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New Sensing Technologies for Indoor and Outdoor Air Quality Control

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ARTIFICIAL OLFACTION SYSTEMS FOR AIR-QUALITY MONITORING APPLICATIONS

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Pure Intrawise Project

Air quality studies in London demonstrated that a large proportion of homes (18%) exceeded one or more of the WHO guideline values for carbon monoxide (Croxford et al., 2006).

- Project aims:
  - Develop an integrated decision-support framework for more sustainable management of indoor pollution associated with the provision, conservation and use of energy in buildings

Pure Intrawise Project

- Objectives:
  - Identify the main options for more sustainable provision, conservation and use of household energy
    - Energy efficiency- Sustainability trade-offs between efficiency, ventilation and pollutions.
    - Modal switching- Sustainability implications of switching from gas to electricity.
    - Micro-generation- Sustainability comparison of distributed and centralised energy provision for households.
  - Develop a decision- support framework to enable sustainability comparisons and trade-offs of different options.
  - Develop guidance on building regulations, indoor pollution control and policy for more sustainable provision and use of energy in households.

Pure Intrawise Project

- Academic collaborators
  - University of Manchester
  - London School of Health and Tropical Medicine (LSHTM)
  - University College London (UCL)
  - University of Sheffield

- Non academic partners
  - ARUP, Department for Communities and Local Government, Health Protection Agency, Environment Agency, Max Fordham, Sheffield City Council, Titon and Residential Ventilation Association, Veolia Environmental Services.

Objectives

- to measure the quality of the indoor environment associated with household gas and electric heating and cooking in urban areas;
- to record concentrations of ambient pollutants in real time over extended periods from household heating and cooking events;
- to identify similarities, differences and trends in indoor pollutants between gas and electric energy supply and combustion at the household level; and
- to identify the main impacts and issues that could arise from a change in the type of energy supplied to city residential homes i.e. electrification of heat.

Measurement of pollutants in “typical” households in the UK

Species of interest

Species	Sources	Typical indoor to outdoor ratio
Nitrogen dioxide (NO_2)	Combustion appliances	Higher
Particulate matter (PM)	Combustion appliances	Equal or Higher
Sulphur dioxide (SO_2)	Combustion appliances	Lower
Carbon dioxide (CO_2)	Exhaled breath, combustion appliances	Higher
Carbon monoxide (CO)	Combustion appliances	Equal or Higher
Volatile Organic compounds (VOCs)	Emission from building materials	Higher

Field sampling unit

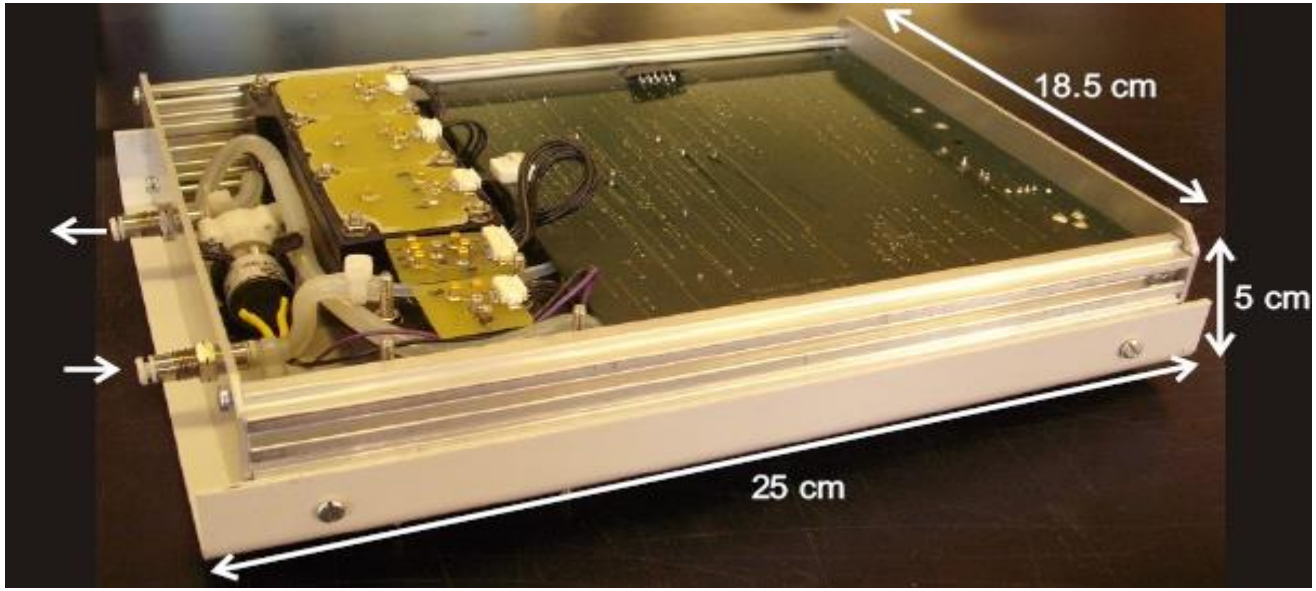
Sensor	Manufacturer	Range	Calibration gas
Carbon monoxide (CO)	Alphasense	0 to 1000 ppm	103 ppm
Carbon dioxide (CO_2)	Alphasense	0 to 5000 ppm	4976 ppm
Nitrogen dioxide (NO_2)	Alphasense	0 to 20 ppm	0.957 ppm
Sulphur dioxide (SO_2)	Alphasense	0 to 20 ppm	1.17 ppm
Volatile Organic Compounds (VOCs)	Alphasense	5 to 100 ppm	isobutylene permeation tube 6.30 ppm at 100 sccm
Relative Humidity	Sensirion	0 to 100% RH	
Temperature	Sensirion	-40 to 125 °C	

