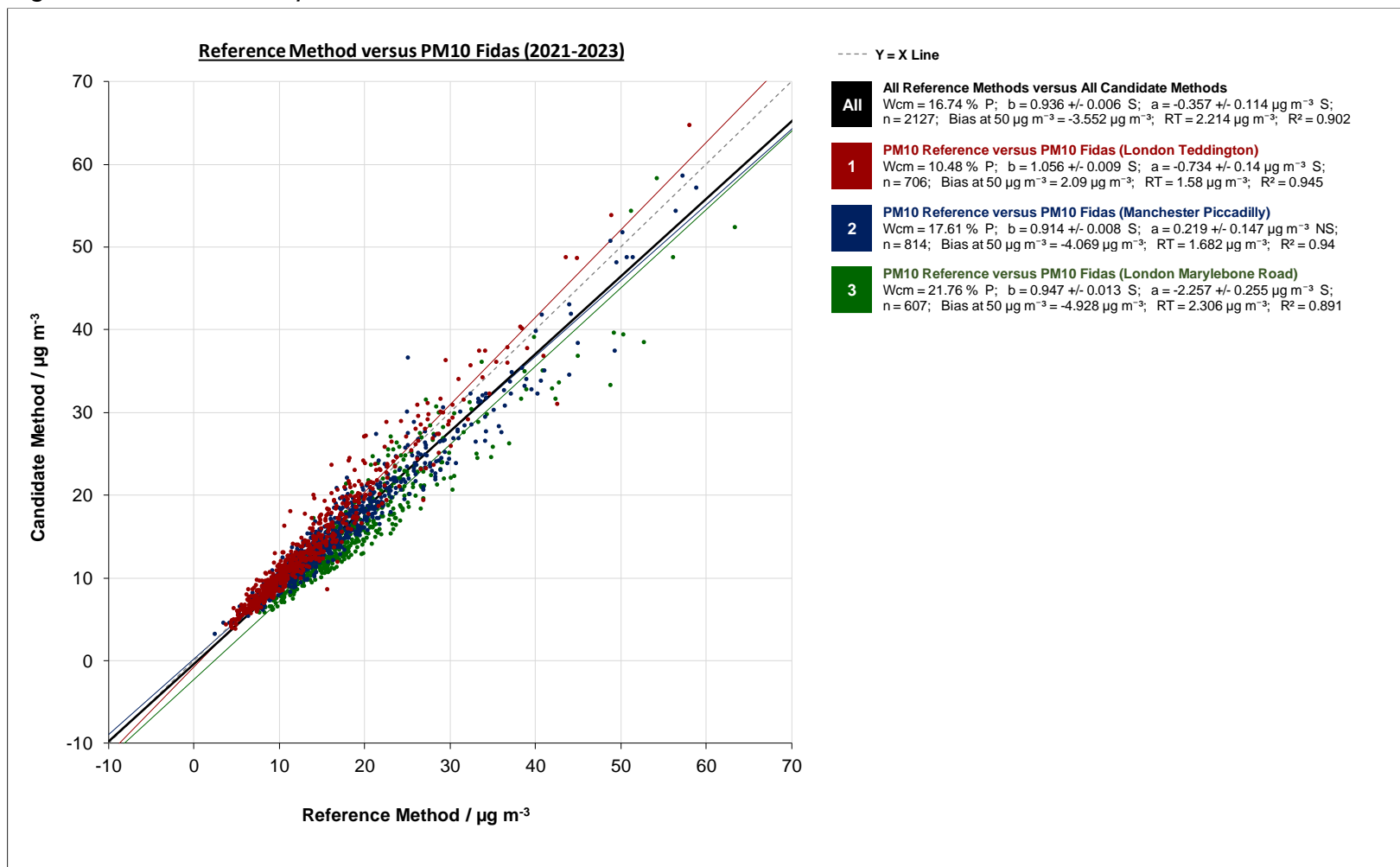


Figure A.23: Equivalence calculations for the PM_{2.5} Fidas 200 Method 11 at all sites for 2021-3.