Sensors

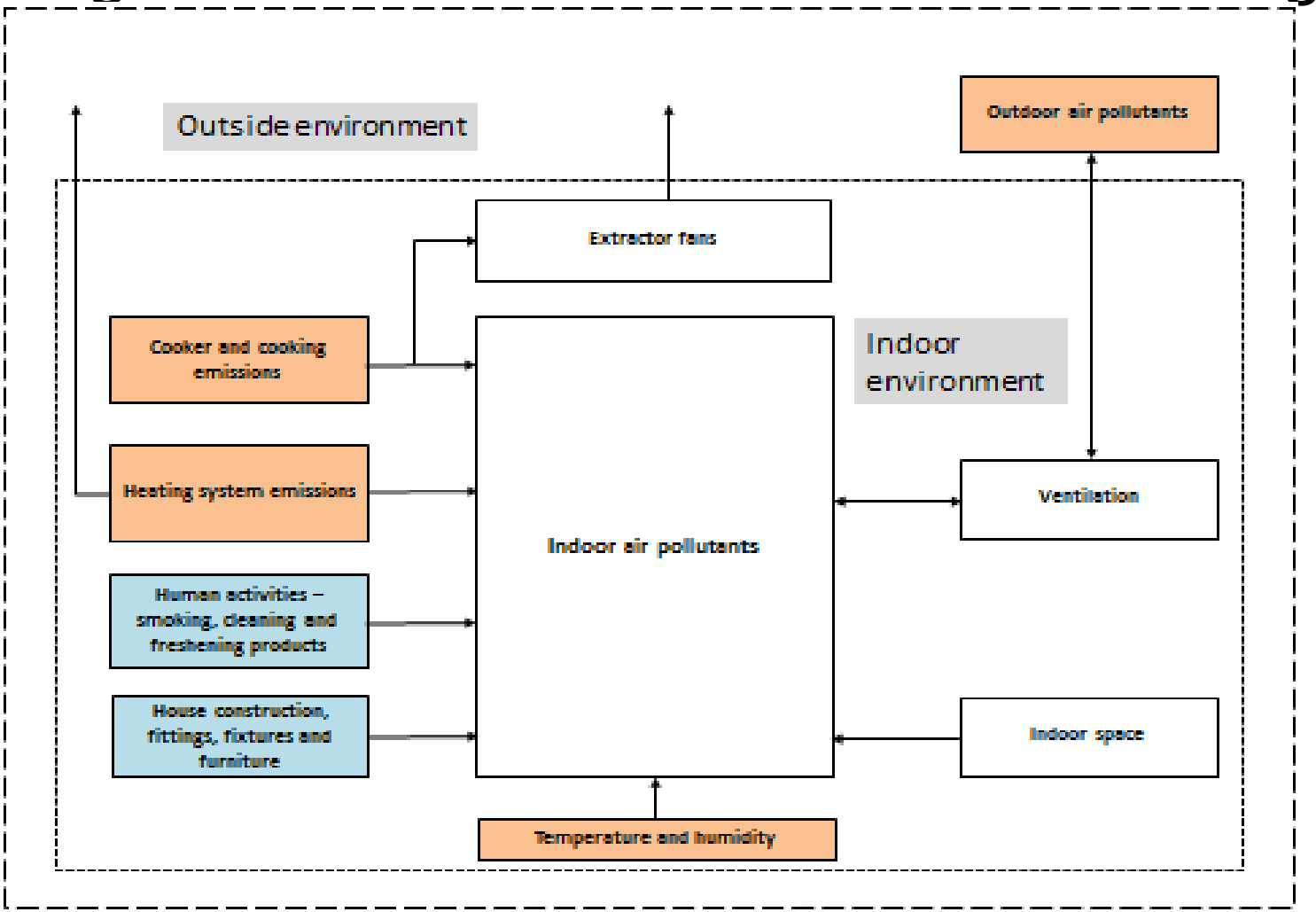
- NO_2, SO_2, CO: Electrochemical sensors
  - Generate a current that is linearly proportional to the fractional volume of sample gas.
- $CO_{2:}$ Non-Dispersive Infra-Red sensor
  - Gas concentration is measured optically by absorption of a specific wavelength in the infrared (IR)
- VOCs: Photo Ionisation Detector
  - Consists of a UV lamp and an ionisation chamber. The UV lamp emits high energy photons which ionises the VOC.
  - An electric field generated between the cathode and anode attracts the ions.
  - The resulting current is proportional to the concentration of the VOC

Field sampling unit

- Sampling unit:
  - Battery operated- 2 week sampling duration
  - Memory card on-board to allow collection of data over long periods of time: USB interface to PC
  - 8 channels (7 sensors and 1 real time clock) per sampling unit



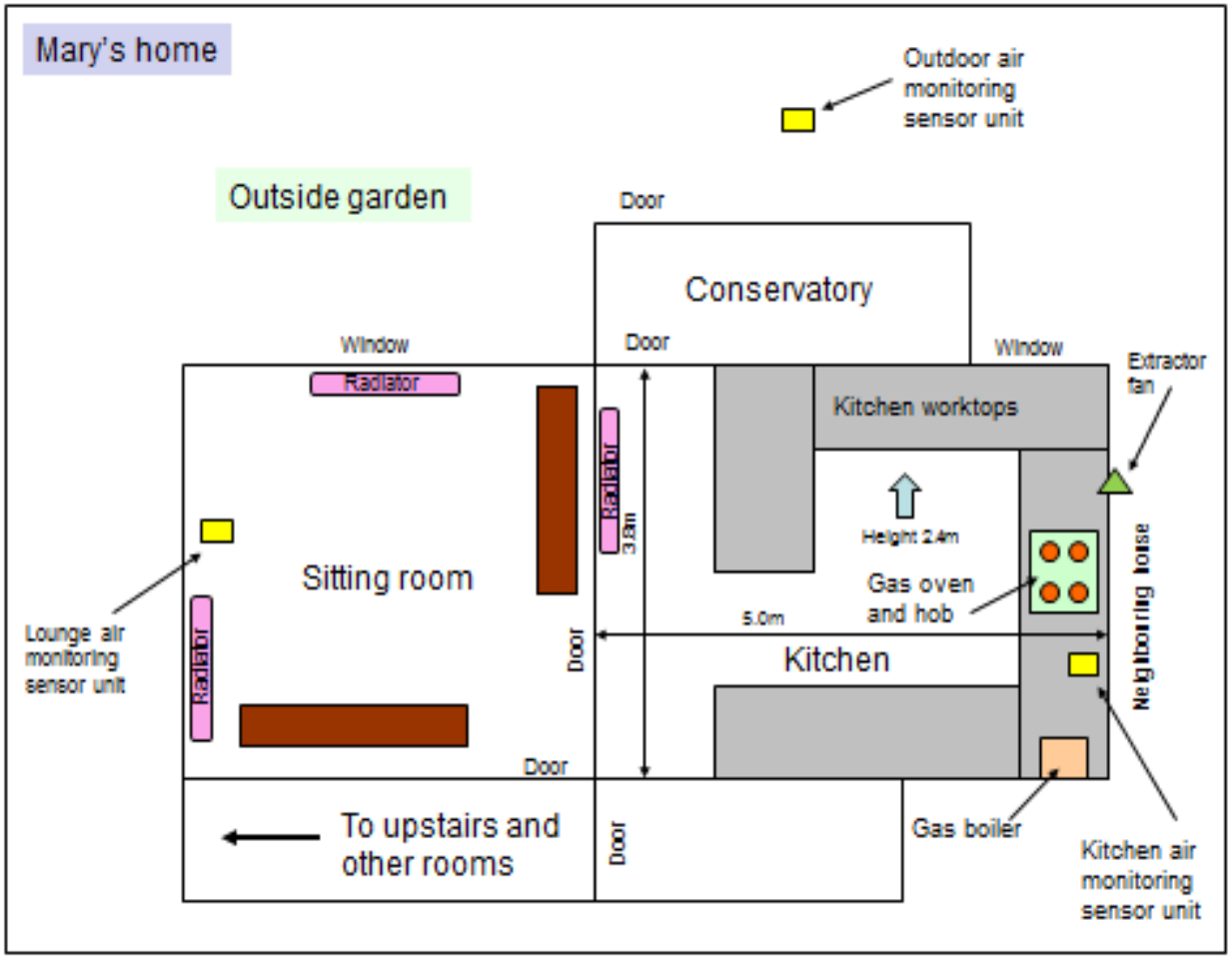
Air quality monitoring system boundaries and stages considered for domestic dwelling



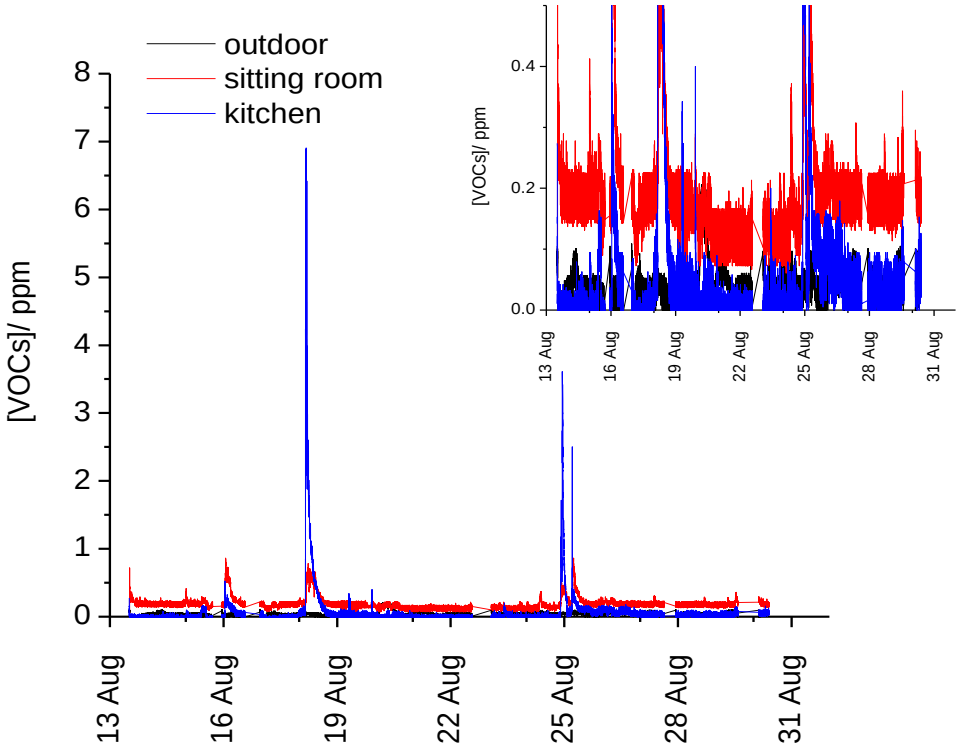
Homes studied

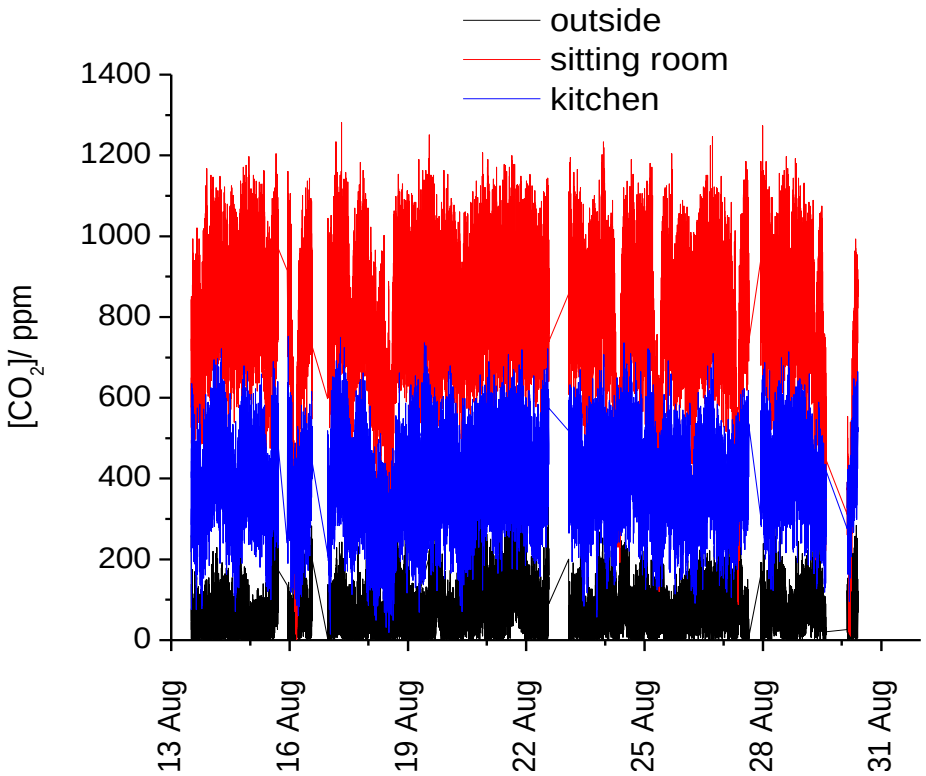
Studied home	Cooking combination	Space and water heating	Home construction details	Home insulation standard
Mary 'all gas' home	Gas oven and gas hob	Wall mounted older style non-condensing gas boiler, radiators and hot water storage cylinder	1980's brick built tiled former local authority end of terrace house	Cavity wall and loft insulation UPVC double glazing Conservatory reducing door ventilation or leakage
Madelief 'all electric' home	Electric oven and electric hob	Electric storage heaters and immersion heaters in water storage cylinder	2000's brick built apartment – 1st floor level	Cavity wall and loft insulation UPVC double glazing
Margaret 'all electric' home	Electric oven and gas hob	Wall mounted modern condensing gas boiler, radiators and hot water storage cylinder	1930's brick built and tiled semi-detached house	Loft insulation – kitchen extended and cavity wall insulated UPVC double glazing Conservatory reducing door ventilation or leakage
Desmond 'all electric' home	Electric oven and electric hob	Wall mounted older style non-condensing gas boiler, radiators and hot water storage cylinder	1970's brick built former mid terraced house	Loft insulation fitted but not cavity wall UPVC double glazing Conservatory reducing door ventilation or leakage

Sensor Placement

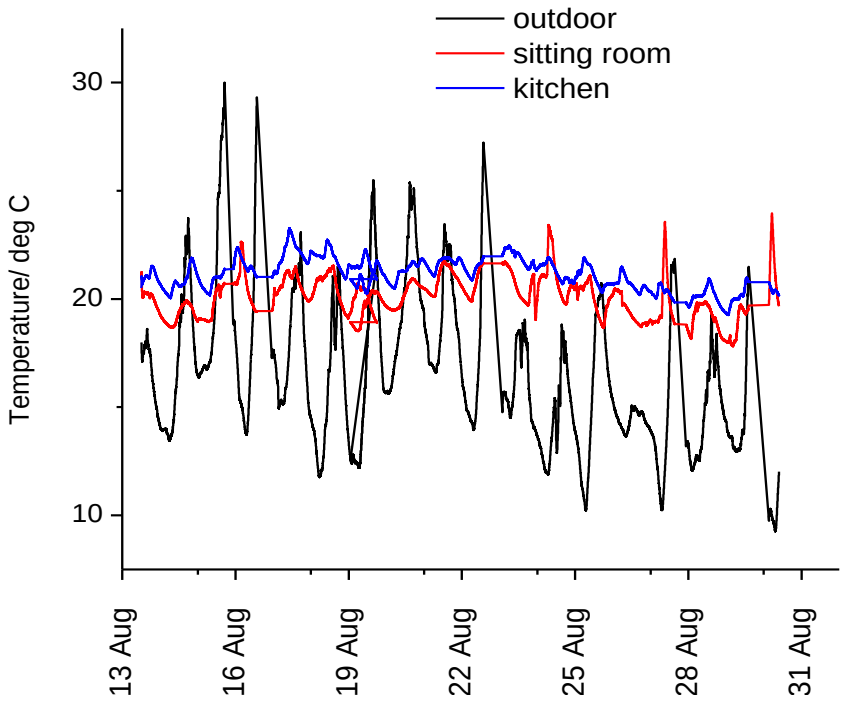


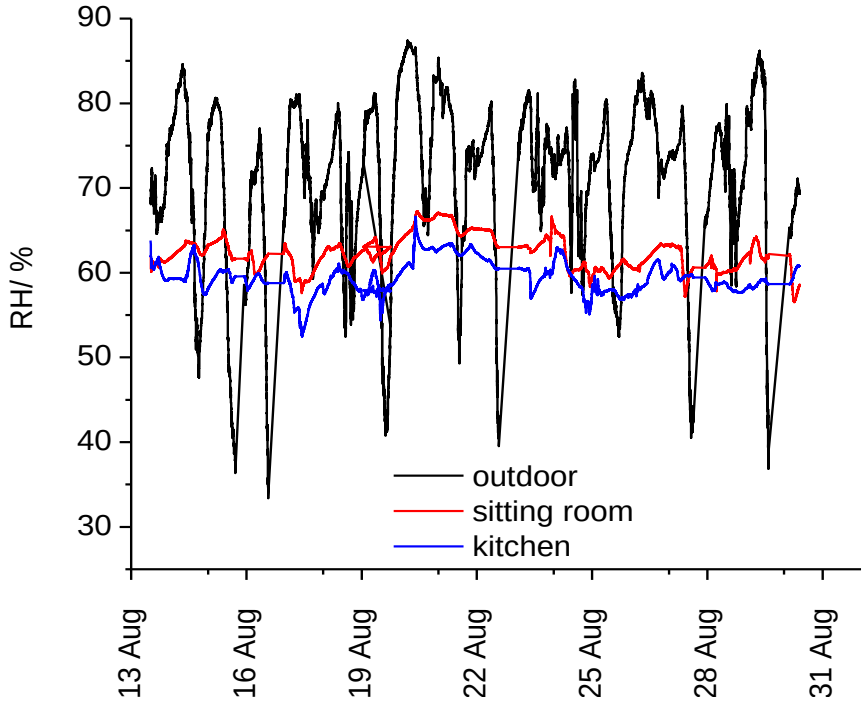
Preliminary measurement campaign- summer 2010: Hathersage



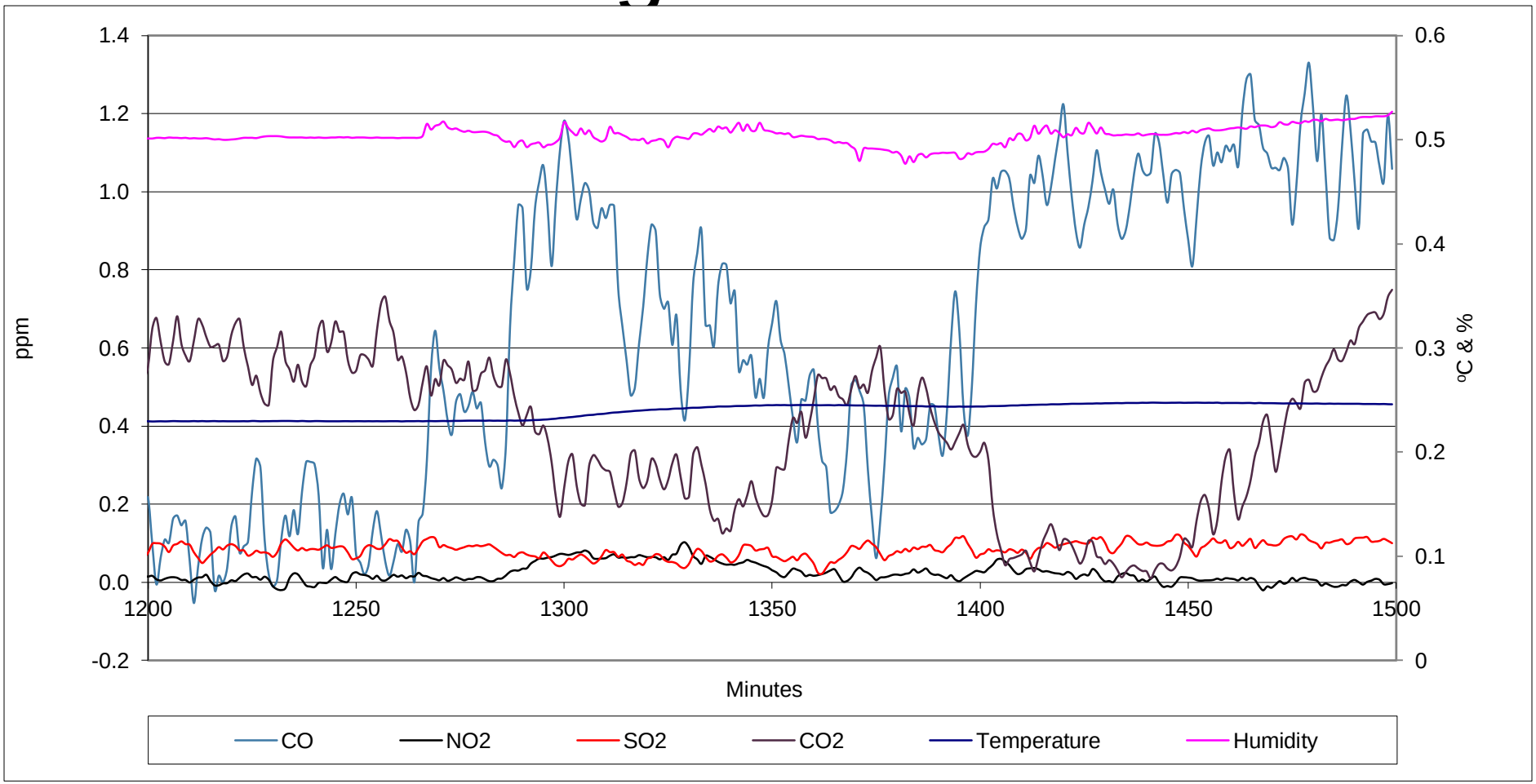


Preliminary measurement campaign- summer 2010

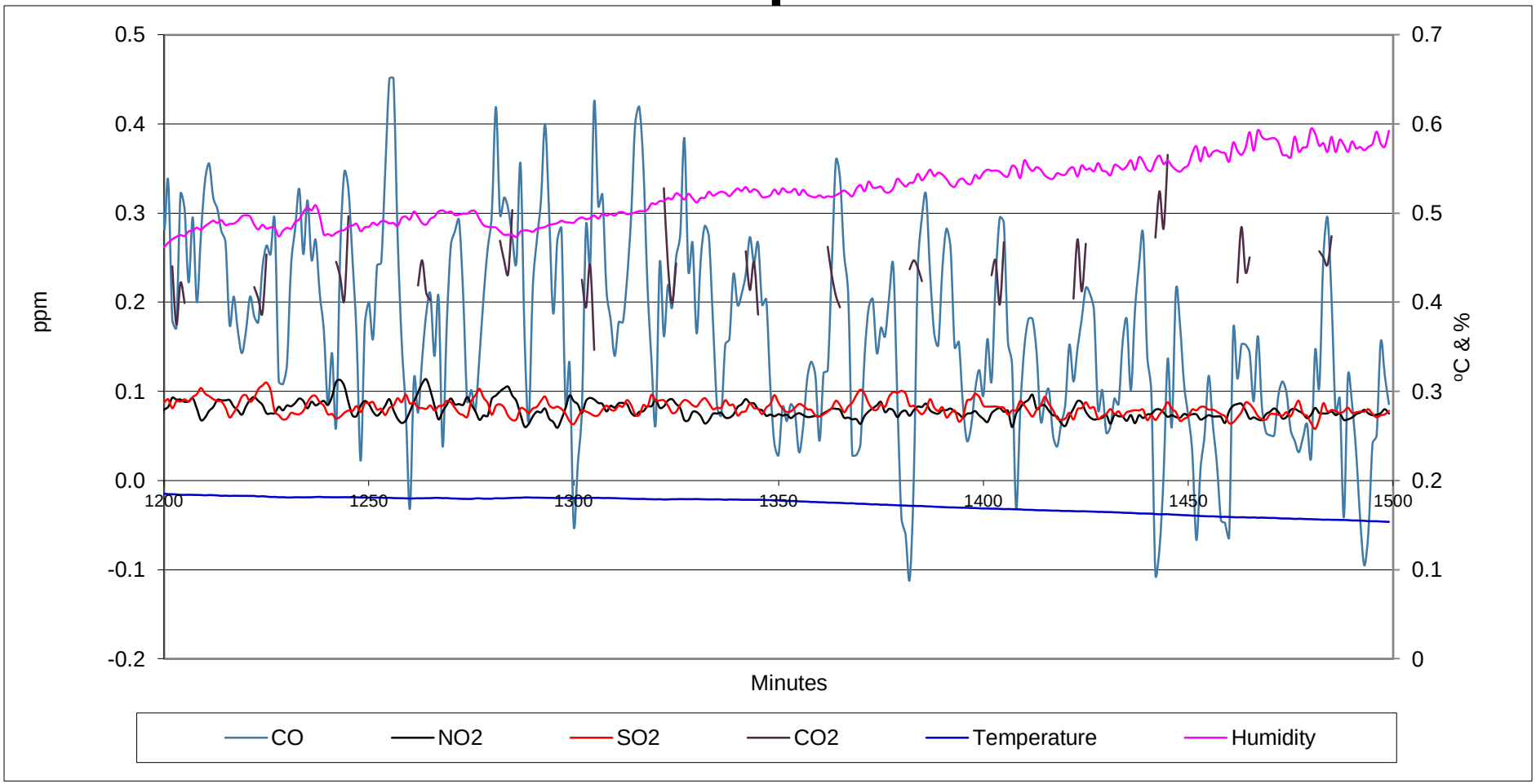




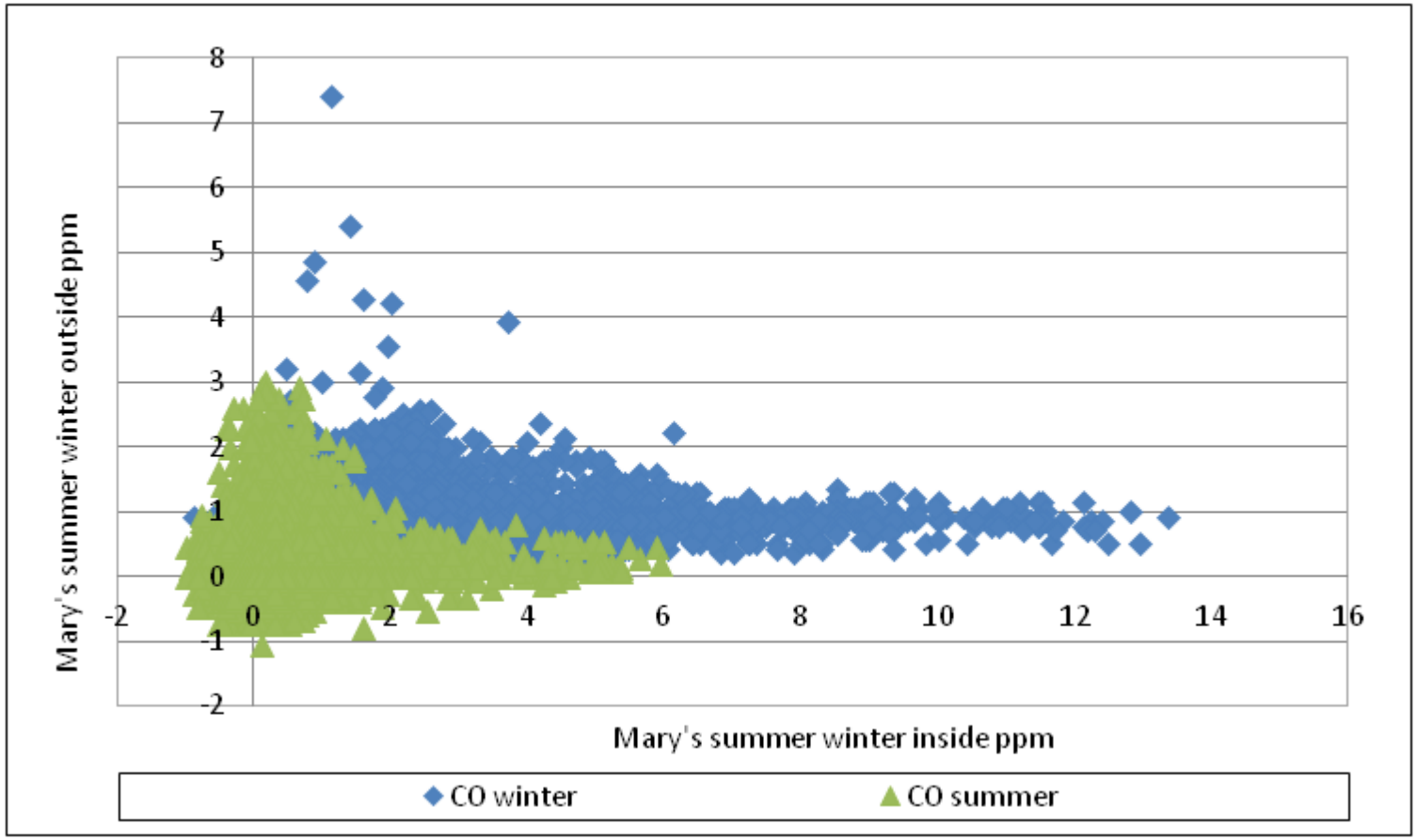
Dinner preparation
All gas house



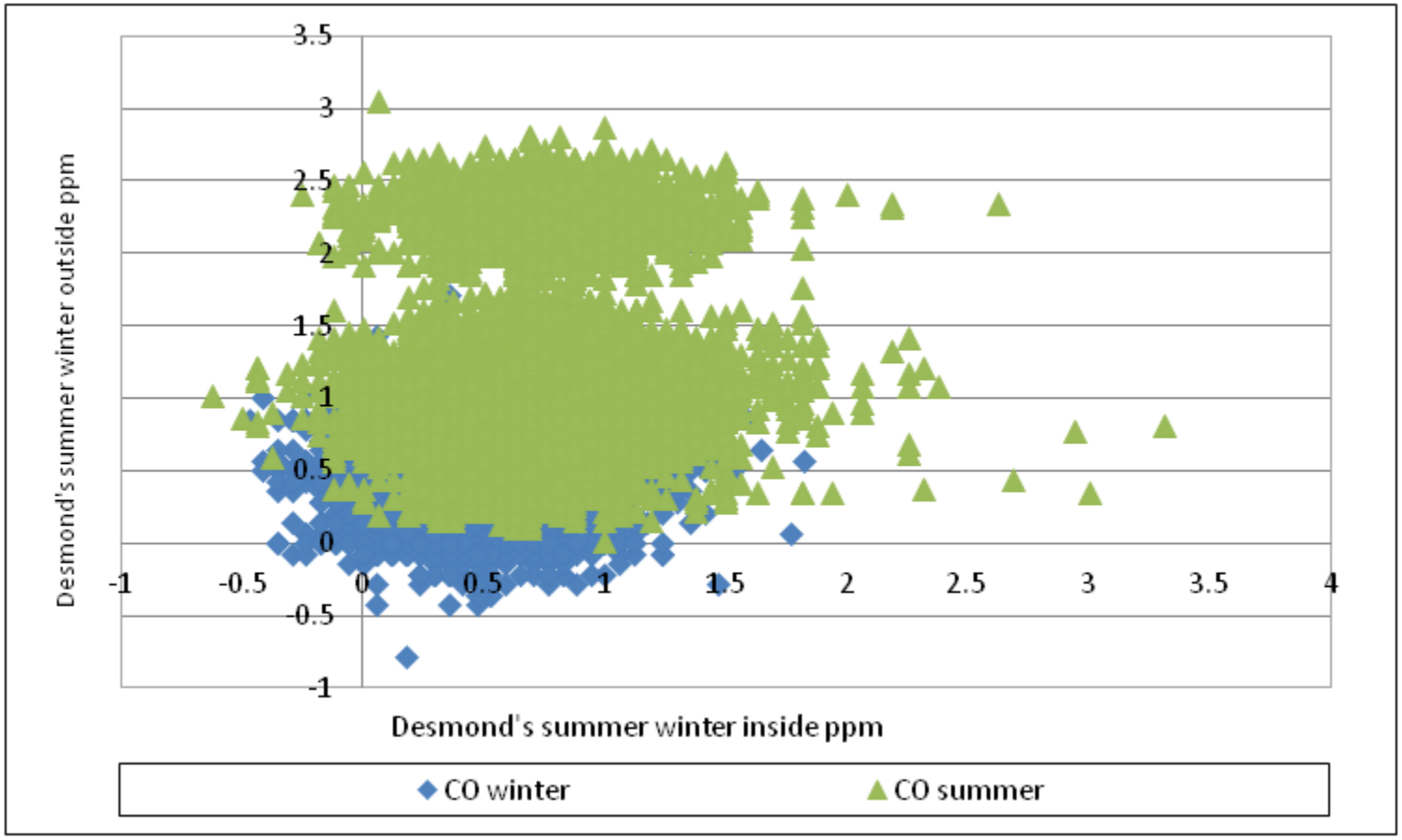
Outdoor gas concentrations during same period



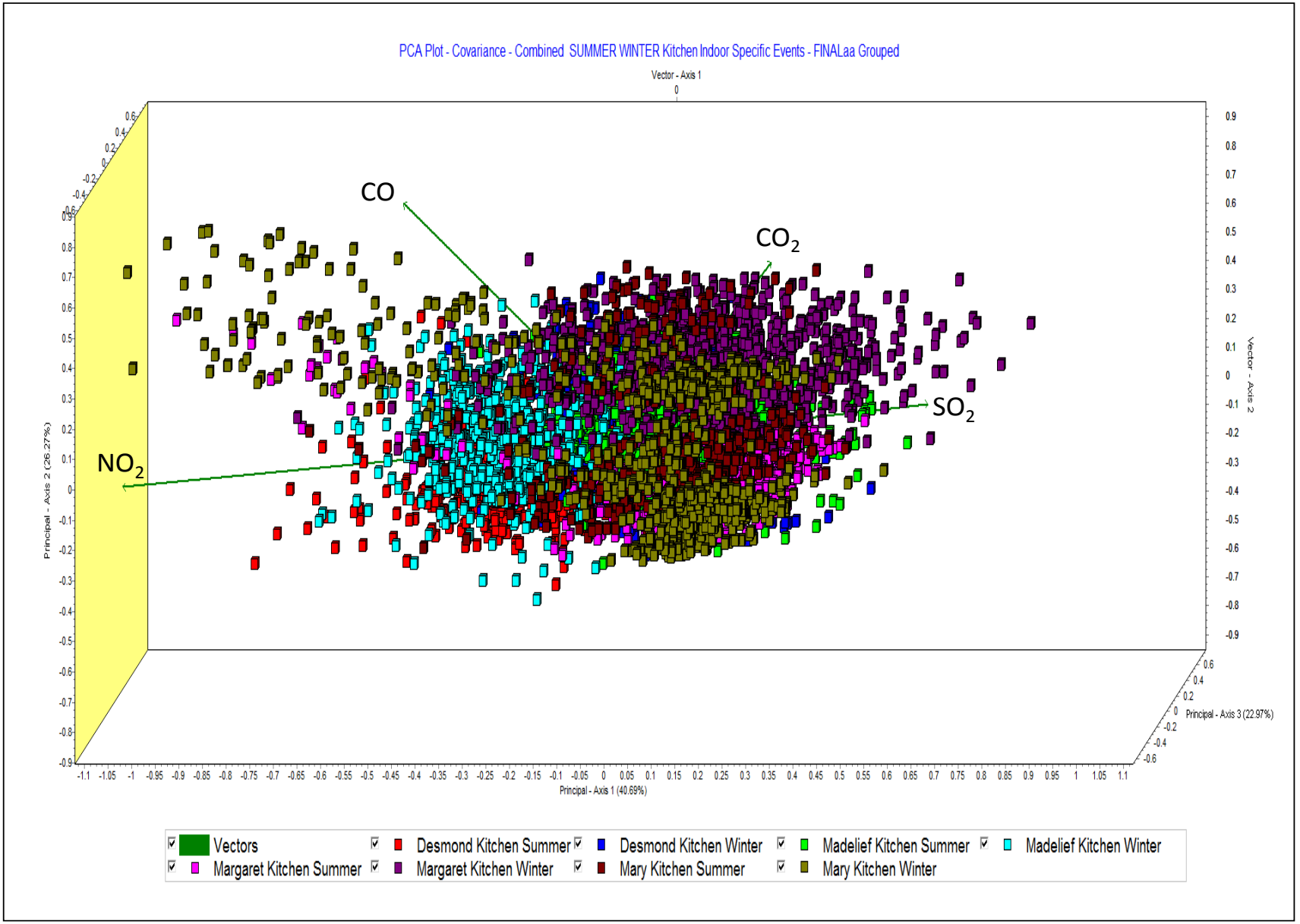
Kitchen and outdoor CO concentrations during summer and winter for an ‘all gas’ home’



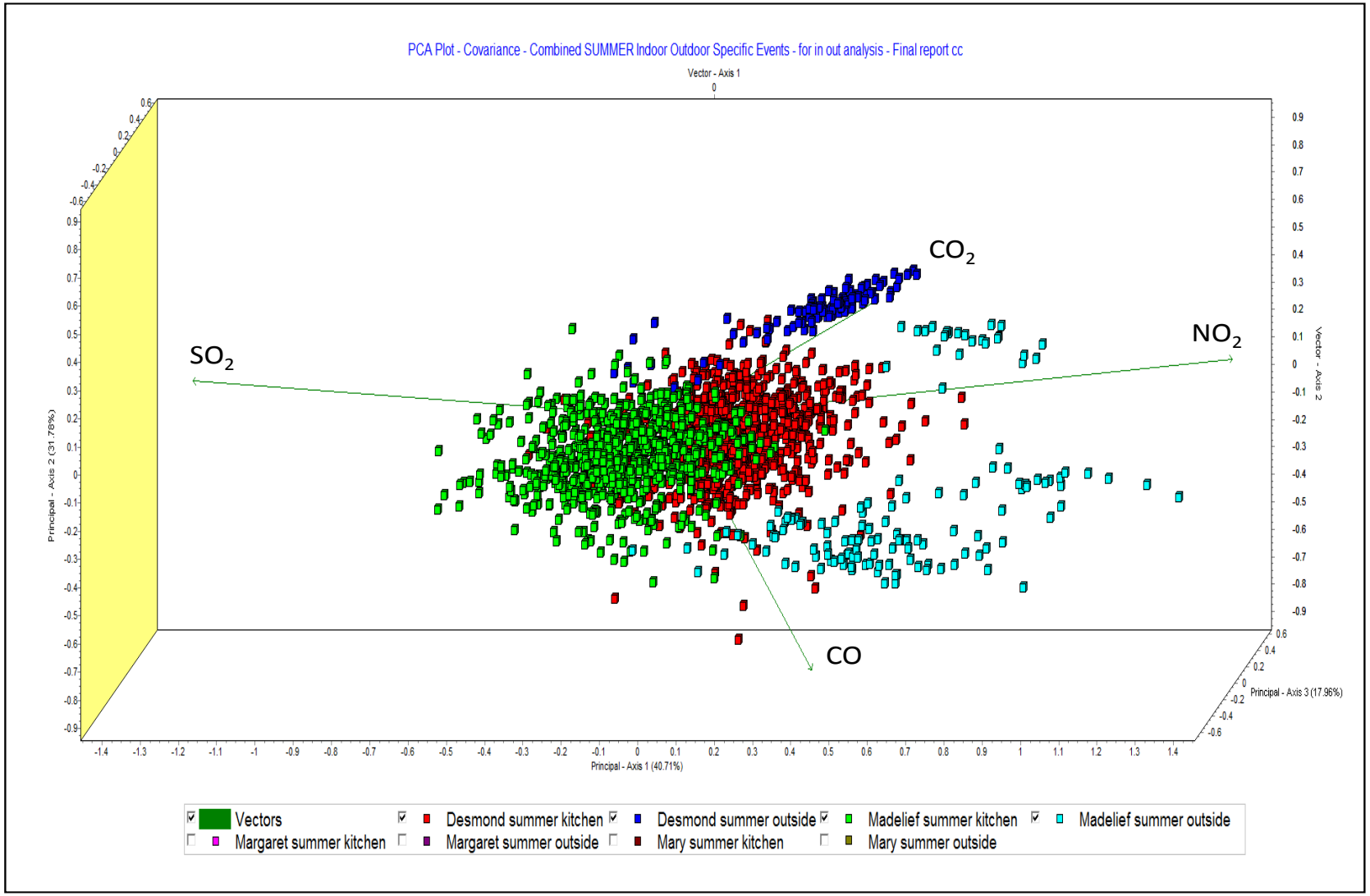
Kitchen and outdoor CO concentrations during summer and winter for an ‘all electric’ home



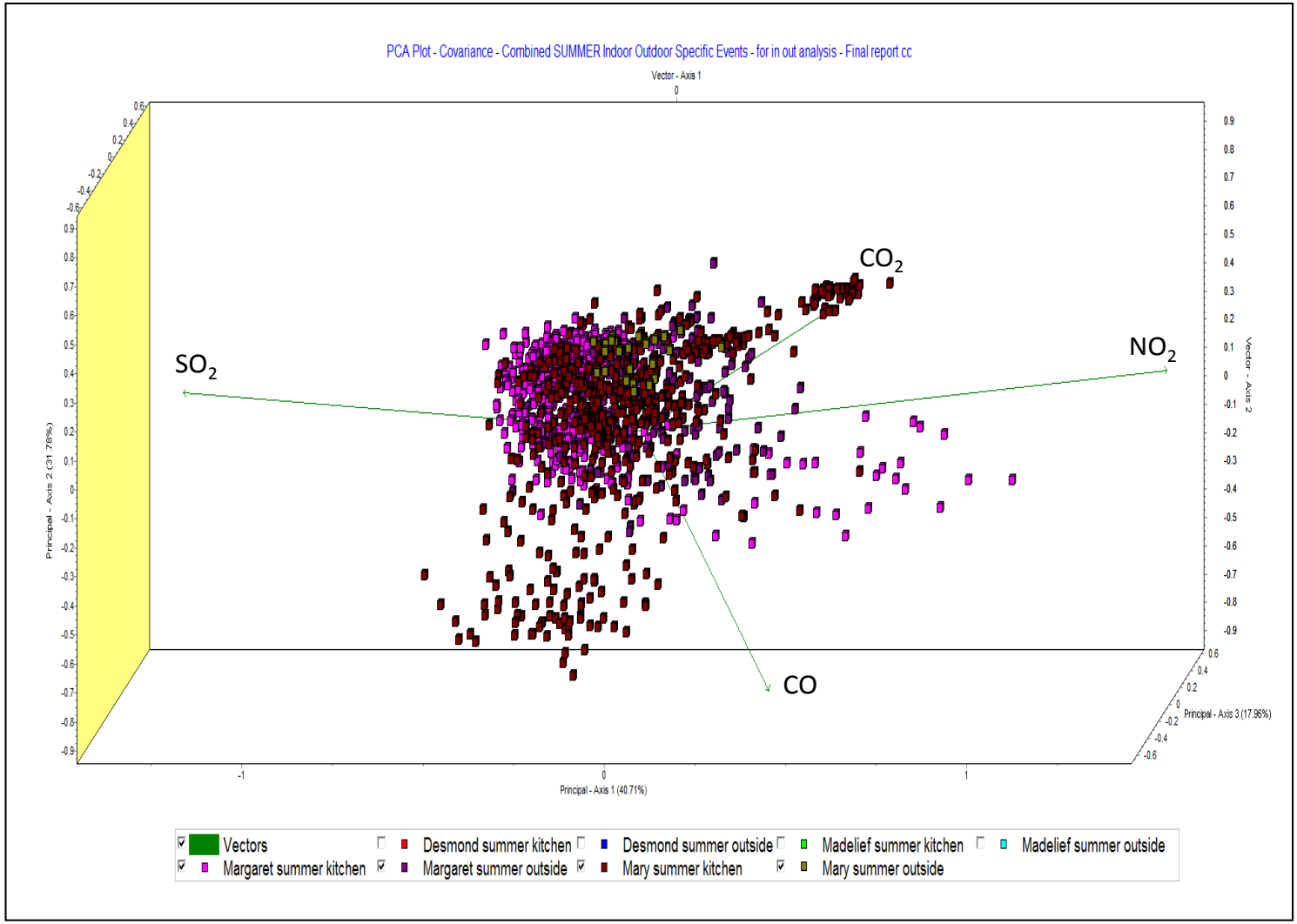
All homes summer and winter



Principal component analysis - 'all electric' only homes data during summer emission monitoring



Principal component analysis - ‘all gas’ only homes data during summer emission monitoring



CONCLUSIONS

- When considering guideline limits – ‘all gas’ homes have a tendency to come close to or exceed both the NO_2 and SO_2 limits and produce higher levels of peak CO concentrations than ‘all electric’ during cooking events.
- The work conducted on cooking event data using principal component analysis suggests that much of the variability in emission composition can be expressed in 3 dimensions. The vectors suggest that ‘all gas’ kitchens are strongly correlated with CO and NO_2